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Sustainability and Universities

Their Contribution to Reach the 17th SDGs

Edited by
Giulio Mario Cappelletti, Luca Grilli, Giuseppe Ioppolo and Carlo Russo

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Sustainability and Universities: Their Contribution to Reach the 17th SDGs

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About the Editors

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Giulio Mario Cappelletti graduated in economics. In 1996, he obtained a PhD in "Environmental effects of commodity production cycles". In 1997, he completed a two-year post-doctoral fellowship in "Commodity Sciences" with a thesis on environmental accounting methodologies. In 2000, he was a researcher at the Department of Economics of the University of Foggia. He is currently an associate professor in Commodity Sciences at the Department of Economics, Management and Territory at the same university. His research interests concern accounting and environmental sustainability methodologies, the application and study of the LCA (life cycle assessment) methodology, the environmental aspects of the agrifood sector, the exploitation of agrifood by-products, and the quality and characterization of agrifood products. He is the author of over 110 publications in international conference proceedings and national and international journals. He has been a member of 17 research projects on agrifood issues, of which one was international, two were European, eight were national, and seven were local. He has been the Rectoral Delegate for the Environmental and Social Performance of the University of Foggia from November 2019 to today. He has been a member of the energy working group of the Network of Sustainable Universities (RUS) since May 2020. He has been a coordinator of the working subgroup on Energy Indicators and Metrics of the Sustainable Universities Network (RUS) since May 2020.

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Preface

The topic of sustainability has become increasingly present among the objectives of universities, especially in recent years.

The role of universities is not limited to teaching and research but also extends to the whole of society through the dissemination of their research results and their awareness of public opinions on specific issues, to which the university can make its own scientific and cultural contribution. One of the most pertinent current issues is the environmental sustainability of any university that provides important services, taking into account their responsibility regarding students and the community. This occurs, for example, in teaching activities, such as when providing degree programs, masters, etc. in sustainability; in research activities, encouraging projects in the environmental sector, preferably following a multidisciplinary approach; and in the dissemination of research and efforts to raise awareness, organization of conferences, congresses, etc. on specific environmental issues.

Universities also have an impact as consumers of goods and services (energy, water, paper, etc.) and as waste producers, and should endeavor to reduce their environmental impact. In the latter case, in order to carry out their activities, universities occupy spaces, are consumers of water and energy, are important consumers of paper and office equipment; manage catering activities, generate waste, waste water, and air emissions. Universities and their structures can be examples of sustainability, if they implement sustainability policies during the course of these listed activities. In recent decades, universities have established a series of initiatives and declarations on this topic. Some national and international institutions have also presented papers on the role of environmental education in higher education.

Integrating sustainable development within universities is not a simple task, as it represents a radical innovation destined to face resistance from both suppliers and the entire academic community. This is explained through individuals not being willing to change their attitudes, habits and lifestyles, preferring to maintain their status quo.

Every single member of the university community, from the rector to the students, must feel responsible for the processes of change that are implemented.

The purpose of this Topic is to collect information on initiatives, scientific studies, and the dissemination of culture and good practices in sustainability, both inside and outside universities, in addition to the positive impacts in environmental, ethical, social, and economic terms following the actions implemented. The studies published in this Topic can be a valuable guide not only for those who study these topics but also for universities that want to collect useful information to implement actions to spread a culture of sustainability and to improve their social and environmental performance.

Giulio Mario Cappelletti, Luca Grilli, Giuseppe Ioppolo, and Carlo Russo
Editor

Section 1—EDUCATION

sustainability

Article

Landscape, Environmental Sustainability, and Climate Instability—The EDUSCAPE Project: University Research for Innovation in School Education

Giorgio Caprari *, Rosalba D'Onofrio, Roberta Cocci Grifoni, Piera Pellegrino *, Ludovica Simionato and Elio Trusiani

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Abstract: This article presents the main contents, methods, and results of the European project EDUSCAPE (Erasmus+) developed by a team of international researchers from four countries, just over a year and a half after its launch with a focus on SAAD/UNICAM contributions. Into the scientific-disciplinary frame of environmental education and climate adaptation, EDUSCAPE aims to integrate the polysemic, transversal, and multidisciplinary concept of landscape and its decline, as a promoter of new forms of knowledge in response to emerging dynamics, within the educational offer of school programs (6–15 years). This paper presents the general structure of the project, the methodology experimented (PBL educational approach), and the qualitative and quantitative intermediate results obtained so far (literature review, curriculum analysis, and needs analysis). To integrate landscape into school curricula and renew them, EDUSCAPE is preparing Didactic Units (DUs) as the final result of the project to provide theoretical foundations and practical solutions supporting teaching which will be tested in the schools of the partnership network. In general, this paper explores the possibility to disseminate the pedagogical and social role of the landscape through a new way of teaching based on a deeper exploration of the theme that can stimulate critical thinking in current and future generations regarding the global/local challenges of the 21st century.

Keywords: landscape; climate change adaptation; landscape and environmental education; Sustainable Development Goals (SDGs); project-based learning (PBL); problem-based learning (PBL); Erasmus+ project

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1. Introduction

1.1. Landscape and Climate Instability in Education

The landscape, according to Art. 5 of the European Landscape Convention (ELC), is considered an essential component of the living context of populations, from degraded to ordinary landscapes, an expression of the different characters of the cultural and natural heritage and the foundation of their identity [1]. The ELC envisages that each country should undertake to promote "school and university courses which, in the relevant subject areas, address the values attaching to landscapes and the issues raised by their protection, management and planning" (ELC, Article 6, point B, paragraph c) [1] in order to encourage greater awareness of the importance of the landscape and the places where people live. This awareness can also be conveyed and promoted through formal and nonformal education and training, regardless of age and educational level [2,3]. Landscape education in school and training paths is a debated issue in the cultural and scientific-disciplinary framework [4–7]. Several authors agree that landscape education should start from the youngest age groups; encourage the development of the senses and awareness of one's perceptions; and teach to be aware of the value of places, take care of them, and respect them [5,8–13]. Some studies, on the basis of European experiences, promote strategies to raise awareness of the landscape through specific communication programs for the various subjects in the area, emphasizing the relationship between landscape and the challenges of the 21st century [14,15].

Nowadays, therefore, it appears necessary to educate tomorrow's adults with active knowledge paths: discovering, trying to read and interpret the landscape constitutes a rich educational experience capable of involving both the cognitive–rational and the emotional–sensorial spheres [5,8,15,16], reinforcing the sense of belonging to a territory, a neighborhood, a street, a landscape.

1.2. The EDUSCAPE Project: Aims and Context

The EDUSCAPE project "Landscape and Climate Change Adaptation in Education" (www.eduscape.online accessed on 29 December 2023) is articulated on these theoretical bases and fits into the framework of the Erasmus+ program, involving five partners: the Czech Technical University (CTU—CZ) (lead partner), the University of Camerino (UNICAM—IT), the Universidad Rey Juan Carlos (URJC—ES), the Technische Universität Wien (TU Wien—AT), and the Child Friendly City (MPD—CZ) (Figure 1). These are joined by a network of associated partners (educational institutions)—at least one per country—who will act as a bridge for the direct testing of the project results.

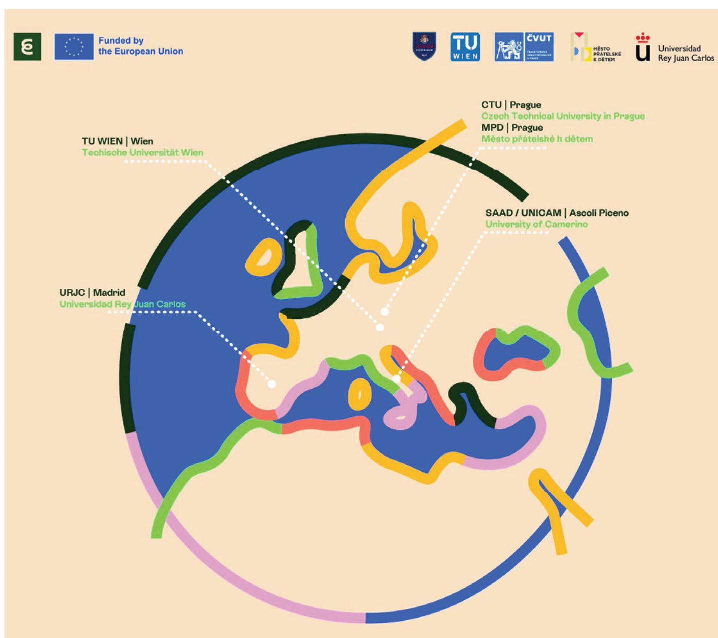

Figure 1. EDUSCAPE Partners. Source: UNICAM Team.

Particular emphasis was placed on the dialogue between the partnership—consisting of researchers from interdisciplinary backgrounds—and the teachers. This approach increased the quality of the materials and the relevance of the activities, widened and strengthened the research network, worked in synergy at the transnational level, etc. All of these mutual-exchange activities stimulated the internationalization of activities, the development of new practices/methods, and the sharing and exchange of ideas, meeting the primary objective of the Erasmus+ call.

The project investigates the potential decline of landscape in the school systems of the partner countries in the 6–15 age group. The contents and results of the project are aimed not only at students but also at educators themselves, the various educational institutions, and the international scientific community and professionals working in the field. With this perspective, the project assumes a pedagogical–social role that pursues a main objective: to propose teaching contents/tools/methods for school curricula on the basis of existing subjects in order to promote the value of landscape culture, inclusivity, a sense of belonging to places and critical knowledge of the man–nature relationship [17]. In line with European strategic programs and strategies (i.e., the Green Deal), the project integrates the central theme of adaptation/mitigation to climate change, not only raising awareness of climate–environmental issues [18–21] and the multiple social implications but addressing the landscape–climate–city relationship for sustainable development (2030 Agenda), in particular, Goals 4, 11, and 13 [22].

With specific regard to Goal 4, the EDUSCAPE project, through experiments in schools, promotes inclusive, socializing, and group activities with a view to conveying a sense of participation, community, and care that is at the basis of both teaching and landscape education. The quality of teaching–learning is closely linked to living places and social, political, and economic conditions—all values inherent in the concept and design of the landscape of today and tomorrow. In this sense, the project aims to provide quality educational material for the understanding of the inevitable contaminations between landscape, society, and global/local challenges, both in the younger segments of the population and for the teachers themselves as fundamental players in the process towards the renewal of skills and the development of sustainable models and lifestyles.

To this aim, EDUSCAPE is developing Didactic Units (DUs) as the final result of the project. DUs provide "ready-to-use" teaching materials for students and teachers to support teaching activities, within school curricula (6–15 years old), in order to innovate methods/tools/content of CVs through landscape.

EDUSCAPE therefore contributes to the interdisciplinary debate on the subject with a view to enriching the education system and contributing to the long-term development of a culture of landscape in society, starting with dialogue with schools, practical experiments, and feedback from teachers.

In this perspective, the academic and school realities involved are cooperating to transfer knowledge and skills to an adolescent audience who is already sensitive to these issues and who will inevitably be the citizens of tomorrow. On the basis of shared ideas, methods, and visions, new contents calibrated to the different local specificities (cultural, regulatory, etc.) were developed which seek to respond to the current limits and potential of landscape education, especially in Italy.

To this end, the UNICAM team reflects on the ways in which the topics can be included in the curricula of primary and secondary schools in Italy (6–15 years old) in order to foster the development of a critical understanding of the living environment of students, trying to arouse a proper interest in emerging issues.

This paper presents the theoretical and application contents common to partners in order to focus on the contribution provided by UNICAM, both in the development of the general results of the European project and in the ways of researching and promoting the project in the Italian context.

This Introduction explained the scientific framework and objectives of the EDUSCAPE project. The three main sections that follow are as listed below:

- *Materials and Methods* (Section 2): It presents the different phases of the project, clarifying how the results were identified and achieved;
- *Results* (Section 3): It describes the products obtained so far, with a focus on the Italian case;
- *Discussion and Conclusions* (Section 4): Outlines the next steps of the project, emphasizing the relevance of classroom experimentation of materials produced.

2. Materials and Methods

The EDUSCAPE project is structured in several interconnected steps (Figure 2).

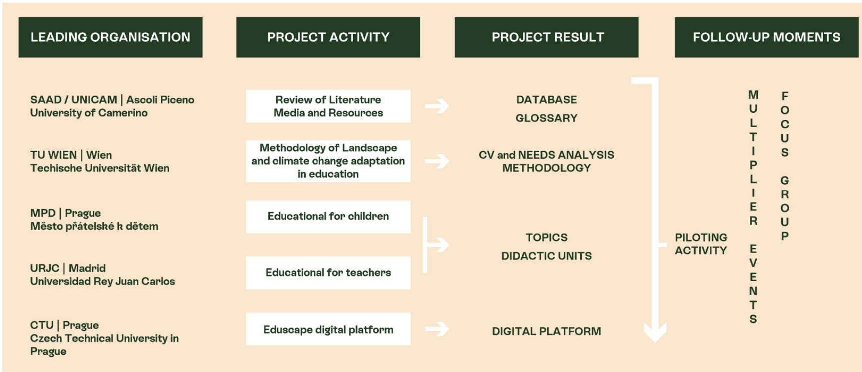

Figure 2. Concept map and project steps. Source: authors' re-elaboration (EDUSCAPE data source).

Firstly, a thorough critical review of the relevant scientific literature and existing best practices on landscape and climate change education on a national and international level was undertaken. In order to systematize these materials, a database was set up (Figure 2) which catalogued publications, studies, and projects, as well as siteographic and audiovisual material (media, video lectures, theoretical and case study videos, etc.), enabling the reconstruction of a state-of-the-art (approaches, methods, and research initiatives) on the general topics of the project. The partners were able to integrate the database by uniquely cataloguing the document according to agreed keywords (Figure 2), specifying the type of material collected and the user target it addresses. On the one hand, this activity defined the contents of the subsequent project results and products; and, on the other hand, it produced a set of useful sources for further investigation of the individual topics (landscape, climate, landscape education, pedagogical methods, etc.), which will be made available in an open-source form to teachers, academics, professionals in the field, and students.

In order to ascertain existing gaps and deficiencies in landscape education, not only in general but especially in relation to climate instability, a critical review of institutional training programs, school curricula, and teachers' needs (needs analysis, NA) was carried out in the 6–15 age group and in the four partnership member countries.

In this sense, a review and critical reading of school curricula was carried out in which topics related to both landscape education, for its abiotic and biotic structural components, and climate change were extrapolated according to grade and subject (qualitative analysis).

This analysis (presented below in Sections 3.2 and 3.2.1) was conducted by the partners and was summarized in analytical matrices, organizing the contents by school grade, age, and subject, in line with the EDUSCAPE themes. In particular, the topics of landscape and climate, which are already present in the individual curricula, in the broadest sense of their term and concept, were highlighted with respect to the common subjects of geography, science, technology, history, art, literature, physics, and chemistry.

In parallel, an NA was carried out, with the support of the partners, by means of two questionnaires administered to schoolteachers in the 6–15 age group and to professionals in the field (quantitative analysis). Professionals from the landscape–environmental sector were involved because activities related to environmental sustainability issues in schools are often carried out by external parties.

This methodological step was promoted in the different partner countries with common preset questions in order to collect existing or potential information, knowledge, methods, and teaching models on the project topics. The gaps highlighted by the target groups and the shortcomings of the teaching programs will be filled with the preparation of the EDUSCAPE methodology and then with "ready-to-use" teaching materials, organized in DUs for students and teachers.

These initial project actions supported the preparation of the project methodology that aims to respond to three main tasks:

- To explain *why* landscape is an important theme for school education;
- To clarify *what* is understood by the contemporary idea of landscape and to highlight its origins;
- To elaborate on *how* this understanding can be applied in a teaching and learning context.

The method structured by TU-Wien with the support of the partnership defines a roadmap for teaching and learning processes *in*, *on*, and *through* landscape, thus achieving the following:

- Talk about landscape as a vector for developing awareness and understanding of the emerging issues summarized by the mentioned SDGs (*through* landscape);
- Address and learn the cause–effect dynamics/relationships between man and environment (*on* landscape);
- Emphasize the role of landscape as a learning environment and fertile ground for experimenting with PBL activities (*in* landscape);
- Emphasize the pedagogical/educational component of landscape, for new forms of knowledge, skills, and qualifications in an increasingly competitive and complex world.

The developed method understands landscape as a promoter of differentiated and incrementally difficult teaching activities according to the age of the students and the different school levels. The transversality of the landscape concept is therefore a vector for a teaching/learning process capable of intercepting the different school subjects. Furthermore, the methodology defines four crucial fields of social challenges that need to be addressed from a physical–spatial and sociocultural perspective: biodiversity, climate change, social inclusion, and heritage/identity.

In this sense, the project contributes to the rethinking of the traditional approach (homiletic) in order to develop new active pedagogical forms (maieutic) in a more critical–reflexive form, by encouraging the class to think about interdisciplinary problems and relations (e.g., landscape–climate) through the use of DUs and the interdisciplinary/multiscalar landscape approach.

The DUs presented in Section 3.3 were conceived and conceptually structured according to the EDUSCAPE method and by following five methodological steps (Figure 3):

- Conceptualizing: Teachers introduce the topic, presenting problems or challenges that go along with it, encouraging the students to activate existing knowledge and preconceptions on the topic;
- Perceiving: This phase allows students to connect personal experience with the subject matter. All kinds of perception (sight, hearing, smell, touch, and taste) form the groundwork for drafting assumptions on phenomena, questioning their reasons, and phrasing hypotheses on possible connections and contexts. Perceiving may also challenge the investigation of different perspectives on a subject, offering new ideas for customizing activities according to the personal response of the class group;
- Analyzing: The students collect, observe, and systematize data and information by applying the science-based approach. A multitude of research questions (either from natural, social, historical, or other scientific perspectives) can be investigated, applying every methodological framework;
- Shaping: The students create knowledge, ideas, and solutions for dealing with and solving societal challenges and coming into focus with active responsibility for landscape;
- Reflecting: The students reorganize the knowledge and review the activities carried out and evaluate the experience.

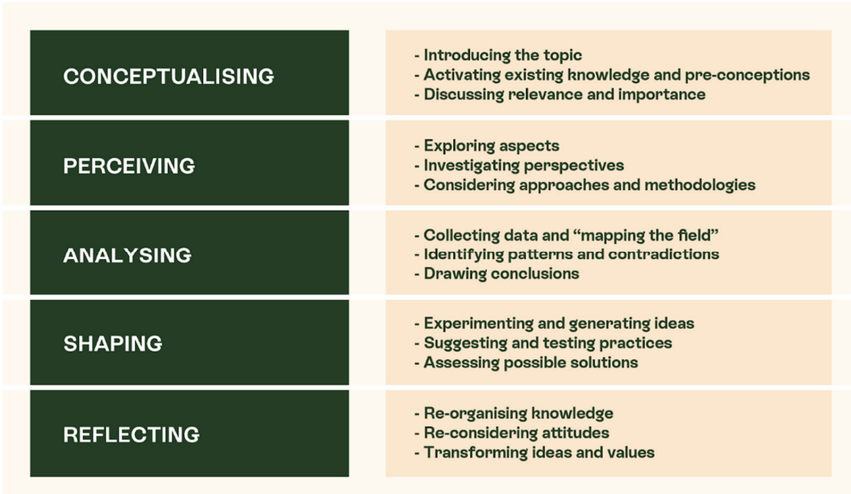

Figure 3. Stages in teaching on, with, and through landscapes. Authors' re-elaboration (credits to TU Wien EDUSCAPE Team).

The project, as already mentioned, envisages field testing (DUs) through piloting activities with students and teachers. To this end, the teachers at the partner schools have already been involved in various activities and formal and informal meetings, as they are main actors in the process illustrated and a fundamental support for the evaluation of the EDUSCAPE results, for their implementation, and for their promotion and dissemination in the territory.

Finally, at the end of the project, an open-source digital platform, which is currently being developed, will be open to the public to which the outputs will be uploaded. The platform will be an interactive and educational portal and will provide free educational materials accessible from the project website "www.eduscape.online (accessed on 29 December 2023)" in the four languages of the partner countries and in English.

2.1. PBL and Landscape Education in the Scientific Literature

The methodology of the EDUSCAPE project is conceived as an interdisciplinary cooperation between actors and school subjects and is based on the teaching–learning model called project-based learning (PBL). This model, as made explicit in some recent theoretical/applicative studies also related to environmental education [23–26], assumes that the project stems from real, concrete questions and that it collaboratively involves students and teachers in problem-solving, decision-making, and in-depth activities. In this perspective, EDUSCAPE is currently producing materials for the DUs based on place-based methodologies which will be modified/adapted by teachers according to class and context (geographical, skills and competences, etc.). The need for new teaching tools better suited to global challenges has promoted a growing interest in the PBL educational stream.

In the experiences of landscape education in the 6–15 age group [10,27,28], references to the use of experimental, outdoor, and place-based methods are highlighted, introducing the topic of landscape as an extracurricular or in-depth workshop.

As is further explored in the following sections, the theme ties in well with the growing need to address the 2030 Agenda, innovation for transition and climate change. In order to be able to use the landscape to look at and understand climate change in the territories experienced by students, the PBL educational stream was chosen as most suitable.

The literature suggests multiple potentials:

- Listens to and promotes the perceptual, learning, and cultural diversity of students and teachers. Active methods in teaching and learning have been requested in many educational debates at national and international levels to (i) promote inclusion and (ii) introduce new teaching methods that are more engaging, stimulating, and attentive to individual needs [29,30]. PBL can encourage students to transfer learning to unfamiliar contexts [31], disseminating new ways of looking at climate change.
- Listens to and promotes contingencies and contextuality of particular places. In facing global issues such as climate change, methodologies that study the specific landscape of each context help us to "think local" and understand the scale of possible impacts of individuals (or schools) and develop solutions based on the "local character" [32]. The local approach provides a corrective to an overemphasis on decontextualized and universalizing knowledge by traditional education [33].
- Connects the sciences to societal and environmental challenges. In this virtuous relationship, landscape is a tool to make the sciences visible, practical, and usable to better understand the local effects of global phenomena such as climate change [34,35].
- Activates good practices through the exploitation of the sense of place of students and teachers. Indeed, PBL has been advocated for its relevance and potential to attract the knowledge of phenomena that change the landscape in which they live, potentially prompting them to take local action [36,37]. The relationship between place attachment, place meanings, and pro-environmental behavior is self-enforcing, enhancing students' awareness by promoting positive behavior, as well as a greater reception of topics [38]. Because PBL involves students working on real environmental problems in their own communities, it also strengthens community support for schools and teaches children the skills and rewards of good citizenship [31].
- Links several subjects and cross-sectional reflections. It is increasingly used in geoscience (marine, earth, and atmospheric science), where the multidisciplinary approach and the experimental method of data collection are more experienced. Dealing with the same subject with different teachers helps to deepen knowledge and stimulate students to perform better on tests [31,39]. The climate emergency allows for the use of the landscape for scenario building from a singular perception, reading the context over time. Updating teachers' tools and knowledge will help students find solutions for a more sustainable future through developing complex solutions.
- Promotes the use of multiple tools. Teachers draw on their specific toolbox, adapting it with new techniques and necessarily using culturally responsive pedagogies such as reasoning by analogy, storytelling, virtual field trips, and sketching. The use of practical tools that encourage critical and singular thinking develop science content and skills, science identities, and interest [40].

2.2. Stakeholder Engagement for Assessing the Reliability of Project Results

In this perspective, the creative-realization process of the project is implemented with activities, times, and resources defined in collaboration with the schools and teachers involved with the individual partners. The associated project partner schools were already in contact with university partnership, as well as being geographically close, allowing for a better dialogue and relationship. This allowed for a faster involvement, as well as continuity of the university–school relationship.

Since the start of the project, various discussion events have been organized between the teachers/researchers/technicians of the partners themselves (transnational meeting—TM) and between an expert audience consisting of teachers, experts, and researchers (multiplier event—ME). The project includes five international MEs in the different partner countries, three of which have already been held in Prague, Ascoli, and Madrid between 2022 and 2023 (Supplementary Videos S1 and S2). On the one hand, the MEs provided an opportunity to introduce and disseminate the EDUSCAPE project and the progress of the work to a wide audience; and, on the other hand, they provided an opportunity to engage in a fruitful dialogue with lecturers from outside the partner universities and local experts who deal with or have dealt with the topics of interest.

During the MEs, the focus was on the strategy for the development of the project results (PRs) and the methodology of landscape and climate change adaptation in education and its innovative approach. The participation of expert guests on the project topics, as well as in innovative pedagogical approaches, allowed for discussion and constructive feedback in order to better draft the methodology and produce effective materials drawing on already tested case studies, methods, techniques, and theories.

In addition to the results obtained from these moments of transdisciplinary and transcalar comparison and learning, a number of focus groups (FGs) were organized by the individual partners with the teachers of their associated partners both to gather specific information in the local school context and to verify the contents and results of the developed DUs.

To this end, UNICAM organized two FGs in June and October 2023, attended by around 90 teachers from the associated partner schools (IC Betti and IC Paoletti, Marche region; and IC Pescara 4, Abruzzo region). In particular, the suggestions received referred to the structure of the DUs and the objectives of the individual activities, which must be clear and comprehensible to the teacher. In addition, the participants highlighted the need to (i) simplify some specialized terms and vocabulary to be able to speak to a wide audience of non-experts in the field, (ii) state the objectives and competency targets of each individual DU and practical activities, (iii) propose stimulating and motivating contents and activities that are comprehensible for young students, and (iv) provide tangible objectives that are able to gratify the student without a real judgement or grade of the final papers or activities carried out. During these meetings, the teachers expressed doubts and raised critical points regarding the materials produced in a process of mutual exchange. This relation contributed to the creation of the materials based on the needs of the partner schools and the experience of the teachers, who know the conditions/levels of the classes and the potential beneficial effects of some of the activities proposed by DUs.

3. Results

3.1. Literature Review: Placing the Project within the Scientific–Cultural Debate

The literature review (LR) produces a database that offers a useful overview of the predominantly European state-of-the-art on what has been produced on landscape and climate change education, although not exhaustive and definitive but, instead, implementable by future research.

The database (Figure 4) was structured in a way that makes it easy for teaching staff and experts in the field to consult it by means of data-based filters and queries with respect to the topic of interest (landscape, climate change, adaptation to climate change, pedagogy, and education) and/or the project glossary (biodiversity, education for sustainable development ESD, engagement, European citizen, experience-based teaching, global citizen, heritage, innovative instruments, literature review, ready-to-use teaching materials, etc.), the user target, and/or the type of document surveyed.

EDUSCAPE_REFERENCES													
Partner	FER	EARCH TOPIC in educa	TARGET	Reference KEY WORDS	Year	AUTHOR and/or ORGANISATION	TITLE and publisher	DOCUMENTS_type	MENTS_la	DESCRIPTION_short	he original w	TRY_ref	CONTACTs
	de li	choose from the list	choose from the list	x, x, x.. (max 5)	e.g. 2022	surname and name, organization	"...................."	choose from the list	se from th	200 characters max.		e.g. ITA	ame, e-mail, telephon
UNIVERSITÀ DEGLI STUDI DI CAMERINO (UNICAM)_IT	1	landscape & climate cha	pupils 6 - 10 years	plant a tree, climate activi	2000	Plant for the planet	Plant for the planet	media, web e social	English	Climate Justice Ambass	https://a.pla	EU	Tom Crowther, Institu
	2	landscape	teachers 10 -15 years	landscape education, cog	2010	Benedetta Castiglioni (ITA), Counci	Educare al Paesaggio	technical doc. (e.g. guid	available i	Text for "Landscape Ed	https://www.	ITA	Prof.ssa Benedetta C
	3	landscape	pupils 6 - 10 years	what is landscape, identit	2009	GIZ: One day. Four people. Many s	Assessorato alla Cultu	audio-visual media	English	Video to explain what is	https://www.	GER	Deutsche Gesellscha
	4	landscape & climate cha	pupils 6 - 10 years	what is landscape, landsc	2009	Wageningen Centre for Developme	The landscape puzzle	audio-visual media	English	Video to explain what is	https://www.y	NET	Università di Wagenir
	5	landscape & climate cha	teachers 6 - 10 years	eTwinning platform, best	2010	Irene Pateraki, Alexandra Hanna Li	Classrooms in action	EU-Project (Erasmus+,	available i	Education project. Use	https://www.	EU	Central Support Servi
	6	landscape & climate cha	teachers 6 - 10 years	cultural landscape, UNES	2019	Regione Piemonte in collaborazion	Orizzonti UNESCO tra	technical doc. (e.g. guid	Italian	As part of the project Th	http://paesa	ITA	Direzione Ambiente,
	7	adaptation to climate ch	teachers 6 - 10 years	Tool kit, education and cli	2020	ISPRA_Silvia Bonaventura, Stefani	Kit didattico di giocosi	technical doc. (e.g. guid	Italian	Simulation game about	https://www.	ITA	Silvia Bonaventura: s
	8	landscape & climate cha	teachers 6 - 10 years	education methodology	2020	Sara Bonati, Marco Tononi	Cambiamento climatic	technical doc. (e.g. guid	English	The participation of chil	https://serie	ITA	Sara Bonati: sara.bor
	9	landscape & climate cha	teachers 6 - 10 years	Environmental problems,	2021	Benito Campo-Pais, Antonio José M	Environmental probler	scientific literature	English	In Ontinyent (Spain) wa	https://www.r	SPA	Benito Campo-Pais,
	10	climate change	pupils 6 - 10 years	environment&climate cha	2020	a2a Life Company | Per le scuole. E	#AMBIENTEaSCUOL	audio-visual media	Italian	Video to raise awarenes	https://edutv.	ITA	http://www.a2a.eu/, s
	11	landscape	both teachers&pupils	intergenerational worksho	2021	Luca Mori, Emanuela Schir, Rete d	Catalogo, Sette idee p	technical doc. (e.g. guid	Italian	The educational propos	https://www.a	ITA	Rete degli Ecomusei
	12	landscape	both teachers&pupils	identity&landscape, lands	2022	Istituto Alcide Cervi - Biblioteca Arc	Per l'educazione al Pa	media, web e social	Italian	Institute that organise s	https://www.	ITA	Istituto Alcide Cervi -
	13	landscape	both teachers&pupils	Landscape European Co	2020	Benedetta Castiglioni	https://in20amoilpaesa	media, web e social	Italian	"In20Amo il Paesaggio"	https://in20a	ITA	sara.bin@unipd.it, ett
	14	landscape	teachers 10 -15 years	landscape education, lan	2019	Cisani M., Castiglioni B., Università	Idee di paesaggio nei	scientific literature	Italian	Il rapporto tra paesaggi	https://www.	ITA	Dipartimento di Scien
	15	landscape	teachers 10 -15 years	landscape literacy, landsc	2018	Cisani M., Università degli Studi di	Progetto RACCONTA	examples of good practi	Italian	Collaborazione alle rice	https://umar	ITA	Dipartimento di Scien
	16	climate change	teachers 6 - 10 years	global warming, climate c	2019	Monica De Filpo, Epifania Grippo	"Il grande caldo": una	audio-visual media	Italian	"Alla scoperta della Ge	https://www.	ITA	Monica De Filpo (mor
	17	landscape	both teachers&pupils	educational experimentat	2018	Gianluca Cepollaro, Luca Mori	METTERSI AL MOND	scientific literature	Italian	La transizione del conc	http://www.e	ITA	Gianluca Cepollaro, s
	18	landscape & climate cha	teachers 10 -15 years	data, best practices, gove	2018	Gruppo di lavoro e Rete dei referen	L'educazione ambient	technical doc. (e.g. guid	Italian	EAS connects the colle	https://www.	ITA	Paolo Tamburini, Emi
	19	landscape	both teachers&pupils	environmental awareness	2020	Istituto Superiore per la Protezione	Sic2Sic-In bici attrave	EU-Project (Erasmus+,	available i	Il Progetto LIFE Sic2Sic	https://lifesic	ITA	lifeSIC2SIC@isprami
	20	landscape	both teachers&pupils	environmental education,	2021	Istituto Superiore per la Protezione	PROGRAMMA DI INIZ	technical doc. (e.g. guid	Italian	Promuovendo il "Progra	https://www.	ITA	educazione@ispramb
	21	landscape & climate cha	teachers 10 -15 years	free seminars, civic and e	2022	FAI (Fondo per l'Ambiente Italiano)	"Ambiente? Tutto ciò	media, web e social	Italian	Il FAI (Fondo per l'Ambi	https://fondo	ITA	scuola@fondoambier
	22	landscape & climate cha	both teachers&pupils	awareness Agenda 2030,	2020	ASviS e Fondazione Edoardo Garr	Global Goals Kids Sh	audio-visual media	available i	Il Progetto "Global Goal	https://asvis	ITA	ASviS - Alleanza Itali
	23	landscape & climate cha	both teachers&pupils	Soil as a resource, desigr	2020	CREA- Consiglio per Ricerca in Ag	SOIL4LIFE-L'essenzia	EU-Project (Erasmus+,	Italian	Il Progetto Soil4Life pre	https://soil4l	ITA	www.legambientescu
	24	climate change	pupils 6 - 10 years	green energy, renovable	2019	GSE-Gestore Servizi Energetici	"GSE incontra le Scuo	examples of good practi	Italian	Nel 2011 nasce "GSE in	https://www.	ITA	GSEincontraleScuo
	25	landscape & climate cha	both teachers&pupils	urban landscape, city&na	2021	CDCA Centro di Documentazione s	Piccolo manuale per l'	audio-visual media	Italian	Questo testo vuole ess	http://cdca.i	ITA	CDCA Centro di Docu
	26	climate change	both teachers&pupils	climate change impacts,	2019	ARPA Lombardia - Fondazione Lon	"Studiamo il clima e i	audio-visual media	Italian	Nell'ambito delle attività	https://www.	ITA	educazione.ambienta
	27	climate change	teachers 6 - 10 years	simulation games, climat	2016	Education for a Just World: An in	Creating Futures - 10	technical doc. (e.g. guid	English	Creating Futures, 2016	https://www.	IE	info@trocaire.org
	28	adaptation to climate ch	teachers 6 -15 years	best practices, open scho	2022	Foundation for environmental educ	Eco-Schools	media, web e social	Italian	Network of italian schoo	https://www.	ITA	Foundation for Enviro
	29	landscape & climate cha	teachers 6 -15 years	best practices, open scho	2022	Movimento Volontari Italiani	Territori Educativi	media, web e social	Italian	Articles compilation of it	https://comu	ITA	Email: comunicazione
	31	climate change	teachers 6 -15 years	mitigation&adaptation, cli	2022	Office for Climate Education (OCE)	"The climate in our ha	scientific literature	available i	The aim of this guide is	https://land.	FRA	Office for Climate Edu
	32	climate change	pupils 6 - 10 years	climate change education	2022	Earth Science Communications Tea	Climate Kids, NASA	media, web e social	English	Climate Kids is a websi	https://clima	ENG	Program Manager: H
	33	climate change	teachers 6 -15 years	climate change education	2020	Climate Curriculum, Leeds-DEC, D	"Climate Curriculum",	technical doc. (e.g. guid	English	A school-wide framewo	https://leeds	ENG	Hannah@leedsdec.o
	34	landscape & climate cha	both teachers&pupils	school education activitie	2021	REGIONE LAZIO, Direzione Regio	CATALOGO GENS_ F	technical doc. (e.g. guid	Italian	The Catalogue gathers	https://www.	ITA	direzioneambiente@r
	35	landscape & climate cha	teachers 10 -15 years	urban landscape, climate	2021	Rapporto 2021 dell'Osservatorio di	Osservatorio Naziona	media, web e social	Italian	CittàClima è un progett	https://cittac	ITA	info@cittaclima.it
	36	landscape	both teachers&pupils	children engagment, scho	1998-200	Arch. Irma Visalli e Comune di Bell	Esperienze di progetta	examples of good practi	Italian	Buona pratica per il coi		ITA	
	37	landscape & education	researchers	landscape awareness, lar	2011	Generalitat de Catalunya Departam	La Sensibilizzazione a	EU-Project (Erasmus+,	available i	Il progetto PAYS.MED.U	http://www.p	SPA	PAYS MED URBAN:
	38	landscape & education	teachers 6 -15 years	civic education, cross-sch	2019	Camera dei deputati, Senato della	Linee guida per l'inseg	other	Italian	L'educazione civica vier	https://www.	ITA	email: segreteria.mini
	39	landscape & education	both teachers&pupils	ross-school education, te	1999-on	RAI Cultura- Ministero Pubblica	La Scuola in Tivù	audio-visual media	Italian	Lezioni divulgative e for	https://www.	ITA	Rai - Radiotelevision
	....												

Figure 4. Reference database for the Review of Literature, Media, and Resources. The contents are organized according to research topic, target, key works, year, author, title and publisher, document type, language, short description, link, country, and contacts. Source: UNICAM Team.

This type of analysis about the state-of-the-art placed the project within the scientific debate, verifying the gaps and strengths existing in the literature. Among these, the analysis highlighted how the topic of education on the environment, nature, and environmental sustainability, especially for the youngest children, is already a theme that is addressed by creative and outdoor activities often in extracurricular hours. In addition, climate change has also become part of some educational experiences or materials, especially through a simplified type of narration (e.g., comics, websites, video lectures, etc.) that focuses not so much on the landscape–climate relationship as on the heat emergency in the city and global warming as a global effect. In other words, nature is present in the narrative, but there is a lack of the anthropic imprint: the system of relations between anthropic and natural factors is missing, so it speaks of environment and nature and not enough of landscape.

From an analysis of the bibliographical references, the catalogued materials concerning climate change are the most copious (64%), going along with the growing interest in the subject [2,27,41]. Many documents (71%) are ready-to-use materials, often useful as a starting point or inspiration for the activities proposed by the project [42–44]. Others are essays, basic texts, and the scientific literature (15%) for in-depth study, acquisition of notions, or preparation of the teachers themselves [4–6,45].

The review also includes methodological contributions, which helped to reflect on the integration of innovative and more stimulating teaching methodologies considering the target users.

The dating of the papers (50% from 2020 and 23% from 2018) revealed the growing interest in project topics in recent years. European policies and the updating of national curricula have, in fact, generated a production of tools and bibliographic sources, trying to bridge the gap between competences to be achieved and the supply of school textbooks.

In summary, the international panorama certainly reflects a movement of awareness and renewed interest in landscape and its transversal/interdisciplinary value, which is therefore capable of intercepting different cognitive knowledge and carving out a primary role even in pre-university education. The various materials collected (Figure 5) also highlight the centrality of drawing and the importance of practical activities in child and adolescent education, as well as the proliferation of training organizations, including Italian ones, that promote courses for teachers and educators, focusing, in fact, on a key topic: the role of the teacher and the formation of a sensitivity for the landscape. Like the reference literature, the database is constantly being updated. Although it was conceived in the early months of the project (mid-to-late 2022), its dissemination will take place at the end of the project (2024) in order to allow all partners to integrate useful materials throughout the project's duration.

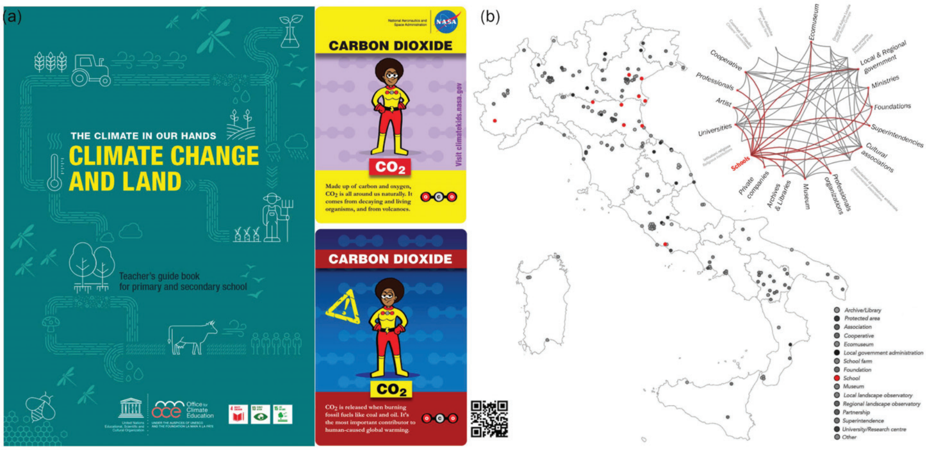

Figure 5. Examples of materials and case studies from the literature review: (**a**) excerpt of downloadable open access playing cards for teachers/students about greenhouse gases emitted by anthropogenic activities [44] and (**b**) the mapping of schools and stakeholders promoting landscape education in schools in Italy, an excerpt from the 'Raccontami un Paesaggio' project [5]. Source: authors' re-elaboration (credits to the authors of data).

3.2. *Curricula and Needs Analysis as Input and Verification of Project Applicability*

The Curriculum Analysis (CA) and Needs Analysis (NA) were developed by all partners with reference to their national context and local partnership network.

With regard to the analysis of the curricula of each school level, the partners noted an increase in interest in the project topics in the four target countries (Italy, Austria, the Czech Republic, and Spain). This process was also supported by dedicated laws and reforms, starting from the addresses of the 2030 Agenda. In Italy, the teaching of "civic education" (Law 92/2019) [46] was established; in Spain, the Lomloe (Ley Orgánica 3/2020) [13,47] was enacted; in Austria, the teaching of "general studies" is underway; and in the Czech Republic, a revision of the national educational offer is underway.

However, these topics are not yet addressed sufficiently and in a clearer way in formal education, where questions are still being asked about how to effectively incorporate the demands of new laws, needs, and emerging issues in school education.

To finalize the NA, the individual partners administered two questionnaires online and/or in paper format to schoolteachers in the 6–15 age group and to professionals in the field whom they were able to intercept on the basis of their personal knowledge, research network, and contacts identified through the LR or via social networks (Facebook and Instagram). A total of 92 teachers responded. The level of interest, expertise, or predisposition to the proposed topics among the different countries was rather homogeneous. The responses generally returned a positive attitude to the integration and deepening of landscape and climate change issues. In addition, teachers hint at the fact that PBL methodology is not (or not fully) integrated into school curricula yet. Nevertheless, the responding teachers are convinced of the pedagogical value of such learning and teaching formats.

The results of these two surveys were analyzed and compared between the partner countries. Overall, considering all the results, it is possible to conclude that developing and disseminating materials on landscape and climate change education fill a gap.

Below (Section 3.2.1), the activities and results obtained by the UNICAM team in the national and local context (CA and NA) are highlighted, with a focus on the Italian cultural debate on the subject.

3.2.1. A More In-Depth Look at the Italian Case

In order to analyze the current educational offer in Italy, on the one hand, the contents of the framework programs of the Ministry of Education and Merit (MIUR) were investigated; and, on the other hand, the curricula of different Italian schools were evaluated on a sample basis, also taking into account the specific addresses of the secondary school (linguistic, professional and technical institutes, classical studies, agricultural studies, etc.).

Trying to draw a transversal summary of the contents referring to landscape, we can state that, in primary school (6–10 years), there is already a first approach to the environment and landscape, with a focus on the physical–naturalistic and geographical dimension and on perception through the five senses. In middle school (11–13 years), knowledge on the topics already expressed is refined, introducing historical and social aspects of human activities in the natural environment. Furthermore, considering the more technical subjects, the students approach the topic transversally through some scientific experiences related to soil, materials chemistry, and climate, as well as through laboratory activities. Finally, 14–15-year-old students approach the topics by understanding demographic impacts and changes in modern society, addressing the issue of climate change. In addition, there are already activities in map interpretation and cartographic language, which, especially in the more technical and artistic subjects, translate into basic skills in technical and artistic drawing, analogue or digital.

This brief summary highlights some of the themes already present and referable to landscape and climate change in Italian training programs, which is reflected in the summary table drawn up by UNICAM (Table 1). All partners developed a similar table on the basis of a unique matrix in order to achieve the following:

- Identify the topics already covered in common subjects;
- Realize DUs set in the context of individual national school curricula.

Table 1. Analysis of the Italian training offer and school programs relating to the EDUSCAPE themes (elaboration by UNICAM).

School Order and Age Group	EDUSCAPE Project Themes within the Subjects of Geography, Science, Technology, History, Art, and Chemistry	EDUSCAPE Project Topics Introduced by Civic Education in Italy (L. 92/2019)
Primary school (6–10 y.o.)	• 5 senses for learning about environmental phenomena • Respect for and role of nature • Value of cultural heritage (historical–artistic heritage, etc.) • First simplified concepts of landscape and geography • Physical/morphological elements of the Italian landscape • Historical, social, and economic dynamics of major territorial • Transformations	• Recycling and sustainable use of resources • Agenda 2030 goals (climate change mitigation/adaptation, environmental crisis, etc.) • Heritage awareness

Table 1. *Cont.*

School Order and Age Group	EDUSCAPE Project Themes within the Subjects of Geography, Science, Technology, History, Art, and Chemistry	EDUSCAPE Project Topics Introduced by Civic Education in Italy (L. 92/2019)
Middle school (11–13 y.o.)	• Value of maps at different scales • Effects of the impacts of human activities on natural environments • Scientific and technical elements related to climate and atmosphere • Notes on ecology (concept/process) • Understanding land and cities: form and anthropic/natural elements • Crop types and agricultural cultivation techniques	• Knowledge, protection, and valorization of heritage • Italian Constitution
High school (14–15 y.o.)	• Map interpretation and geo-cartographic language • Demographic impacts and changes in modern society • Climate change • Botany and composition of agro-ecosystems • Geological stratigraphy and geomorphology • Life and technical–analogue or digital drawing (CAD)	• Knowledge, protection, and valorization of heritage • EU sociopolitical agendas: development and environmental sustainability • Meanings, rights, and responsibilities of the 21st-century citizen • Italian Constitution (art. 9)

The Italian context, as mentioned, differs from the curricula of the other partners in the presence of civic education as a 33-h/year cross-curricular teaching, compulsorily introduced in the 2020–2021 school year. Law No. 92/2019 establishes three new compulsory subjects and thematic cores in school curricula at all levels:

1. Constitution: national and international law, legality, and solidarity;
2. Sustainable development: environmental education and knowledge and protection of heritage and territory;
3. Digital citizenship.

The introduction of this subject is fundamental for having disseminated the concept of sustainable development for three years already, promoting the emergence of critical knowledge concerning the environmental and climate crisis even in the youngest segments of the population.

Therefore, this innovative law assumes the role of a transversal subject based on a plurality of learning objectives and expected competences, as well as the "cross-cutting value matrix that must be combined with the disciplines of study, to avoid superficial and unproductive aggregations of theoretical content" (Ministerial Decree No. 35, 22 June 2020) [48].

As emerged from the CA, the teaching in the secondary school curriculum (11–13 years) introduces a central theme for EDUSCAPE: the knowledge, protection, and enhancement of cultural heritage. In this sense, students embark on the exploration of the Italian Constitution, which plays a major role. Lastly, in the 14–15-year age group, more complex themes are introduced relating to the European Union's strategies for environmental sustainability, moving towards a preliminary understanding of the rights and responsibilities of tomorrow's citizens, aware of the challenges of the 21st century.

In particular, the topic of sustainable development reflects the intentions and objectives of EDUSCAPE that inevitably introduce the landscape dimension by extending the concept of environmental education to that of heritage and territory. This positive framework promotes an interdisciplinary integration between the various subjects, in which the concept of landscape, in its polysemy and multidisciplinary nature, finds several opportunities to be more integrated, starting from existing and specific national and local needs.

Looking further afield, the cultural debate in Italy concerning the landscape finds its foundation in Article 9 of the Italian Constitution ("The Republic shall [. . .] safeguard natural landscape and the historical and artistic heritage of the Nation") [49] and, subsequently, in the environmentalist movements and cultural currents that characterized the 1970s–1980s in response to the process of strong anthropization of cities and urban/suburban/rural landscapes, as well as the economic boom and large-scale construction investments to the detriment of the natural and landscape heritage. A process of reassigning value to the landscape, as summarized in Figure 6, can be read through legislation on urban and territorial law in Italy, culminating in 2004 with the Cultural Heritage and Landscape Code (*Codice Urbani*). There, the landscape takes on the connotations of a common good and heritage that is to be known, preserved, and valued (Italian Legislative Decree No. 42, 22 January 2004) [50]. Similarly, it is worth emphasizing a further advancement in the sphere of the protection of the environment–territory–landscape through the updating of Article 9 of the Constitution, where the concepts of ecosystem, biodiversity and sustainable development, "also in the interest of future generations" (Constitutional Law no. 1, 11 February 2022) [51], find their place.

This brief parenthesis helps to understand the context in which the promotion of this new formative teaching moves and the validity of the themes it introduces, which inevitably also refer to the ELC (ratified in Italy with Law no. 14 of 9 January 2006) and the SDGs, and which open up to the experimentation of EDUSCAPE PRs and future landscape education projects in schools.

Reviewing the results of the questionnaires administered for the NA, we see that 70 teachers took part, mostly from schools in the Marche, Abruzzo, and Lazio regions of middle schools (51% middle schools, 25% primary schools, and 24% high schools); and 60 professionals, including university professors, freelancers and/or specialists (architects, urban planners, landscape architects, climatologists, engineers, biologists, physicists, etc.), environmental guides, activists, and members of sector associations, to name a few. Those who participated in the needs analysis were reached through a dissemination of the initiative via email, social media, or personal contact in order to have a greater and better coverage of the national territories of the different partners and not be limited to the associated institutes.

The majority of the teachers interviewed (45.7%) described the existing offer of programs and materials on environmental education as having recently improved, a sign that the introduction of the civic education in Italy (compulsory from 2020) has implemented the materials available to teachers also regarding the landscape component. However, some of them (20%) still consider the offer insufficient or lacking in some content (17.1%). Only 10 interviewed considered the offer sufficient (14.3%) (Figure 7).

Many of the teachers already have experience with landscape-related interdisciplinary education in their school curricula (85%). Only 11% of teachers have no or little experience with EDUSCAPE topics (4%) or they know topics but do not integrate them into lessons. The teachers state that they often deal with landscape-related topics, processing the materials on the basis of other online sources. These topics, also by virtue of Agenda 2030 and the teaching of Civic Education, are already an integral part of the school curriculum. From the responses obtained, the topics most discussed seem to be forests and deforestation, extraction of building materials, renewable energy, and impacts on the landscape.

Figure 6. Civic education in the Italian cultural and international policy framework. A synthesis outside the legislation on the subject. Source: UNICAM Team.

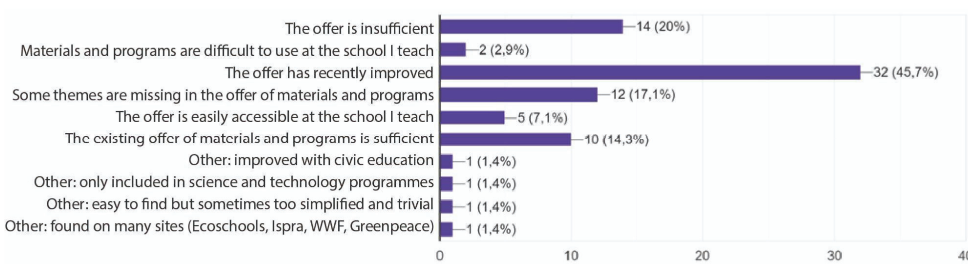

Figure 7. Infogram of the answers given to question 1, "Mark an answer related to the existing offer of programs and materials focusing on environmental education you agree with", extracted from the online questionnaire submitted, "EDUSCAPE questionnaire—teachers". Source: UNICAM Team.

Considering the materials that EDUSCAPE offers, those directly addressed to the students ("ready to use"), concerning activities to be experienced, in-depth materials on landscape and climate change adaptation, and preprepared worksheets, were considered particularly interesting (Figure 8). The feedback received is a sign that the basic materials available in the textbooks are not up to date on EDUSCAPE topics or are lacking, despite the recent reform of civic education.

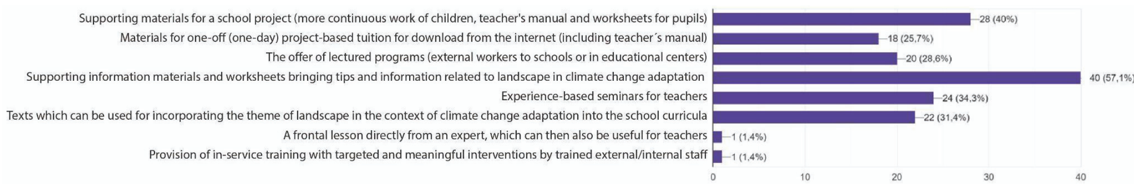

Figure 8. Infogram of the answers given to question 7, "The goal of EDUSCAPE is to create materials for teachers and students which will aid them to use the landscape they inhabit as a tool for teaching various subjects. Which form of support would you welcome?", extracted from the online questionnaire submitted, "EDUSCAPE questionnaire—teachers". Source: UNICAM Team.

3.3. Didactic Units (DUs) as Tool for Teaching/Learning Processes

Following the LR, CAs, and NAs, and after setting up the methodology and the identification of specific gaps in the school curricula, the topics for the DUs—and relative titles—were selected with the participation of all Partners:

- Introduction: 3 units present the general landscape concepts in relation to climate change;
- Construction: 2 units explore the landscape as source of materials and energy and how we shape it for industry and housing;
- Water: 2 units recognize the role of the water in shaping the landscape and as infrastructure (blue and green);
- Agriculture: 2 units focus on the productive landscape and its role in the cultural landscape and in climate change;
- Greenery: 2 units focus on spontaneous vegetation and plants in general to promote biodiversity and against climate change;
- Connection: 2 units explore all types of connections with and within the landscape (flora/fauna and human) and their impact/importance at different scales and analyze the different actors;
- Culture: 2 units recognize the role of globalization in cultural landscapes and for climate change, looking for the different histories that a landscape can tell.

DUs intercept the contents of the different school subjects of the various levels and grades and are therefore designed using the interdisciplinary and transversal approach. Through those, students will develop not only their knowledge but also training skills and attitudes by developing the necessary competencies for personal development, employability, and social inclusion.

The structure of the DUs (elaborated by MPD with the support of all partners) is made up of 45-min lessons divided and calibrated by age group, to which are added possible one-day trips or short outings during school hours for experimenting and reading the landscape in real time.

The lessons, reinterpreting the five teaching and learning moments developed in the method (Figure 3), consist of three teaching sequences:

1. Motivation and acquiring basic knowledge ("Conceptualizing");
2. Mapping and analyzing the field, problem definition ("Perceiving" and "Analyzing");
3. Designing and shaping solutions for the landscape ("Shaping" and "Reflecting").

The first teaching sequence involves the transfer of basic knowledge and scientific terms and concepts. The activities always aim to motivate students and prepare them for learning the basic concepts through games or presentations that can captivate them. Landscape, in this case, may function as a medium to link the topic analyzed to the everyday environment and experience of the students.

In the second phase, teachers aim to transfer those insights back to practice. Using the PBL approach, students are stimulated in finding a problem by scaling a global challenge in their life context, and they analyze it to identify the role of landscape, its dominant features and elements, its internal and external factors, and the values it assumes for the environment and the inhabiting community. Specifically, the analytical sequence is conducted from a problem-oriented perspective, so that the results could contribute to the solution of a scientifically founded "problem".

In the last sequence, the teacher takes advantage of the obtained results from the previous activities (participatory practices and political education) to reach the "design competences". It will be discovered that the shaping of landscapes is a collective process that involves negotiations between all the actors living and acting within it.

With respect to the overview of the topics covered, the UNICAM team, with the support of the partners, was mainly involved in the development of one of the two DUs on landscape ("Introduction") and the two DUs on ecological–environmental and human connections at different scales ("Connection").

The DUs, which are currently being finalized, follow a pre-established and univocal format that includes the (i) presentation of the contents and (ii) the general and specific aims, (iii) the skills that the students will be able to develop, and (iv) the importance of the topic in relation to the climate issue, with a focus on (v) a series of flexible activities to be tested in the classroom.

Each of the activities imagined and designed for the target group also specifies which objectives it contributes to achieving and which skills the student will be able to acquire with respect to the project topics. Below are just some of the "goals" defined for DUs number 2, "WHAT IS LANDSCAPE? Landscape elements and dynamics" (developed by UNICAM), that refer to the three teaching sequences described above:

1. The student recognizes the different types of landscape (shapes, seasonal colors, actors, and elements);
2. The student understands the importance of the scale of observation (spatial, geographical, local, individual object, etc.) and the point of observation (from above, from within, in perspective, etc.);
3. The student describes and recognizes the different elements of the landscape;
4. The student understands the spatiotemporal dynamic aspect of the landscape;
5. The student understands the relationships between natural and manmade systems: local impacts and global effects.

The student imagines future transformations/solutions with a view to sustainability and adaptation to climate change.

The individual activities are described step-by-step to support the teacher in the construction of the lesson, which can be declined and modified with reference to the subject taught, the area, the number of students and their ages, etc. Teachers, indeed, can extract one or more activities, deepening the topics, using or re-elaborating the contents developed by the project partners (exercises, worksheets, games, etc.) and structuring their lesson. The choice of the scale of analysis through which to look at the landscape is very important: neighborhood scale, city scale, national scale, and the general characteristics of the European landscape. The multiscalar and place-based approach is crucial to integrate theoretical study with reality, recognizing landscapes and how climate change impacts territories.

In this perspective, DUs will increase knowledge and skills for dealing with and facing societal challenges, coming into focus with active responsibility for landscape. This is the level where complex teaching designs such as service learning or PBL education enter into the picture.

4. Discussion and Conclusions

As emphasized by Castiglioni [7–9], landscape education can help build a positive and responsible relationship between each person and the living environment, fostering human growth and a sense of the emotional and rational dimensions and starting an active and proactive participation in the life of the civil community.

In today's crisis scenario (globalization, climate and geopolitical instability, emerging territorial fragilities, etc.), climate change acquires more and more value in the vision of the future for the new generations. Landscape thus becomes an interpretative tool that is useful for acquiring a greater understanding of the places of everyday life in line with national/international policies towards ambitious and much-needed transitions.

Educating on the landscape becomes indispensable to provide a different perspective of nonconceptual learning [36].

Teachers report that they are interested and aware of this potential, and the new European regulations for teaching increasingly look to an education that helps students understand concepts such as sustainability and climate change, which require experiential and experimental approaches based on the peculiarities of the territories.

In fact, based on the LR (Section 3.1), the NAs and CAs (Section 3.2), and the existing trends in education, it is possible to conclude that there is a need to bring the topic of landscape upfront and focus, in particular, on its essential role in approaching the societal issues of today. The research highlights that teachers already incorporate some important topics into their curricula through outdoor-based experiential methodologies, while neglecting the importance of landscape and its multiple relationships between man, the environment, and society.

In this sense, having intercepted the interest and difficulties present today, DUs aim to offer materials that are easy to understand and transferable to different contexts, so that this type of approach to teaching can be implemented by teachers. The activities in the DUs are adaptable to the context and training of the teachers, who have the possibility of modifying contents and materials (photographs, maps, and activities) supported by provided in-depth documents. The DUs also respond to a time constraint that normally prevents teachers from approaching new methods and topics to be integrated into everyday work life.

EDUSCAPE promoted and stimulated, through internal meetings with the community of educators, researchers, and experts (FGs and MEs), the internationalization of activities and the sharing and exchange of ideas and a process of raising public awareness of the role of landscape in the climate change crisis. The exchange of best practices and discussion sessions provided training and updating on emerging issues, methods, and tools for all partners. In light of the international geopolitical framework and the renewed interest in environmental and landscape issues, the project results (although not definitive) support the process of practical transfer of European policies and Sustainable Development Goals.

On this basis, the EDUSCAPE project supports the dissemination of landscape culture and education in schools as a privileged tool for observing and adapting to an already changed climate, emphasizing how the school world can provide valuable tools to support a process of growth and critical awareness of students and communities, moving towards a more sustainable development.

EDUSCAPE has, in fact, highlighted a demand from the territories (educational, legislative, etc.) that will have to continue to be met, favoring the process towards a more experimental, place-based, and active education.

The implementation of DUs is expected to produce different results depending on the context; the interest of the teachers; and the particular ways in which students relate to their own landscapes, places, times, and cultural attitudes.

Following the dissemination of EDUSCAPE activities and wider experimentation with the project's conclusion, it will be interesting to monitor the managerial implications that the DUs may have within the organization of teaching. At present, it is difficult to predict the project impact in the general process of organizing the school curriculum at the national level. Actually, there are many variables in this regard: the autonomy of each national governance in this domain; the individual sensitivity of teachers and school managers; and the willingness of schools to enter into contact with a European project that, on the whole, implies a process of renewal of tools, methods, and contents of teaching.

Supplementary Materials: The following are available online at "www.youtube.com/watch?v=OTWuwTBvF_0 (accessed on 29 December 2023)", Video S1: EDUSCAPE: How to Approach Landscape in Education, at "https://www.youtube.com/watch?v=92SBo9Z9nkY (accessed on 29 December 2023)", Video S2: 2022 EDUSCAPE Meeting Internazionale: Climate Change Adaptation.

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Article

Developing a Pedagogical Approach with the Aim of Empowering Educators and Students to Address Emerging Global Issues such as Climate Change and Social Justice: A Case Study

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Abstract: The "Green Nudges" program, developed within the framework of the United Nations Environment Programme (UNEP), is based on behavioral science and nudge theory. Aimed primarily at universities, it explores ways to adopt a more environmentally friendly lifestyle. Studies show that many young people recognize climate change as a major problem but that it leaves them feeling helpless and anxious—something that our teaching practice confirms. As we had had no success teaching sustainability using conventional approaches, we used the pedagogical design capacity (PDC) principle to develop a novel workshop format and implement it in a pilot series of three repeated workshops. The workshop concept is based on empowering educators and students to tackle emerging global issues while also boosting critical thinking, field research, and teamwork skills. An important part of the integration of different tools was based on supporting students' self-direction and knowledge- and evidence-based decision making. The results demonstrate that the proposed pedagogical framework resonates with and empowers students. At the same time, the workshop empowers educators to competently navigate complex and sustainability-oriented topics within the field of education for sustainable development (ESD).

Keywords: green nudges; education for sustainable development (ESD); pedagogical design capacity; behavioral design; design thinking; 12 SDGs

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1. Introduction

In 2020, within the framework of the United Nations Environment Programme (UNEP), which dates back to 1972 and is responsible, among other things, for the implementation of the 17 sustainable development goals (SDGs) [1] within the 2030 Agenda for Sustainable Development [2], the "Green Nudges" program [3], aimed directly at universities, was launched. That same year, *The Little Book of Green Nudges* was published [4]. The main goal of the program is "to inspire up to 200 million students around the globe to adopt environmentally friendly habits and greener lifestyles" [5]. It is UNEP's first program that is based on behavioral science and nudge theory. It focuses on human actions while examining ways of changing them.

Earlier in the 20th century, behavioral insights, through incentives and nudges, had already been practically deployed in government projects and in advertising campaigns within the scope of consumerism. The development of nudge theory is associated with the work of Amos Tversky, who was a key figure in the discovery of systematic cognitive bias in humans, as well as in the field of risk management. Along with Daniel Kahneman [6], who worked in the fields of the psychology of judgment and decision making and behavioral economics, they influenced Richard H. Thaler, whose research focused on behavioral economics, which he expanded on by incorporating nudge theory. Together with Cass

R. Sunstein, they popularized the "nudge" concept itself in the book *Nudge: Improving Decisions about Health, Wealth, and Happiness* [7]. We now use the term nudge (or nudge theory) to refer to the use of unobtrusive stimuli to induce a desired behavior. Green nudges include, for instance, "eco" or "organic" labels on products, the use of smaller plates in canteens in order to reduce food waste, the inclusion of infographics on bills or documents illustrating an individual's energy use in comparison with that of other users (e.g., in the neighborhood or city), and other such ways of encouraging environmentally friendly choices and sustainable, or "green", behavior.

The UN's Green Nudge initiative now takes us directly into the field of youth education. Studies show that as many as 77% of Europeans recognize climate change as a very serious problem. More telling still is the fact that "the younger the respondent the more likely they are to mention climate change" among the most serious problems facing the world as a whole, with 52% of 15–24 year olds doing so compared to 43% of those aged 55+ [8] (pp. 22–23). It should be further pointed out that global studies show that more than 50% of young people, clearly aware of the seriousness of the climate change problem, feel "the following emotions: sad, anxious, angry, powerless, helpless, and guilty". Moreover, "more than 45% of respondents said their feelings about climate change negatively affected their daily life and functioning, and many reported a high number of negative thoughts about climate change (e.g., 75% said that they think the future is frightening and 83% said that they think people have failed to take care of the planet)" [9] (p. e863).

In our perception as educators and researchers, similar reactions and feelings are prevalent among our own students as well. Whenever we prepared content that highlighted the urgency of the topic while encouraging a different response aimed toward sustainability, discussion with the students revealed a high level of anxiety and a strong sense of powerlessness. With conventional educational approaches clearly proving inadequate, we pondered the development of a different, more active approach: one that would facilitate the in-depth exploration of the often-complex theory through a combination of a hands-on method and tools in the form of specially designed workshops. With the "green nudge" initiative steering us primarily toward (re)designing services that help us achieve something, we chose postgraduate students of design as the test target audience for research into green nudge theory in the context of promoting the popularization of sustainable behavior and the topic of sustainability within the project. One of our key objectives was to situate the concept of sustainability—as theorized by Bill Reed [10]—firmly in the context of regeneration, with a clear understanding of the so-called Doughnut Model developed by British economist Kate Raworth in her book *Doughnut Economics: Seven Ways to Think Like a 21st Century Economist* [11]. Both regenerative design and the Doughnut Model wonderfully complement the 17 Sustainable Development Goals [1] since all three approaches advocate human well-being and capabilities while acknowledging and respecting the nine planetary environmental boundaries previously laid out by Johann Rockström in collaboration with a group of scientists from the Stockholm Resilience Center [12]. In other words, the combination of all three of these—in part, highly complex—theories and approaches intersects at a point that forces us to focus on designing solutions that will not only preserve the environment but also help regenerate it while, at the same time, being socially beneficial for all of us living on this planet.

With this intersection established, the next step was to propose a thesis: by consciously weaving together green nudges and design, we can not only directly address the UN's 17 Sustainable Development Goals but also offer a response to the International Panel on Climate Change (IPCC)'s report "Climate Change 2022: Mitigation of Climate Change". According to the report's authors, the nature of the global challenge demands an expanded sociological perspective on the problem of sustainable behavior. It is the only way to achieve the much-needed inclusion of new actors and perspectives. This is important because "it (i) provides more options for climate mitigation; and (ii) helps to identify and address important social and cultural barriers and opportunities to socioeconomic, technological, and institutional change" [13] (p. 117). The above leads back to education, which is regularly identified as "one of the keys for achieving sustainability and also one of the targets for a sustainable society" [14] (p. 1).

In addition to UNESCO's document "Global Action Programme on Education for Sustainable Development" [15], a number of recent texts, including those in this journal, address the importance of the intensive integration of sustainability-related topics into education in order to help us, as a society, accelerate the sustainable transition [16–19]. This text thoughtfully integrates the aforementioned "green nudge theory" into the given context, namely the urgent need to expand the scope of sustainability-related topics in education through a measured introduction of design thinking. The practical validation of the introduction of pedagogical design capacity (PDC) into the context of education for sustainable development [20] represents a further enhancement of the above.

By designing and delivering three repeated workshops, we also practically examined ways of engaging students in complex, real-world problems and spurring them to analytically engage with existing scientific information and conduct ethnographic research in order to gain vital insights (including in the area of ethical and social values). They were encouraged to use an evidence-based decision-making process to design proposals while also continuously testing, evaluating, and iterating on the basis of their findings. A very important part of the research involved observing and analyzing which topics within the broader fields of sustainability and green nudge theory appeal to young people and identifying opportunities for a deeper examination of the content and empowering the students in their everyday actions. In case of a positive outcome, the key long-term objective of the research was to provide a foundation for the development and formalization of a specific sustainability education (e.g., a mini-course with certificate of completion) focusing on behavioral design based on green nudge theory.

2. Materials and Methods

Nudge theory builds on an understanding of the psychology of decision making. In most situations we find ourselves in, our capacity to make sense of a complex and uncertain world is limited, so we often take mental shortcuts. We fall back, for example, on "doing what others do", or, given a choice, "choosing the easiest option". In addition, much of our behavior is automatic—we often follow entrenched routines, acting habitually, as if "on auto-pilot". Accordingly, when developing the structure of the workshops, we set out to examine how an understanding of cognitive processes can alter the choices available to us. We further set out to examine how a particular choice can be promoted through the formation of a "choice environment"; in other words, by expressly designing choices with the aim of exploiting or overcoming typical cognitive biases in the form of mental shortcuts. Emotional context can play an important role in the latter in the sense that associating a positive emotional experience (an anchor point) with knowledge acquired about a change can potentially result in a long-term change in behavior. The latter was key to our approach in designing the workshops as we wanted to overcome the negative reaction we frequently observed in students when discussing the rationality of sustainable action.

Since our primary target audience was postgraduate students of design who are familiar with the tools of design thinking, we combined the latter with behavioral science approaches in order to simplify the transition to a sustainable society. The combination with design enabled us to leverage the fact that designers are uniquely positioned to transform how and what services and things are made of. This, therefore, accounts also for tackling the climate issues of our time. To put it differently, overconsumption, wasteful production, processes, and the use of materials are all related to poorly designed systems, products, services, and policies. As Justin McGuirk explains,

> *Contrary to what we might assume, wastefulness is not a natural human instinct—we had to be taught how to do it. Disposability was one of the great social innovations of the post-war years. When the first disposable products became available in the 1950s, from TV-dinner meal trays to plastic bags, consumers had to be persuaded that this magical*

> *new substance—plastic—was not too good to be thrown away. They had to be instructed in the advantages of the throwaway society*. [21] (p. 10)

It would seem that much like different and often unsustainable behaviors needed to be deliberately taught to us, we are now facing a challenge that once again requires us to devise ways of fostering a change in behavior. Selected studies [22–24] show that the best way to tackle sustainability issues is not simply researching how and why people make their everyday decisions, but also to make use of the tools and methods of design that can help us shift human behavior toward sustainability. Behavioral design, a combination of behavioral science and design methods, can inspire radical ideas, create environmental, social, and economic value, and deepen knowledge about our choices and well-being [25]. Or, as Grilli and Curtis state, different approaches to changing and shaping environmental behavior are now in place and in use: awareness raising and education, social influence, rewards, nudges, and behavioral insights [26]. We put the above into practice in three deliberately repeated workshops.

2.1. Workshop Design

When designing the workshop, we sought to develop an approach that would allow us to adapt the content to changing social and cultural contexts and thus respond to emerging global issues such as climate change and social justice. As mentioned previously, one of the objectives was to examine the possibilities of cultivating an interest in actively engaging in changing students' behavior toward sustainability; the second extremely important objective was to establish a framework for the empowerment of educators to successfully address the complex issues we are presently facing. In the latter, we weighed different approaches to adapt learning so that it moves beyond abstraction to make use of the pedagogical design capacity framework [20,27] while taking into account UNESCO's recommendation for how to approach sustainability issues in education [28].

Beginning with the objectives we set, we designed a five-day workshop (Table 1) which was based on co-design approaches [29] and oriented toward fostering critical thinking skills by providing a framework for self-direction and using the insights and findings gained to encourage autonomous and knowledge-based decision-making. An extremely important part of the workshop design was to enable students to independently identify sustainability-related topics within the broader context of sustainability, allowing them to choose topics that closely aligned with their interests and that they were able to explore locally. This approach gave them the opportunity to further explore their own values and attitudes toward local sustainability problems while developing proposals which, if successfully implemented, could lead to positive impacts in both their local community and their personal lifestyles.

Table 1. A structured view of the 5-day workshop design.

	Day 1	Day 2	Day 3	Day 4	Day 5
9:00–9:30	Introductory lecture	Preliminary desk research on the intersection established the first day	Synthesis and choice of focus (the problem identified during field research)	Lecture on data visualization	Finalization of concepts and results (evaluated on the basis of the previous day's testing)
9:30–10:00	Short questionnaire	Field work: participant observation, interviews, etc.	Ideation phase using tools: HMW, HMW voting, Crazy Eights and selecting a concept for further development	Peer feedback on concepts and poster design	
10:00–10:45	Lecture on sustainability				
15 min	Break				
11:00–11:45	Team formation and community canvas task	Continuation of fieldwork and insight gathering, including the first quick tests when the situation permits	Development of the selected green nudge concept (with occasional internal consultations)	Various activities: iteration of concepts according to feedback; retrieving missing data; development of improved solution; preparing for additional field testing	Preparing presentations
11:45–12:05	New Lexicon #1: choosing three keywords and outlining their general meaning				
12:05–13:00	New Lexicon #2: Building a deeper understanding of the selected keywords through reading scientific and expert texts				
1 h	Lunch break				
14:00–14:45	Additional reading	Interim consultations	Designing a poster by formulating answers to 6 questions	Interim consultations	Public presentations and the awarding of certificates of completion
14:45–15:15	Discussing the materials read	Analyzing the insights gathered and identifying opportunities (Affinity Diagram)		Guidelines for final presentations	
15 min	Break				
15:30–16:00	New Lexicon #3: Re-envisioning of the updated explanations; mindmap	Continuing the analysis of the insights gathered	Continuing the design of a poster by preparing answers to 6 questions	Additional field testing of improved concepts	Short questionnaire (KALM or Mentimeter)
16:00–17:00	Short presentations or delivery of 1st blog post	Interim consultations or delivery of 2nd blog post		Interim consultations or delivery of 3rd blog post (covering Wednesday and Thursday work)	Recap: report writing or delivery of the 4th (final) blog post

As Table 1 shows, after an introductory lecture, the main intent of which is to establish the technical framework of the whole week (without disclosing the research topic), the workshop opens with a short questionnaire. The students answer the anonymous questionnaire individually without any prior suggestions or instructions of any kind. The two questions—with no wrong answers—in our case were the following: *(1) If you had the power to change one thing in society, what would it be? And why? (2) And conversely: what is the one thing in our current society that you are absolutely happy with and wouldn't dream of changing?* In its own way, this task would set the tone for the entire week. The answers were very honest, as well as revealing, as they also very clearly showed the cultural and social characteristics of the students' varied backgrounds. This was followed by a long-form lecture establishing the broader context of the research topic within sustainability, the significance and role of regenerative design, and the explanation of two theories: (green) nudge theory and the theory of change (the theory emphasizes what we want to achieve rather than what we want to do). The rest of the first day was primarily devoted to forming groups and collectively generating a simplified community canvas [30]. The latter, in order to increase the effectiveness of collaboration within the interdisciplinary group, helped the group members establish a shared motivation, define common values and identity, and reflect on what they consider success (including in terms of group success at the end of the workshop). This step is supremely important as all the substantive decisions subsequently taken by the group either derive from or are tested and validated against these four common principles.

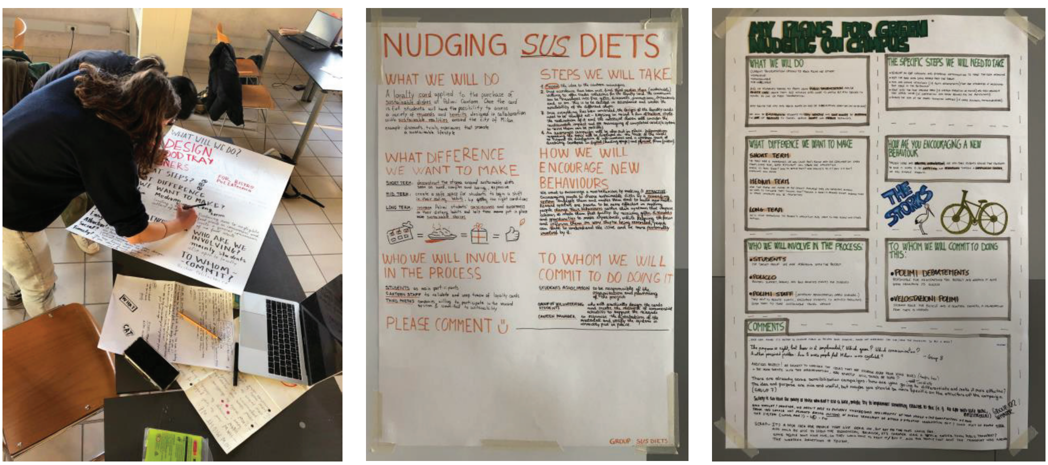
The first substantive decisions follow on the same day. In the first two workshops, students narrowed down the topic by selecting three concepts/phrases from a set of 9–10 keywords thoughtfully derived from the aforementioned theories and concepts: the UN's 17 Sustainable Development Goals, Bill Reed's interpretation of sustainability in the context of regeneration, Kate Raworth's concept of Doughnut Economics, understanding the implications of the nine planetary environmental boundaries, and, finally, the role of behavioral science in design. The background to the selection of the chosen keywords was based on opening new perspectives and approaches to the understanding of sustainability, which the students then gained in the next step through readings of the listed selected authors. The third workshop was completely open-ended; we simply asked the students to choose a focus within the broader topic of sustainability that was closely linked to green nudges. The three subsequent steps, which we called the *New Lexicon*, led them from establishing a general meaning to a very in-depth understanding of each of the selected concepts (arrived at with the help of a selection of scientific articles and individual chapters from the professional literature). Building on the newly acquired meanings, they subsequently mapped out the existing as well as overlooked or, potentially, new relationships between the selected keywords. This could be carried out in the form of an exercise involving, for example, the establishment of new meanings and descriptions for the new lexicon, or even simply in the form of a mindmap. It is already at this juncture that participatory learning is introduced and higher-order thinking skills, on both sides, are being fostered [28]. It is impossible for the teacher to know in advance which combination of keywords the students in a group will pick; as a result, considerable adaptability is required on the part of the educator, mostly in the sense of the ability to guide discussions and further research opportunities. The first day concludes with the first independent reflection on the part of the students. By choosing, on the basis of their own values and attitudes toward sustainability, a starting triangle, which does not in any way pre-suppose a particular solution, the newly mapped interrelationships built on existing (but previously unfamiliar to most) scientific knowledge allow them for the first time to view from multiple perspectives topics that they would otherwise likely perceive by making use of mental shortcuts. They can present their findings in the form of a public presentation with the help of the mindmaps they created, or in a written form on a publicly available blog.

The second day of the workshop is largely dedicated to ethnographic research [31]. The first task of the day is to define potential local sustainability topics, situations, locations and potential problems at the intersection established the day before. After some desk research on any existing efforts in the areas identified, the students (having been given the tools but not a clearly defined problem) are sent to do field research. In the first phase, they are told to carry out at least two out of three tasks. They can choose from among the following approaches: participant observation, interviews with users, employees, or any other relevant stakeholders in a situational context relevant to the topic and, if possible, acquiring user-generated data, as well as any existing visualizations and other instructions present at the target locations. The students are free to combine and repeat these approaches as they wish. The aim of the exercise is to gather insights in order to achieve an optimal understanding of the actual context, everyday and most likely routine behavior, with an emphasis on identifying unsustainable behavior in the form of reactions, actions, or choices. Even though time is quite limited due to the nature of the workshop, this step, which has students spend most of the second day conducting field research that involves systematic observation of and participation in real-life situations, as well as talking to passers-by, is extremely important. In one case, the students tried to skip this step, relying solely on their past experience. In the very next phase, however, they encountered issues defining the situation that would be subject to redesign. Unable to proceed without the insights gathered in field research, they ended up having to return to the location and carry out the ethnographic research in earnest. After the first interim revision, in the afternoon session of ethnographic research, we further encouraged the students to carry out the first quick tests of the existing green nudges that are expected to work in the chosen situation. The majority sourced existing nudges from *The Little Book of Green Nudges* and tested them within the previously observed context. The intent is to provide some additional impetus toward active participation and critical thinking since they are not emotionally invested in others' proposals. Conducting these preliminary tests also provides them additional experience in how to perform focused observations, while the additional field experience yields an excellent set of further insights into how the individuals under observation respond and adapt to the change. If the situation in question does not permit this step, the students continue with the same approach they used in the morning. The day concludes with an analysis of the insights gathered (an Affinity Diagram [32] can be a helpful tool). The analysis is meant to facilitate a reformulation of the problem identified and highlight opportunities for changing behavior toward greater sustainability.

The third full-day session is devoted to ideation directed toward the workshop's original goal, which is to promote environmentally friendly habits and a sustainable lifestyle. Starting with an analysis of the second day, the students begin the day by synthesizing and choosing a focus (a problem or a situation identified) for their subsequent steps. Since all group members must agree on the choice of focus, the community canvas is often very helpful at this stage. Having identified the values they share on the first day, as well as what they, as a group, will consider success at the end of the workshop, the community canvas can be of great help when selecting a specific opportunity among those identified on the basis of the insights gathered previously. At this stage, a range of design thinking methods come into play. In order to improve the awareness of and positively reframe the problem identified, the students first use the IDEO Design Kit methods "How Might We (HMW)" [33] and "HMW Voting" [34]. Both individual tasks are useful as they offer the opportunity to create an active framework for addressing the perceived challenge before any responses to it are actually designed. After voting and re-prioritizing according to the top-ranked HMW questions, the next task is Crazy Eights, a core Design Sprint method [35]. The aim of this exercise is to push beyond the first idea, which is typically the least inventive. By asking the students to produce eight answers to the same question in eight minutes—a very short time—we make them to think outside the box. The reason this is so important is because the group members can use the proposed methods to view the chosen focus from various perspectives which, in turn, allows them to generate a wide variety of responses to the situation chosen initially. Nicolas Nova condenses the change in perspective into four approaches that occur most often in the process of defining insights into transformed concepts:

> *'Inversion' consists in inverting an observation: a user fear is turned into an interface that is supposed to prevent this fear from happening. 'Translation' relies on the idea that a design concept occurring in one field can be applied to another. With 'Multiplication' moves, the point is to take a certain phenomenon and repeat it or make it less important. By 'Complexification', some designers add or remove steps in a process they observed*. [31] (p. 63)

The afternoon session of the third day is devoted to the development of the green nudge concept selected and its presentation in the form of a poster (Figure 1). The structure of the poster reflects the six questions from *The Little Book of Green Nudges* [4] (p. 47). The students' main task is to develop their concept to a point at which they can describe it in a clear and readable way that can be understood by someone who knows nothing about their research, topic, and task. We can see in Figure 1 that just over half of the poster is devoted to introducing the concept, which is achieved through answering six questions. The rest of the poster is devoted to comments and feedback.



(**a**) (**b**) (**c**)

Figure 1. (**a**) Making the presentation poster on day 3; (**b**) the presentation poster ready for feedback; (**c**) completed feedback at the bottom of the poster.

The fourth day opens with a lecture on data visualization and information design in the context of sustainability and green nudge theory [36]. When the aim is to change habits, visualization techniques are supremely important and can be very effective if executed well. The lecture therefore described the field and provided an overview of the possibilities that students can use to improve their concepts. Our aim was to establish to an even greater extent the objective conditions that would, in the next step, allow the students to see their own and their colleagues' posters through the lens of new insights, overcoming, as a result, typical cognitive biases and consequently formulating quality responses. The lecture was therefore immediately followed by a review of the resulting posters. Each group was asked to provide peer feedback for all the other groups' posters. The bottom part of each poster was used to record the comments made. Repeating suggestions previously given by another group was not allowed. The instructions demanded they express their opinion clearly and provide reasoned comments on the research carried out, the suggestions offered, and the way the content was presented. They had eight minutes to read each poster and prepare their feedback. The students were immediately enthused by the task. They were thrilled to have the opportunity to freely provide reasoned feedback on their colleagues' work. This allowed them to further explore and examine their values and attitudes toward sustainability within the group. Many of the groups' comments provided well-reasoned criticism, with many additional questions asked and ideas for improvements given. This was followed by the iteration of the concepts in response to the feedback received and then by preparation for another round of field tests, which were carried out in the afternoon. The fourth day concluded with the writing of a new blog post that summarized the results of the work of the third and fourth days. This gave the students the opportunity to reflect on the work they had completed and another chance to practice writing for a reader who is initially entirely unfamiliar with their project. It was in the light of this last aspect, i.e., clear language, that we also provided them with feedback on what they had written.

The morning session of the fifth day of the workshop was devoted to finalizing the concepts based on the results of the previous day's testing. This was followed by preparing 10-min public presentations. The presentation had to reflect all five days of work, clearly formulating the problem statements and the evidence-based decisions made during conceptualization, as informed by the insights gathered and the testing conducted. They were also required to include the theoretical background, the principal beneficiaries of the proposed concept, the potential owners of the project (any third parties or institutions that could be involved), and their hopes regarding the project's achievements in the long term. After the presentations, there was a short ceremony wherein the students were awarded certificates of completion. Afterward, they concluded the day and the workshop by writing either a final report or a weekly summary blog post. We found that by having to respond and summarize in various ways, the students developed the skills to communicate using a variety of communication channels.

The structure of the workshop is laid out in Table 1; it is important to note, however, that both the timing and the content of the workshop phases can be adapted according to the desired emphasis and pedagogical objectives. Blog writing can be substituted entirely or combined as appropriate with shorter interim presentations. The latter can be particularly effective when the groups do not all progress at the same pace. Short group presentations can encourage slower groups to be more active when responding, as usually no one wants to be left behind in a public comparison with other groups. The number of consultations during the week may also vary, depending mainly on the desired degree of the educator's influence in the management of the process as compared to the level of autonomous decision making on the part of the students.

2.2. Research Strategy Design

This research was based on qualitative data gathering. The workshops carried out formed the basis for validating the effectiveness of the set objectives in the form of a case study [37]. The workshop format was chosen deliberately as it allowed us to thoroughly test what we had set out to achieve within a predefined timeframe and in a predefined context [38]. In other words, the five-day workshop held at selected faculties provided a framework that allowed us to observe students as they collaboratively examined modern environmental issues, gained different perspectives through ethnographic research, learned about the interests of different individuals and groups, and continuously integrated their scientific knowledge with environmental, social, and ultimately ethical considerations in the process of making informed decisions. We identified these insights in the next step using an exploratory approach to the case study. The decision to undertake an exploratory case study was also taken with the aim of gaining key insights for the potential further development and formalization of specialized education in the field of sustainability. At the point at which we were seeking any tangible changes in attitudes and behavior that may have occurred during the workshops, we also complemented the exploratory research with descriptive research [37].

We held the prototype workshops three times with different groups of postgraduate design students, twice at the Politecnico di Milano–School of Design (Visualizing life in the doughnut, February 2022, and How to empower communities to tackle climate change through design, February 2023) and once at the University of Ljubljana, Academy of Fine Arts and Design (How to empower communities to tackle climate change through design, October 2022). The participants were selected based on the comparability of the study program and the institution they were studying at (similar age, similar programs), but with important differences in order to achieve diversity: the size of the institution and the cultural background from which the students came. Thirty-four students participated in the first workshop, twenty-six in the second, and thirty-four in the third (i.e., the whole sample of our research was 94 participants). In all three workshops, the students worked in groups of 4–6, of which there were seven in the first Milan workshop, five in the Ljubljana workshop, and eight in the last one, again in Milan. In order to establish a constant, we led all three workshops ourselves, while the students changed with each workshop. In Milan, both workshops featured students from the second year of the Master of Science degree DM 270/04 in Communication Design (Design Della Comunicazione). In the Ljubljana workshop, we took the opportunity to weave together different disciplines, as the workshop was attended by second-year masters-level students of graphic design (26.9%), industrial design (26.9%), illustration (23.1%), and photography (15.4%). The last two workshops were also attended by exchange students participating in the Erasmus program (two in Ljubljana; six in Milan), so all three workshops were held in English, following the structure defined and described above.

The data generated during the workshops were collected on a daily basis. In the first workshop, this occurred in the form of presentations which, each time, summarized the steps taken, the insights perceived, and the results, as well as envisaging further steps to follow. In the second workshop, the daily presentations were ultimately complemented by a final report summarizing all the steps taken and featuring a detailed record of all the findings arrived at during the week. In the third workshop, diary entries covering all the steps taken on a particular day, together with the insights, results, and future steps, which took the place of the earlier presentations, were converted into a blog format. In addition to studying the collected materials and the aforementioned participant observations, we also had regular discussions in natural settings during the workshops. All three workshops concluded with either a short individual and anonymous questionnaire based on the KALM Retrospective approach—Keep, Add, Less, More [39]—or with a Mentimeter [40]. The main aim in collecting feedback was to obtain valuable insights for improvement, with the primary focus being on identifying positive emotional experiences connected with participation in a workshop dealing with sustainability in depth.

2.3. Data Analysis

For the data analysis, we began with the traditional Harry F. Wolcott approach [41], as ethnography and case study analysis represent the foundation of his data analysis strategy [42]. The emphasis was therefore on selecting and contextualizing key information, identifying patterns, and presenting findings. It is important to note that throughout the data analysis, the first phase involved "[staying] close to the data as originally recorded" [41] (p. 10). In the next phase, this descriptive approach was substituted with our interpretation of the collated data. To ensure the external validity of the results, we repeated the workshop—the case study—three times, each time with a different group of students. Another factor that importantly contributed to the external validation of the results is that the workshops took place in two separate educational organizations spanning different cultural and social settings.

3. Results

The original motive for designing the workshop as a case study was the high level of anxiety, anger, sadness, and powerlessness we noted among students whenever we tackled pressing issues connected to the environmental crisis and climate change in our lectures. The research questions posed, namely: "*Which topics within the field of sustainability and green nudge theory appeal to young people?*" and "*Where are the opportunities to go more in-depth and to empower [young people] in their everyday actions?*" were answered over the course of the first two days of the workshop through a series of short exercises and assignments. As mentioned previously, the first short task already set the tone of the workshop. Students answered two questions to determine what they would change in society if they had power, and why, and what they are satisfied with and would do anything to preserve. The answers received at each of the workshops were grouped into thematic clusters with similar characteristics (Figures 2 and 3). Figure 4a,b, on the other hand, provides a combined view of selected answers from all three workshops.

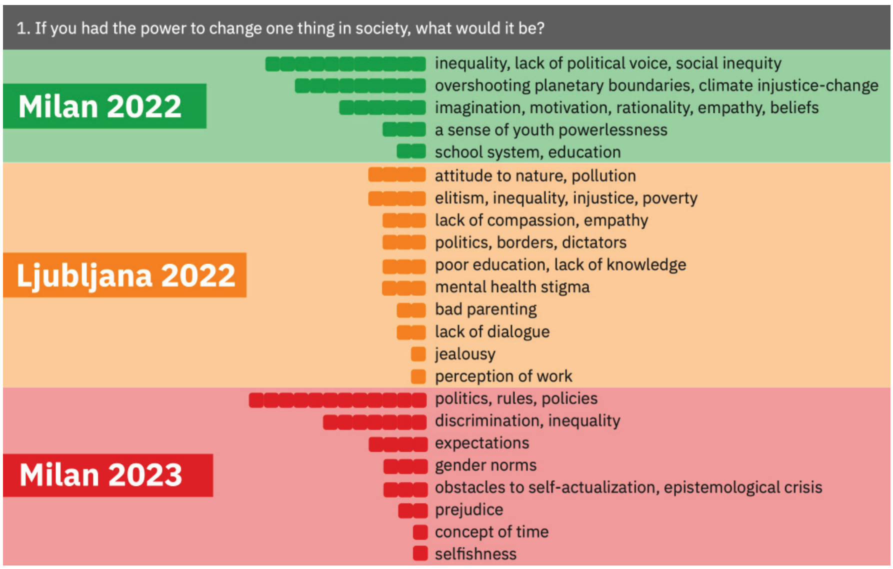
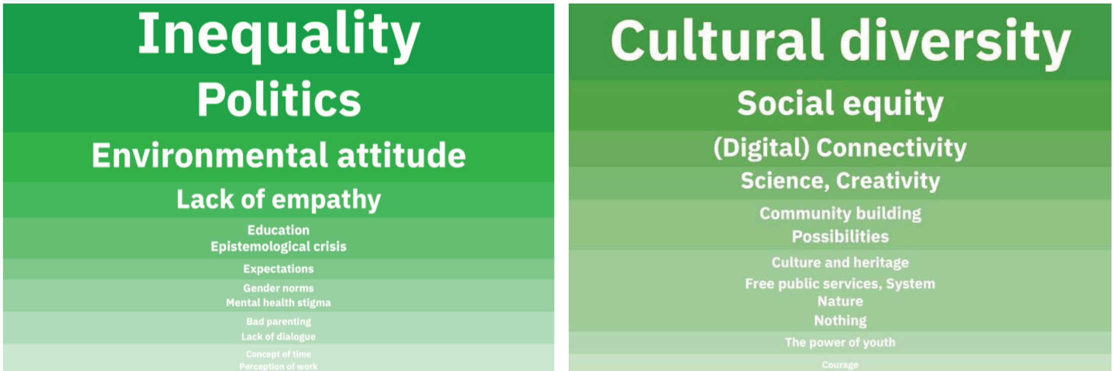


Figure 2. The thematic clusters of all three workshops, consisting of answers to the first short question: "If you had the power to change one thing in society, what would it be? And why?" The task was to be completed individually and was anonymous. Students had 15 min to respond.

Figure 3. Thematic clusters of all three workshops, consisting of answers to the second question: "What is the one thing in our current society that you are absolutely happy with and wouldn't dream of changing?". They likewise had 15 min for this task, which was individual and anonymous.



(**a**) (**b**)

Figure 4. The combined and unified thematic clusters of all three workshops, consisting of answers (**a**) to the first question, detailed in Figure 2; and answers (**b**) to the second question, detailed in Figure 3.

It is particularly telling that in all three workshops, the list of answers regarding what the students wished to change (Figure 4a) is topped by the issue of inequality, which garnered nearly a quarter of the votes (24.7%). This issue encompassed economic and social inequality and gender-based discrimination as well as, ultimately, the lack of a political voice. With this, the students—likely extrapolating from their own position and, at least in the first workshop, still strongly impacted by the pandemic—directly touched on the tenth SDG [1]. Reducing inequalities and ensuring no one is left behind are integral to achieving the Sustainable Development Goals. Kate Raworth similarly identifies addressing inequality as a key step in and a prerequisite to achieving a safe and just space between social and planetary boundaries since, in her view, tackling inequality will force us to rethink the distribution of global resource use in both consumption and production [11].

With inequality topping the list of things that students would immediately change, when asked what is the one thing that needs to be preserved and cultivated, cultural diversity was factor the most voted for (23.5%). The latter is, in a way, the opposite side of the same coin. When proclaiming 21 May as the World Day for Cultural Diversity for Dialogue and Development, the United Nations wrote that "the 17 Sustainable Development Goals can best be achieved by drawing upon the creative potential of the world's diverse cultures and engaging in continuous dialogue to ensure that all members of society benefit from sustainable development" [43]. We are therefore talking about a factor of sustainable development that can improve human well-being; by fostering coexistence in a community and promoting action based on justice and inclusion, it also directly combats inequality. The two answers have another common denominator: they both put us—people—first. The students ranked the issue of our negative attitude toward the environment in third place, with 14.6% of the vote.

Further focused insight into what appeals to students within sustainability was provided by the next task, which involved the selection of three keywords. The in-depth examination and elaboration of their meanings with the help of scientific and scholarly texts pushed them to search for and establish relations and their interrelationships. To investigate how the choice of the three keywords is influenced, the first two workshops featured previously prepared lists of keywords the students were able to choose from. They had the following concepts to choose from (listed alphabetically): behavior, care, circularity, degrowth, distributive design, futuring, invisible women (only at the Ljubljana workshop), regenerative design, social innovation, and survival. In the third workshop, wishing to see how far they would go in their independent choice when exploring new terms, we left the selection of the three keywords entirely up to them. Our only suggestion was that their selection of keywords be based on the lecture in which the broader context of the research topic in the field of sustainability was established and defined (the lecture was the same in all three workshops) and on the list of scientific and professional texts which, as in the first two workshops, were used to more deeply examine and elaborate on the selected keywords. The three keywords were as follows:

Milan WS1:

- Group 1: circularity, degrowth, and regenerative design;
- Group 2: behavior, futuring, and social innovation;
- Group 3: behavior, degrowth, and futuring;
- Group 4: behavior, distributive design, and social innovation;
- Group 5: circularity, degrowth, and social innovation;
- Group 6: care, circularity, and futuring;
- Group 7: behavior, degrowth, and regenerative design.

Ljubljana WS2:

- Group 1: behavior, care, and social innovation;
- Group 2: distributive design, social innovation, and survival;
- Group 3: care, circularity, and invisible women;
- Group 4: care, social innovation, and survival;
- Group 5: behavior, regenerative design, and survival.

Milan WS3:

- Group 1: agency, behavior, and food (resources);
- Group 2: behavior, degrowth, and water (resources);
- Group 3: education, regenerative design, and tourism (reduce and localize);
- Group 4: behavior, carbon footprint, and energy (resources);
- Group 5: care, engagement, and social innovation;
- Group 6: behavior, education, and recycling;
- Group 7: behavior, degrowth, and waste;
- Group 8: confirmation bias, degrowth, materials (resources).

Below we examine the frequency of the choice of each term. To achieve a more coherent picture, we combined the keywords of the third workshop that were close either in terms of meaning or the topic addressed to our own concepts; we thus folded recycling into circularity, carbon footprint in tourism into degrowth, agency and engagement into futuring, and confirmation bias into behavior. Following the frequently repeated terms from the students during the third workshop, we added the following keywords to the selection: education and resources (while also incorporating waste into the latter). The rationalization described above produced the following results (see Figure 5):

The answer to the question "*Which topics within the field of sustainability and green nudge theory appeal to young people?*" is therefore reflected in the most frequently chosen keywords: behavior, degrowth and social innovation. The choice of the term behavior is partly explained by our choice of initial theories to handle sustainability: nudge theory and the theory of change; the terms degrowth and social innovation, on the other hand, largely represent the students' own choices. It is interesting to note that distributive design [11] (pp. 163–205) is among the overlooked concepts even though it offers the most tangible answers regarding the establishment of processes to reduce inequalities in society. This is likely to be indicative of a broader lack of understanding of a concept that is relatively new and certainly poses a challenge for how to address it in the future. The students instead gravitated toward a more familiar term that they likely perceived as a suitable surrogate, namely *social innovation*, which, according to Ezio Manzini, emerges "from the creative recombination of existing assets (from social capital to historical heritage, from traditional craftsmanship to accessible advanced technology), which aim to achieve socially recognized goals in a new way" [44] (p. 11). Social innovation is, in a way, also linked to degrowth because, as stated by Francois Bonnici, social innovation "supports the shift from growing organizational models to systemic action" [45]. However, when we talk about degrowth, we are not just talking about cosmetic fixes to the system but about finding tangible alternatives to the existing system, "which pursues growth at all costs, causing human exploitation and environmental destruction" [46].

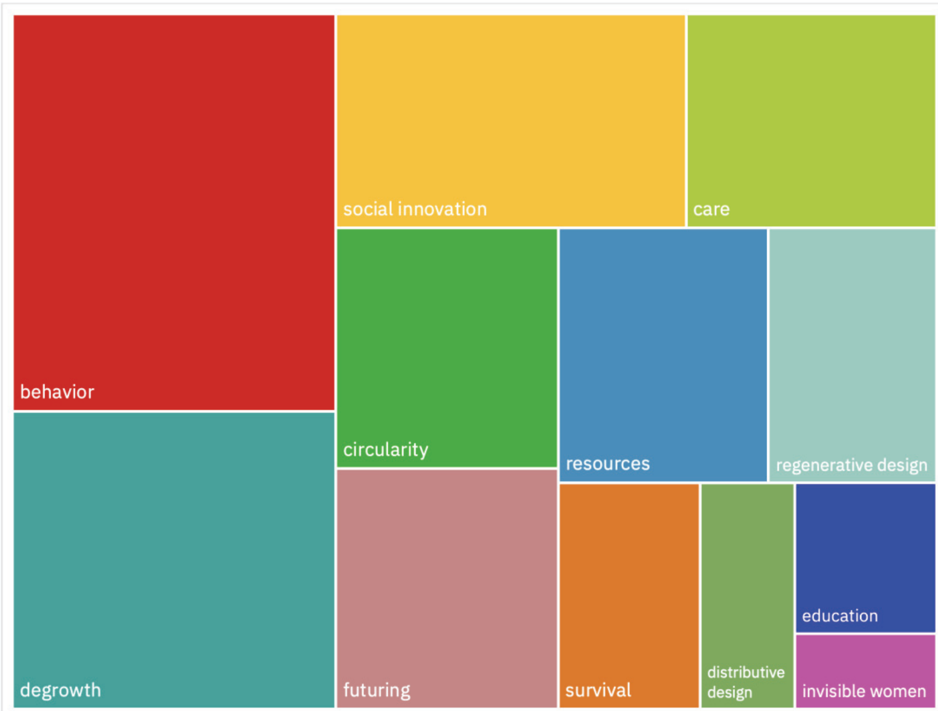


Figure 5. An overview of the selection frequency of each concept (all three workshops combined).

Before interpreting the choice of the three keywords with or without a pre-selected set of words, it is useful to look at the results of the next phase. In this phase, building on the established interrelationship between the selected keywords and on the basis of their ethnographic research, the students were asked to identify an intersection of the above and define a narrower field as a basis for the topic that they would focus on until the end of the workshop (Table 2).

Table 2. The selection of more specific sustainability topics based on the steps taken on Days 1 and 2.

Milan WS1	Ljubljana WS2	Milan WS3
everyday actions	access to education	sustainable diets
social provocation as reflection on sustainable action	commons and community spaces	water conservation
combating biodiversity loss due to consumerism	women's image and position in society	sustainable mobility
ethical and responsible use of local resources	social isolation	energy conservation
sustainable communications	environmental legislation	engaged community
engaged community		recycling of waste
finding links between the needs of the individual and the collective		food waste
		reduced material consumption

As is evident from the sequence of the selection of the three keywords and the subsequent steps, a pre-selected list of keywords provides a better starting point, yielding choices that are more varied and less impulsive. A pre-defined, carefully selected set of keywords is in fact a nudge through which a choice environment is established that pushes students to depart from their everyday understanding of sustainability. As the third workshop clearly shows, when students are not thus encouraged to explore new terms, their understanding of sustainability remains largely constrained to conventional areas: recycling, waste management, and searching for ways to reduce the use of natural resources. While these are all no doubt important topics, the selection also indicates the narrowness of the initial view of the topics that students spontaneously associate with sustainability. It also shows that the thematic lecture is not sufficiently impactful to spur students to seek out additional knowledge in the scope of the newly introduced topics. Moreover, this change in how keywords are chosen has clearly demonstrated that if the choice is left open-ended, the students immediately begin narrowing down their thinking toward specific topics of research, thus prematurely preparing the ground for the next steps. This indicates a somewhat more pragmatic approach—a mental shortcut—which, however, limited from the very outset both the field of research and the potential for gaining new knowledge and new insights into what action in the field of sustainability is possible. The selection of the nine keywords by the educator can, from the outset, be considered a biased choice as well. However, as explained at the beginning of this text, the main purpose was to open new perspectives and approaches to sustainability. The aim was to explore novel possibilities for stimulating students' interest in actively engaging in behavioral change toward sustainability.

Despite this moderate cognitive bias in the second step of the third workshop, the clearly structured concept allowed us in all three workshops to engage students in real-world problems, encouraging them to analytically engage with existing scientific information, carry out ethnographic research, and conduct actual field tests, all with the aim of gathering key insights (including in the field of ethical and social values). By insisting on field research, we directly (and spontaneously) encouraged them to explore behavior and sustainable practice in a local environment. As soon as the community canvas was completed, the group had the opportunity throughout the workshop "to learn negotiation, problem-solving and decision-making skills through discussions about ecological, social, economic and ethical principles concerning local and global responsibility in their own lives" [14] (p. 2).

Below (in Table 3), based on the data obtained, we evaluated the resulting student concepts (20) using the following three factors:

- Factor 1: We examined the primary lens through which the students viewed the field of sustainability: environmental or social aspects. Of particular interest to us was which aspect predominated in cases in which there was a change in behavior based on the proposed concept.
- Factor 2: In the context of the seventeen SDGs, we were interested in which of the five core areas (the so-called five Ps), people, planet, prosperity, peace and partnership [47], is (or are) dominant both in the students' understanding of sustainability and in their choice of focus (the problem identified during field research) and the final design of the concept.
- Factor 3: Finally, in pursuit of the Education for Sustainable Development (ESD) parameters, we examined which aspect of sustainability is predominant: the anthropocentric approach (Human-Centered Design) or a planet-centric future (Environment-Centered Design). In the lecture, we highlighted the need to start perceiving non-human actants as valid stakeholders of our practice.

Table 3. The resulting student concepts were evaluated using three factors.

Student Concepts	Environmental or/ and Social Aspects	Five Ps of the SDGs	ESD Approach and Potential
De Guide–small measures for big changes (a monthly guide in the form of an interactive tool for sustainable action)	environmental and social aspects	people, prosperity	anthropocentric approach
A Looming Reality Polimi * 2050 (using a speculative design approach to visualize the future through augmented reality, they set out to break the mold through social provocation to trigger reflection in the user)	social aspects	people, prosperity	anthropocentric approach
Meat the Revolution (an initiative for a movement that would fight for animal rights and against mass factory farming by exposing shocking information about the actual conditions in animal agriculture)	environmental aspects	people, planet	planet-centric future
ECOFFEE: Start to Drink Differently (promoting a change in coffee consumption habits by building on knowledge of the carbon footprint and the environmental impact of vending machine coffee)	environmental aspects	planet	anthropocentric approach
Think Before You Send: Digital Impact Awareness (raise awareness and encourage a better behavior on the impact of digital activity)	environmental aspects	planet, prosperity	anthropocentric approach
Zero Festival (a festival organized by students with the aim of bringing people together around sustainability issues in a fun and interactive way)	social aspects	partnership	anthropocentric approach
We Must be the Voice of Science (a subject that will equip students with knowledge of and skills in using analytical tools for the purpose of communicating all systemic and process-based sustainability activities)	environmental and social aspects	prosperity	anthropocentric approach
Funding for Student Projects: How to Reduce Financial Burden During Studies at the Academy of Fine Arts and Design (fighting poverty and inequality)	social aspects	people	anthropocentric approach
Cohabitation (finding a way to overcome the lack of community spaces facilitating interdisciplinary collaboration)	social aspects	prosperity	anthropocentric approach
Illuminate (fighting harassment and violence against women with light)	social aspects	people, prosperity	anthropocentric approach
The Bridge (homelessness is one of the most extreme forms of exclusion from society—finding ways to bridge/overcome)	social aspects	people	anthropocentric approach
Eco Jail (the legislative authority has the power to change our unsustainable habits by changing legislation to force those who refuse to change through civil society incentives)	environmental and social aspects	planet, prosperity	anthropocentric approach
BITEWISE (designing a service that will encourage PoliMi students to make a conscious change toward sustainable eating)	environmental aspects	people	anthropocentric approach
One Liter is Enough: Water you doing? (fighting water waste on campus)	environmental aspects	people	anthropocentric approach
Ride the Change (How can we mediate personal necessities and environmental needs?)	environmental aspects	planet, prosperity	anthropocentric approach

Table 3. *Cont.*

Student Concepts	Environmental or/ and Social Aspects	Five Ps of the SDGs	ESD Approach and Potential
SKIP THE STEP IF (seeking to create a fun and engaging way to encourage students to choose the stairs over the elevator and make more sustainable choices in their daily lives)	environmental aspects	planet	anthropocentric approach
Give Life to the Community: Encouraging Engagement–From an Aloof Code of Ethics to a Participative One	social aspects	people, prosperity	anthropocentric approach
ReCraft (designing a new recycling approach at PoliMi)	environmental aspects	planet	anthropocentric approach
Pitching the Change (How might we prevent the discussion on food waste from being boring?)	environmental aspects	planet	anthropocentric approach
Bring Your Cup, Do Your Part! (reducing the consumption of disposable cups)	environmental aspects	planet	anthropocentric approach

* abbreviation for Politecnico di Milano.

The results showed that students prioritized environmental aspects (10) over social aspects (7) when addressing sustainability, with three equally combining both aspects. It was interesting to note that in the first workshop in Milan, both aspects were treated almost equally; in the Ljubljana workshop, students gave priority to the social aspects; and in the third Milan workshop, the environmental aspects were dominant. The fact that both aspects were incorporated is undoubtedly due to a new understanding of the Doughnut Model by Kate Raworth (which makes the pursuit of environmentally safe and socially just space a prerequisite for achieving sustainability) [11], which the participants had the opportunity to learn about both at the introductory lectures and through the selected readings. A review of the five core areas of the 17th SDG shows the predominance of three areas: people, planet, prosperity, which should be read together with factor 3. Here, despite the emphasis established initially, the anthropocentric approach is still completely dominant. Of the twenty concepts, there is only one that does not prioritize people. This also means that when the goal chosen from among the five Ps belongs to the "Planet" aspect, it is understood and considered through the perspective of a person who, in their daily activities, must seek ways to achieve better harmony with natural resources. Here, we identified significant potential that needs to be systematically leveraged in the next phases. We must create nudges along the way that will enable students to move away from a purely anthropocentric approach, in a knowledge-based way, and toward the equal treatment of all other non-human actants.

Further insights regarding potential improvements to the workshop (Table 4), as well as regarding the positive emotional experience of participating in the workshop, were provided by the spontaneous reactions of the students (sent by e-mail after the workshop), excerpts from the final reports, and an individual and anonymous questionnaire conducted using the Mentimeter tool (Milan) or the KALM retrospective format (Ljubljana). Gathering insights helped us take a closer look at the original motive for the design of the workshops, namely, finding a way to make students aware of the urgency of addressing climate change while overcoming the feeling of powerlessness. It is also important for the further development and improvement of the workshops.

Similarly positive to the feedback gathered in Table 4 above was the response indicated via the KALM retrospective. On the basis of all the responses received (26 students participated), we formed thematic groups, interpreting them as positive or negative depending on the nature of the response. Figure 6 shows the three most frequent responses, that is, the topics that resonated with the students the most and were mentioned most often. They were extremely positive about the teaching experience in the form of a workshop, i.e., the pedagogical approach. There were 21 positive opinions praising the scheduling/time structure and organization of the workshop, the quality of the lectures, the choice of working methods and approaches, as well as the "enthusiasm of the tutors", the "positive vibe" and the "atmosphere of the workshop". Opinions were mostly negative (with four positive and seven negative opinions) about the technical aspects of the workshop environment they worked in (with most criticism directed at the MS Teams application through which they received the assignments). There were individual negative opinions related to the instructions for the assignments and the report they were required to write at the end of the workshop. The response to the (interdisciplinary) teamwork, however, was exceptionally positive. No fewer than 23 students expressed an opinion on group collaboration (with 20 positive and 3 negative responses), highlighting the discussions generated through teamwork and the solid networking opportunities. They also expressed a desire for more cooperation among different departments and faculties, as well as external stakeholders.

Table 4. A selection of students' responses.

Participant	Responses
PCP 1	Thank you for the great opportunity and experience!
PCP 2	As a direct result of the intensive workshop, we have learned how to approach a problem in-depth and start dealing with it step-by-step, in order to achieve efficient results. We got to know different approaches and methods which can be beneficial in the future when teamwork will be needed for design solutions.
PCP 3	Thank you once more for this stimulating workshop week, I hope we can stay in contact in the future for any possible collaborations.
PCP 4	We feel very positively uplifted by the feedback we've gotten from the different potential actors in this process, and different service providers, which leads us to believe, that this project could actually become something real and tangible.
PCP 5	This week was a real breaking point–until now, when something happened, we laughed it off and continued our daily lives as if nothing ever happened. It is okay to put your past behind you and live your life to the fullest, but because these problems keeps on repeating themselves, we must stop for a second and do something about it.
PCP 6	Thank you so much for this creatively stimulating week (and for the chocolate)! It was truly a pleasure being a part of your workshop!

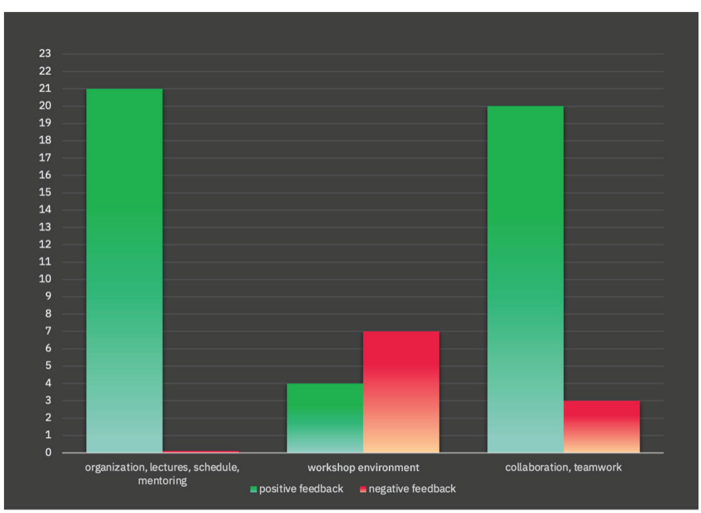


Figure 6. The three most frequent themes in the students' responses to the Ljubljana workshop.

4. Discussion

At its core, our research was greatly influenced by the following underlying epistemological position: how we know what we know [37], or, as elaborated on by Abercrombie et al., a theory of knowledge that is based on how knowledge of the external world is acquired [48]. The pedagogical decision to develop workshops for different groups of European students addressing a complex field like sustainability was driven not only by the awareness of the urgent need for action regarding climate change but also by our previous lack of success using conventional (not student-centered) approaches to learning. Based on personal observation and experience, as well as scientific research [9] indicating that students experience anxiety as well as apathy and inertia when dealing with complex, sustainability-oriented topics, we decided to develop a different approach. An approach which, among other things, seeks to provide additional encouragement to learn from the external world, while actively responding to the goals of the European Climate Pact objectives: raise awareness of climate issues and EU actions; encourage climate action and catalyze engagement; and connect citizens and organizations that act on climate and help them to learn from each other [49].

Students were not the only focus of our research; we also sought to explore pedagogical capacities in the field of Education for Sustainable Development. Previous studies have shown that engaging students to directly explore real-world problems while simultaneously striving to understand their contexts is an important part of active knowledge transfer. In this process, a lack of capacity and skills on the part of educators is an often-encountered barrier to achieving the goals of ESD [20,50]. The workshop that was developed over the course of the research and tested in a real-life setting proved to be a well-conceived framework that allows educators to competently navigate through complex, sustainability-oriented content. In other words, the workshop builds on pedagogical design capacity in practice and allows educators to further develop (during the workshop itself) their skills in pedagogical design capacity for ESD. This is further facilitated by the structure of the workshop itself, which encourages teachers to accept their role in the workshop as co-designers.

A strong practical confirmation of the latter in our case was our experience of pedagogical work in two different institutions in two European countries. This shows, among other things, the necessity of having a framework that allows for flexibility in the pedagogical approach since knowledge of both the content and the pedagogical approaches that students develop in other classes during their studies in the different study programs varies considerably, which can have an impact on implementation and the final outcome. The one-week workshops revealed differences in the research literacy of the students and their sensitivity to different topics they had (or had not) already covered during their studies, as well as their attitudes toward both independent project work and teamwork. In light of the above, we, as educators, needed to be able to quickly understand the existing situation and make sensible adjustments to integrate existing circumstances in order to create the desired learning contexts. The workshop framework as designed facilitated these adaptations without limiting the students' creative potential. On the contrary, the given framework proved to be an excellent testing ground for mutual development and, additionally, our observation and analysis of the results. For the latter, we followed John W. Creswell's thesis that it is impossible to completely escape the influence of social and historical perspective but that also people construct meanings when actively engaging with the world [51].

The results presented show that the framework designed offers tangible and promising insights. At the same time, they point to the possibility of further deepening the delivery of content, not only through interdisciplinary cooperation among students from different fields but also on the part of educators. By integrating different perspectives on a common sustainability starting point, this research could be a foundation for the further development and long-term formalization of a specialized and certified lifelong education in sustainability primarily based on nudge theory.

5. Limitations

As a case study, the research was limited to a workshop concept that was repeated three times within the framework of the postgraduate design studies at the Politecnico di Milano, School of Design, and the University of Ljubljana, Academy of Fine Arts and Design. To further enrich the study, it would be valuable to explore avenues for integrating additional activities for qualitative data collection. However, this would necessitate the inclusion of more educators or researchers within the team, especially for activities like participant observation. Another potential enhancement to the research methodology could involve establishing more robust and possibly pre-arranged opportunities for students to engage directly with stakeholders during their fieldwork research. It is important to acknowledge that this could potentially limit their autonomy in choosing topics and areas of focus.

6. Conclusions

The results of this study show that an intensive five-day workshop was a sensible and effective choice. It was repeatable throughout various social and cultural milieus and consequently offered a degree of adaptability without actually departing from the fundamental concept as the workshop structure, as set up, allows for the comparability of the data collected at all key phases. This makes us optimistic that our concept (both in terms of structure and the tools and processes chosen), with suitably adapted content, can be replicated in other (inter)disciplinary areas of education, especially when we want to stimulate the students' interest in sustainable action and different sustainability-oriented behaviors. Our research also shows that the workshop enables educators to respond to emerging global issues such as climate change while overcoming students' feelings of powerlessness. Moreover, students can be equipped with new knowledge in the process, and their interest in collective and sustainability-oriented problem-solving in their own environment can be stimulated.

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Institutional Review Board Statement: The study was conducted in accordance with the Guidelines for Ethical Conduct in Human Research by the University of Ljubljana.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available upon request from the authors.

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Article

Examine an Intelligence Education Framework of Landscape Architecture (EFLA) Based on Network Model of Technology in Landscape Architecture (NMTLA)

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Abstract: The discipline of Landscape Architecture (LA) is currently expanding its disciplinary boundary. The supporting Technology in LA (TLA) is always evolving and optimized to solve environmental problems. Considering the uncertain classification of the current LA knowledge for education and the importance of technology in LA education, a refined education framework of LA is needed. This research first established a Network Model of Technology in LA (NMTLA) using Network Analysis (NA) and expert interviews. Then, this research proposed an Education Framework of LA (EFLA) based on the NMTLA. To build the NMTLA, this research identified 23 key categories of TLA through content analysis of secondary research. Then, the expert interview and network theory were used to analyze and visualize the relationships among the categories. By examining the degree centrality, closeness centrality, and betweenness centrality of different TLA, this study developed an EFLA which summarizes the twenty-three categories of TLA into four domains: core techniques, applied technologies, integrated technologies, and specific technologies. This study also proposes a series of suggestions for how to apply different categories of TLA in today's and future LA education. The proposed NMTLA and EFLA in this research can contribute to the development of future LA higher education. They also can potentially address the Sustainable Development Goals (SDGs) in LA education and industry. However, the scope of this study is currently limited to LA education in the USA, which could be expanded to include a worldwide perspective in future research. To enhance the validity of the conclusions, a larger sample size for interviews should be employed in further studies.

Keywords: technology in landscape architecture (TLA); landscape architecture (LA) education; interdisciplinary collaboration; network analysis (NA); SDGs

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1. Introduction

The discipline of LA is currently expanding its disciplinary boundary. Scholars and practitioners in LA discipline nowadays are required to take more responsibility for sustainable development and explore ways to tackle complex environmental problems in more synthesized ways. The supporting TLA is always evolving and optimized with the advancement of technologies, and its significance in LA practice and education cannot be ignored. Meanwhile, contemporary LA education tends to focus more on cultivating future LA talents with comprehensive and interdisciplinary skills [1]. To satisfy the requirements of future LA education, clarifying the theoretical framework and categorizing the current TLA is crucial. In terms of SDGs, sustainable design and planning are always among the most important tasks of LA education. Achieving sustainable development of both natural and artificial living environments using landscape design is regarded as one of the key responsibilities of LA higher education. Therefore, clarifying the categories of TLA will benefit the SDGs of LA education as well.

There are various ways to categorize the current TLA in LA education, but many of them fail to examine the relationship between different categories comprehensively. Therefore, to refine the uncertain categorizations of TLA, this research aims to first establish an NMTLA using NA, expert interviews, and content analysis. Then, based on the findings drawn from the NMTLA, this research will develop an EFLA to explain, predict, and guide the expansion of discipline boundaries of LA. At the same time, this EFLA has the potential to offer solutions to the critical problems faced by LA education today and contribute to the advancement and development of future LA education.

1.1. Expansion of LA's Disciplinary Boundary

LA originated from Landscape Gardens. Versailles in Paris, the Taj Mahal in India, and Humble Administrator's Garden in China, for instance, are all categorized under "landscape garden" as a form of art [2]. While these examples are all from after the 15th century, the concept of landscape gardening is much older and has been an important part of many cultures throughout history. The aesthetic styles and scales of historic gardens were influenced by designers' efforts to turn landscapes that existed in people's fantasy into reality. By then, the field was greatly affected by local culture, religions, social ethos, and art movements. The design of the garden placed great emphasis on social status, religious tradition, personal cultivation, and taste.

These characteristics of landscape gardens shifted after entering the 19th century, successively due to the prevalence of modernism concept of "form and function" and post-modernism's focus on dialectics, individual expression, and personal cultural emotional value [3]. Since the discipline of LA was founded at Harvard University in 1900, landscape architects and scholars have been arguing whether LA belongs to science or art, given the coexistence of science, functional practicality, and artistic aspects in the design process. Via both rational and emotional perspectives, the subject is carrying the responsibility of opening dialogues and building a coexistence environment for humans and nature, individual and collective. Norman Newton defined LA in the book "Design on the Land" as "an art or science, mediating between nature and culture" [4]. More recently, as growing attention and exploration are given to social ecosystems, more and more scholars tend to consider LA to be an interdisciplinary subject. In 2012–2013, the 36th edition of Harvard Design Magazine was titled LA's Core; the collected articles aimed to explain the core of LA. Each article claimed expertise in a facet of LA, such as "Immanent Landscape", "Landscape Infrastructure", "Beyond Sustainable Landscapes", "Digital Landscape Now", "Landscape Navigator", etc. Such one-sided articles cannot explain the core of the landscape.

Apparently to see that during the past few decades, many ideas, methodologies, and technologies from various disciplines, such as ecology, environmental protection, agriculture, food science, computer science, and so on, have been employed as references throughout the practice of LA [5,6]. The increasing frequency of transdisciplinary communication leads to the appearance of many new terms, for example, landscape urbanism, ecological urbanism, sustainable design, etc. These new ideas do expand the boundary of LA and change what had previously been the traditional responsibility of practitioners. Nevertheless, the rise of these new terms is more of a grouping and simple overlapping of existing knowledge from LA and those from other fields. Hence, the field of LA needs to incorporate them into new creative and intelligent theories that integrate aesthetic design principles and scientific technologies [7]. In this way, people would gain a deeper understanding of what is meant and encompassed by the term LA in the 21st century.

It is also worth noting that this development of LA is what separates it from sister disciplines of study such as Urban Planning, Urban Design, and Architecture. The latter disciplines have different scopes in terms of the environment under their consideration and how much innovation and management are required. Urban Planning and Design takes care of the urban and built environment in general to determine the best practices to promote sustainability, equity, and economic development through the design and management of urban systems and environments. Architecture is the design and construction of buildings and other physical structures. Architects work to create structures that are functional, aesthetically pleasing, and meet the needs of their occupants. Contrary to these disciplines, Landscape architects use their expertise in ecology, horticulture, and design to create functional and aesthetically pleasing outdoor environments that promote sustainability and enhance the quality of life for users.

1.2. Blurry Definition of Technology in LA (TLA)

The application of technology branches out in various disciplines; thus, technologies as tools gain further specialized developments and become expertise-led professional techniques [8]. Imaging has been used by various disciplines, such as art, biology, medical science, astronomy, and geology, due to its ability to reproduce and visualize real objects for different purposes. The needs and requirements of each field determine the evolution of imaging technology. For example, medical diagnosis, photography, and geological investigation all use optical and acoustic survey instruments, but they result in different imaging technologies due to factors such as the disease being tested, patient side effects, commercial value, aesthetic perspectives, and the clear presentation of soil types for identification. Each technology has its own unique parameters and operating rules.

For LA, the definition of TLA in current literature, most of which originates from the research about the classification of landscape design topics, remains a relatively huge difference. Some scholars believe that computer application software, such as AutoCAD, BIM, and geographic information system (GIS), is the core of TLA. Some scholars also believe that TLA is about construction details, plant design, and other construction details; other scholars argue that LA technology is the combination of technology and landscape design in the field of science [9–14]. A shared situation of these perspectives is that many of these "technologies" are borrowed directly from other academic fields, most of which are only viewed as a visualization tool to convey design concepts. LA practitioners find it challenging to keep up to date with and take full advantage of the potential of constantly upgraded modern technology directly to update subject knowledge [15]. Additionally, the knowledge renewal within the LA discipline has a relatively high dependence on innovation in other fields for the application of science and technology.

If no specialized transformation occurs while employing technology and theory from other subjects, LA will possibly lose its unique voice and irreplaceable position in combining scientific environment planning and human environmental design [16]. On the other hand, exploring scientific technology does not imply a reduction in the impact of aesthetic representation. In contrast, technology will make those representations more meaningful. The missing parts that connect "technique" and "technology" in landscape design and the vague boundary of LA discipline confuse practitioners from the discipline themselves, hinder the future development of landscape research, and further influence the effectiveness of design practice and education. Some questions still remain to be answered: "What is the core of LA?"; "What technologies belong to LA?"; and "What are the boundaries of LA?" Hence, it's vital for the discipline to clarify "technology" with those has been transformed into "technique of landscape design", meanwhile organizing their relationships with LA and reflecting current progress and effectiveness of knowledge transformation to define and expand discipline boundaries [17–19].

According to several studies on research trends and the theoretical development of LA, digital tools and certain techniques emerged as trends and were perceived as major ways to categorize TLA [9–14]. Compared to construction technologies in LA, nowadays, professional tools in LA are more related to digital tools. (Table 1). The table shows that most scholars combine digital tools and technology and visualized expression with TLA. Part of scholars regards landscape design technologies as the implementation and details of design. The LA Education Conference (CELA) released 14 hot topics of landscape design in 2022, which "Geo-spatial and Digital Analytics", "Climate Crisis and Ecological Restoration", and "Landscape Design and Implementation" involve TLA relatively conform to the classification of "TLA" in Table 1.

Table 1. The definition of 'TLA' in landscape design thematic studies literature.

Author/Source	TLA Related Topics	Topic Related Terminology
Powers & Walker, (2009) [20]	Material and Construction	Vegetation/Horticulture/Innovative construction technology/Materials/practice
Gobster et al., (2010) [9]	Technology and Digital Tools	GIS/PC/Graphic/Visualization
Cushing et al., (2015) [10]	Technology and Digital Tools	Digital software/Technology/Skill
Meijerin et al., (2015) [11]	Technology and Digital Tools	Digital software/Skill/Technology
Vicenzott et al., (2016) [12]	Material and Construction	Ecological restoration/Planting
Langley et al., (2018) [13]	Technology and Digital Tools	Digital software/Technology/Skill
Newman et al., (2021) [14]	Technology and Digital Tools	Technology/Tool/Digital/GI/Environment/Software/Vocality/Reality/Geo-design/Application/Visualization/Virtual/Decision/Space/Scale/Enabling/Platform/Future/Detail/Soundscape

From the above illustrations, there are major gaps in the clarification, classification, and relationships among multiple categories of technology in LA. Thus, this study further refined categories of landscape design technology and built the relation model through the NA of technology categories with discipline technique and future research areas. Via critically reviewing the existing literature and archival materials on the development of LA, the research is also seeking to provide the foundation to identify the logic and method of building up inter-discipline knowledge by transdisciplinary communication to achieve the expansion of LA boundaries.

2. Materials and Methods

This research first collected the data by applying Secondary Research to clarify the scope and categories of TLA. The second step was to apply expert interviews [21] and NA [22] to analyze the relationships among each technology in LA, then generate EFLA Based on data analysis of NMTLA. Figure 1 can briefly show the framework of this research (Figure 1).

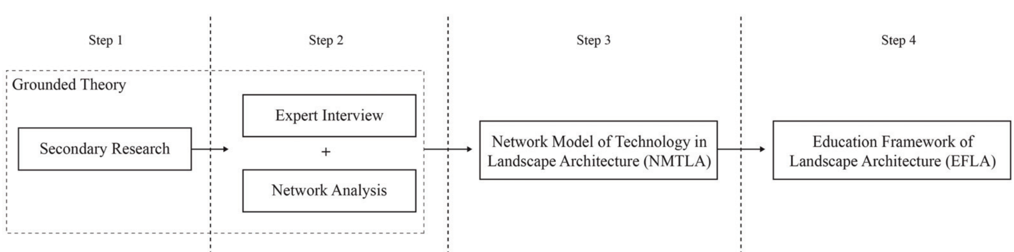

Figure 1. The analytical framework of the research.

2.1. Secondary Research

The data analysis, resolution, and comprehension of the categorization of current TLA require a multiplicity of perspectives that must dialogue, articulate, and integrate into an interdisciplinary, intelligent, and creative dynamic. Grounded Theory (GT) is a theory-building methodology from data collection developed by Glaser and Strauss in 1967 [23]. GT aims to formulate theoretical results that are derived from qualitative analysis of data. In this research, the GT is applied in the form of content analysis of Secondary Research to build the categories of TLA.

The secondary research of this study is built on the work by Powers and Walker (2009); Gobster et al. (2010); Cushing and Renata (2015), Meijering et al. (2015); Vincezotti et al. (2018)

and Newman et al. (2021) whose team explored the categorization of current TLA through a study of journal articles [9–12,14,20]. Based on their work, researchers developed preliminary categorization criteria for the current TLA. Meanwhile, this research reviewed journals that investigate TLA in LA education and industry, including *Journal of Digital LA* (2016–2021), *Landscape Research* (2015–2021), *Landscape Journal* (2013–2021), *Landscape Review* (2013–2021), *Journal of Landscape Architecture* (2013–2021), and *CELA's Landscape Research Record* (2011–2021), and Credential LA program syllabus from CELA. Researchers examined the title, keywords, and abstract of every article, then summarized the core LA knowledge of the articles. After that, the article was categorized into the relevant category based on the preliminary criteria mentioned above. If no category meets the core knowledge of the article, new categories will be generated using the method of content analysis. Through the journal review, the preliminary categorization criteria for TLA can be refined. Finally, 23 categories of TLA were developed.

2.2. Expert Interview

After developing the 23 categories of current TLA, semi-structured (open-ended) interviews with experts were adopted to further refine the categorization and study the relationship between each category; 40 experts in LA discipline were recruited to attend the interview. The qualified experts should have at least 20 years of experience in LA higher education and LA design practice. The interviewed experts in this research included faculties of many universities and landscape architects in professional design firms in the USA. Snowball sampling is adopted to recruit potential participants. Researchers contacted 15 experts based on their social network, then the 15 experts introduced this study to qualified people they know and invited them to the expert interview. Among all experts, 22 of them are male, while 18 of them are female. Their age is between 45 and 85 years old. The interviews were conducted remotely through Zoom meetings. The average duration of the interview is 25 min. Two researchers participated in the interview; one worked as an interviewer, while the other research focused on taking notes. During the interview, experts will review the 23 categories of current TLA and give their comments. In addition, they were asked to decide whether 2 categories have correlations or not using an evaluation matrix shown in Section 3.2.

2.3. Network Analysis (NA)

A comprehensive set of techniques known as NA is used to portray the relationships between examined targets and to investigate the mutual influences that result from the persistence of these relationships. In order to perform this analysis, relational data is gathered and arranged in a matrix. Actors can be represented as nodes, and their relationships can be shown as lines connecting pairs of nodes, transforming the idea of "a social network from a metaphor to a practical analytical tool that makes use of the mathematical terms from graph theory, matrix algebra, and relational algebra". NA can be seen as a collection of approaches having a common methodological stance. By defining and measuring conventional all-purpose concepts, NA enables researchers to define empirical indicators and manage field hypotheses.

Based on the relationship within TLA generated through expert interviews, the experienced LA experts are further invited to finish a questionnaire of the relationship matrix among the sub-categories of TLA to gain the initial data for TLA Relationship Matrix. A visualization of this matrix will intuitively present the relationship, intensity, and status of influence among landscape design technologies. Subsequently, the analysis and the comparison of the degree centrality, closeness centrality, and betweenness centrality of the matrix will lead to the classification and development models of TLA.

3. Results

3.1. Categories of TLA

Based on the secondary research, this study divides contemporary TLA into three initial dimensions: "Geo-spatial and Digital Analytics", "Landscape Design Implementation and Construction", and "Climate Crisis and Ecological Restoration". These three initial aspects are subdivided by taking a literature review as the main method, supplemented by the expert interview

3.1.1. Geo-Spatial and Digital Analytics

For the initial dimension of "Geo-spatial and Digital Analytics", nine categories (A1–A9) were identified through the research methods introduced in the previous section; 90 reviewed articles are related to the dimension of "Geo-spatial and Digital Analytics". How they support the categorization is shown in Table 2.

Table 2. Summary of Topics of Geo-spatial and Digital Analytics from 2019 to 2021.

Geo-Spatial and Digital Analytics (A)	Subject (Sub-Category)	Source
A1	Geographical design method and GIS technology	[24–40]
A2	Landscape algorithmic design and analysis	[41–58]
A3	VR and AR in landscape design	[59–79]
A4	Information modeling (LIM and BIM) of landscape and building	[80–89]
A5	Landscape visualization and analysis	[90–98]
A6	UAV imagery and remote sensing	[99–105]
A7	Mobile devices, internet-of-things, and "smart" systems	[106–110]
A8	Social media in landscape design	[111–114]
A9	Point cloud applications in landscape design	[115–120]

3.1.2. Landscape Design Implementation and Construction

Scholars from this category argue that TLA is related to the landscape material and implementation, which have the ability to transform terrain, organize drainage, build roads and sites, reshape sites, and so on. This study finds there is little research in this area, with no record in the Landscape Research Record (CELA) in recent 10 years. However, the proposition of this category tends to be emphasized more in academic institutions and their curriculums. LA education in the USA has a long history, rich experience, and a high reputation around the world. At the same time, the research team of this study has better experience, network, and funding support in the USA's LA discipline. Therefore, this study chose to analyze the syllabus of LA education from the top five academic institutions in the USA ranked by American Design Intelligence (DI). It is shown that the courses of TLA in these academic institutions mainly focus on Design and Implementation (Terrain, Drainage, Details, Materials, Standards, etc.) and Landscape Ecology (Vegetation, Planting design, Soil, Stormwater management, etc.) (Table 3). According to the definition and classification of "Landscape Design Implementation and Construction" by CELA, this study subdivides the dimension of "Landscape Design Implementation and Construction" into seven categories. Table 4 summarizes these technology types and the academic institutions which offer related technology courses.

Table 3. Summary of landscape design techniques courses from leading academic landscape institutions in the USA.

Academic Institution	Course	Number of Institution
University of Pennsylvania	Design Implementation (Grading, Planting Design, Construction Documents)	R1
Louisiana State University	Landscape Technology (Grading, Drainage, Detailing, Materials) Plant Materials	R2
Cornell University	Site Assembly (Construction Materials, Specifications, Cost Estimate, Construction Documentation) Creating the Urban Eden: Woody Plant Selection, Design, and Landscape Establishment	R3
The University of Georgia	Landscape Construction (Construction Details) Soil and Storm Management	R4
The Ohio State University	Ecology/Technology (Landscape Materials, Ecological Dynamics, Planting Design)	R5

Table 4. Summary of landscape design and implementation categories and academic institutions offering related courses.

Landscape Design and Implementation (B)	Subject (Sub-Category)	Number of Institutions
B1	Topographic design and earthwork	R1, R2, R3, R4, R5
B2	Planting design	R1, R2, R3, R4, R5
B3	Stormwater management and engineering	R1, R2, R3, R4, R5
B4	Landscape materials	R1, R2, R3, R4, R5
B5	Landscape construction details and management	R1, R3, R4
B6	Landscape development design and details	R1, R2, R3, R4, R5
B7	Landscape paving design	R1, R2, R3, R4

3.1.3. Climate Crisis and Ecological Restoration

Through the secondary research and expert interview explained in the previous section, the dimension of "Climate Crisis and Ecological Restoration" can be divided into seven categories (Table 5). Table 5 also shows some typical articles supporting this categorization, which were examined by researchers in the process of secondary research.

Table 5. Summary of the Climate Crisis and Ecological Restoration.

Climate Crisis and Ecological Restoration (C)	Subject (Sub-Category)	Source
C1	Plant communities and habitat restoration	[121]
C2	Landscape responses to climate change	[58,121–127]
C3	Urban greening and ecological restoration	[37,123,125,126,128,129]
C4	Disaster responses and technology in landscape design	[97,100,110,112,114]
C5	Wildlife habitat conservation strategies	[121,130,131]
C6	Brownfield remediation technology	[40,132]
C7	Ecological restoration of water environment	[37,122,126,131,133]

Only four sub-categories, including "Landscape responses to climate change", "Urban greening and ecological restoration", "Disaster responses and technology in landscape design", and "Ecological restoration of water environment", are the most appeared topics in the literature released on CELA. Technologies for "Plant communities and habitat restoration" and "Wildlife habitat conservation strategies" are the aspects that lack enough research and integration within the discipline.

3.2. NMTLA

The relationship of 23 landscape design technologies is discussed using expert interviews; 40 experienced LA experts were invited to finish a questionnaire of the relationship matrix among the sub-categories of TLA. The TLA Relationship Matrix consists of 23 columns and 23 rows (Table 6); "0" refers to no correlations, while "1" refers to having correlations identified by experts, filled by experts, and adapted to indicate whether the technologies of the first row exert monodirectional impact on the technologies of the first column. For example, "1" in row 1, column 4 indicates that A4 has an effect on A1, while "0" in row 1, column 4 means A4 has no effect on A1. After collecting experts' answers, if more than twenty experts give "0" for one relationship, then the final answer will be defined as "0". On the contrary, if more than twenty experts answer "1", the final results will be marked as "1". This approach can be regarded as a simplified version of the Delphi Method [134]. Considering that all experts are quite busy and have limited time to participate in the survey, this research method can be a relatively efficient and feasible choice. Moreover, if the number of people answering "0" and "1" is the same, the research team will invite another expert to participate in the interview to obtain the final answer. However, this situation did not happen in the real study.

Table 6. TLA relationship matrix.

	A1	A2	A3	A4	A5	A6	A7	A8	A9	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	C5	C6	C7
A1	-	1	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2	1	-	1	1	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A3	0	1	-	1	1	1	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
A4	1	1	1	-	1	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
A5	1	1	1	1	-	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
A6	1	1	1	0	1	-	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A7	1	1	1	1	1	1	-	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A8	1	1	1	1	1	0	1	-	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A9	1	1	1	1	1	1	1	1	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B1	1	0	1	1	1	0	0	0	1	-	1	1	1	1	1	0	0	0	0	0	0	1	0
B2	0	0	0	0	1	0	0	0	0	1	-	1	0	1	1	0	1	0	1	0	1	1	1
B3	1	0	0	1	1	0	1	0	0	1	1	-	1	1	1	1	1	1	1	1	0	0	1
B4	0	0	0	0	0	0	0	0	0	1	0	1	-	1	1	1	0	0	1	0	0	0	0
B5	0	0	0	1	0	0	1	0	0	1	1	1	1	-	1	1	0	0	0	0	0	0	0
B6	0	0	0	0	0	0	0	0	0	1	1	1	1	1	-	1	0	0	0	0	0	1	1
B7	0	0	0	0	1	0	0	0	0	1	0	1	1	1	1	-	0	0	0	0	0	0	0
C1	1	1	0	1	0	1	0	0	0	1	1	1	0	0	0	0	-	1	1	0	1	1	1
C2	1	1	0	1	0	1	1	0	0	0	0	1	0	0	0	0	1	-	1	1	0	0	1
C3	1	1	0	0	0	1	0	1	0	0	1	1	1	0	0	1	1	1	-	1	1	1	1
C4	1	1	0	1	0	0	1	0	0	0	0	1	1	0	0	0	1	1	0	-	0	0	0
C5	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	1	0	1	0	-	1	1
C6	1	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	1	1	1	0	0	-	1
C7	1	0	0	1	0	0	0	0	0	1	1	1	0	0	0	0	1	1	1	0	1	1	-

The network model, which shows the relationship, intensity, and status of influence among landscape design technologies, is visualized based on the analysis of the relationship matrix (Figure 2). Each vertex represents a TLA, while the size and brightness of the vertex indicate the status of a certain technology in the whole TLA system. The brightness of the connection line between two vertices indicates the strength of the relationship between the two technologies, and the absence of the line means that there is no relation between them. Specifically, the arrow of a line means the direction of influence. For example, the one-way arrow between "Topographic design and earthwork" and "Landscape visualization and analysis" indicates that "Landscape visualization and analysis" has a monodirectional impact on "Topographic design and earthwork".

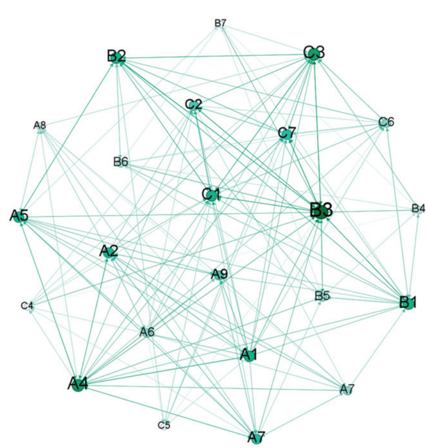

Figure 2. NM and analysis of TLA categories.

3.2.1. Degree Centrality of NMTLA

Degree centrality represents the closeness of the relationship between one element and another. The values of degree centrality of 23 landscape design technologies were calculated and shown in Figure 3. The results indicate that "Stormwater management and engineering (B3)" and "Urban greening and ecological restoration (C3)" have the highest degree of centrality. This means that these two technologies have the closest connections with the other twenty-one categories of TLA. Meanwhile, according to the results, "Landscape paving design (B7)", "Disaster responses and technologies in landscape design (C4)", and "Wildlife habitat conservation strategies (C5)" have the weakest connections with other technologies.

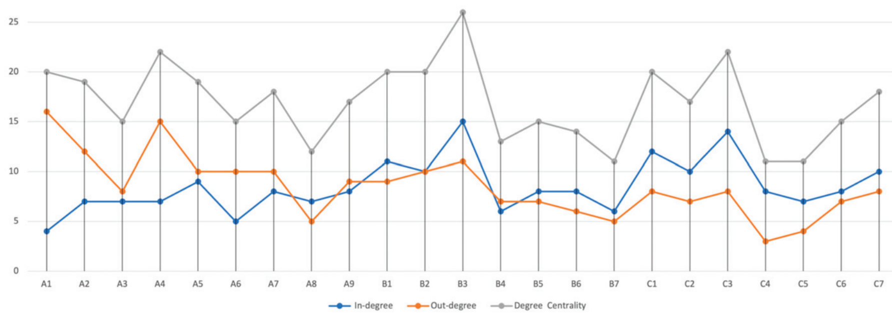

Figure 3. Degree centrality analysis of NMTLA.

In addition to degree centrality, two secondary indicators of degree centrality, in-degree centrality and out-degree centrality, should be discussed as well. In-degree represents the intensity of the influence exerted by another technology. Figure 3 shows that "Stormwater management and engineering (B3)", "Urban greening and ecological restoration (C3)", and "Topographic design and earthwork (B1)" are the top three technologies influenced by other technologies. "Geographical design method and GIS technology (A1)" and "UAV imagery and remote sensing (A6)" have the least possibility of being influenced by other technologies. Out-degree indicates the intensity of the influence that technology exerts on another. For example, "Geographical design method and GIS technology (A1)" and "Information modeling (LIM and BIM) of landscape and building (A4)" produce a great impact on other technologies, while "Disaster responses and technologies in landscape design (C4)" and "Wildlife habitat conservation strategies (C5)" have the least impact on other technologies.

Regarding the NA results of overall degree centrality, in-degree centrality, and out-degree centrality, this study finds that the geo-spatial and digital analytics technologies have more impact on other technologies than being impacted by other technologies. On the contrary, climate crisis and ecological restoration technologies are more likely to be affected by other categories of TLA.

3.2.2. Closeness Centrality of NMTLA

Closeness centrality indicates the difficulty that one element affects another. The higher value of closeness centrality indicates that technology can significantly and extensively affect other categories of TLA. The closeness centrality analysis (Figure 4) shows that "Geographical design method and GIS technology (A1)" "Information modeling (LIM and BIM) of landscape and building (A4)" and "Landscape algorithmic design and analysis (A2)" have extensive and broad impacts on other technologies. (Figure 4).

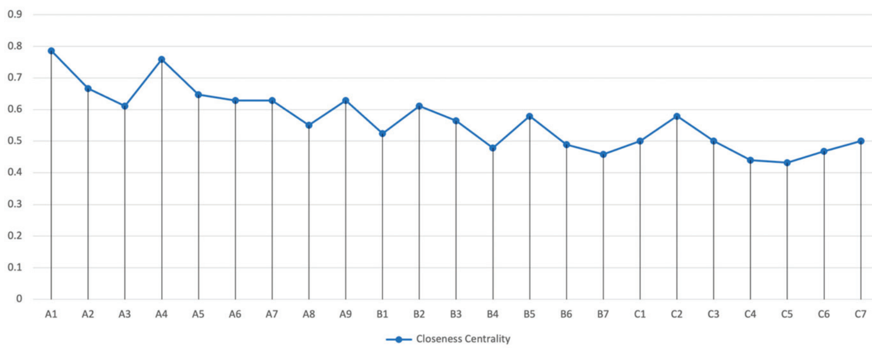

Figure 4. Closeness centrality analysis of NMTLA.

3.2.3. Betweenness Centrality of NMTLA

Betweenness centrality shows the number of shortest paths that relate one technology to another, representing how one technology can influence others through a specific path. The results (Figure 5) show that "Planting design (B2)", "Landscape visualization and analysis (A5)", and "Information modeling (LIM and BIM) of landscape and building (A4)" are the three categories that have the highest value of betweenness centrality, which indicates that these three categories play important roles in bridging various categories of TLA in the NMTLA. Although "Planting design (B2)" and "Landscape Visualization and Analysis (A5)" have low scores in degree centrality analysis, they are still essential in the TLA system.

3.2.4. Comparison of Degree Centrality, Closeness Centrality, and Betweenness Centrality

Comparing the analysis of degree centrality, closeness centrality, and betweenness centrality, it can be learned that "Planting design (B2)", "Stormwater management and engineering (B3)", "Landscape visualization and analysis (A5)", "Information modeling (LIM and BIM) of landscape and building (A4)", "Urban greening and ecological restoration (C3)", "Landscape construction details and management (B5)", and "Landscape responses to climate change (C2)" are seven important categories in NMTLA, they also can connect other categories together like bridges. On the other hand, "Wildlife habitat conservation strategies (C5)", "Disaster responses and technologies in landscape design (C4)", "Landscape paving design (B7)" and "Social media in landscape design (A8)" are four technologies with limited universality according to their low scores in the NA (Figure 6).

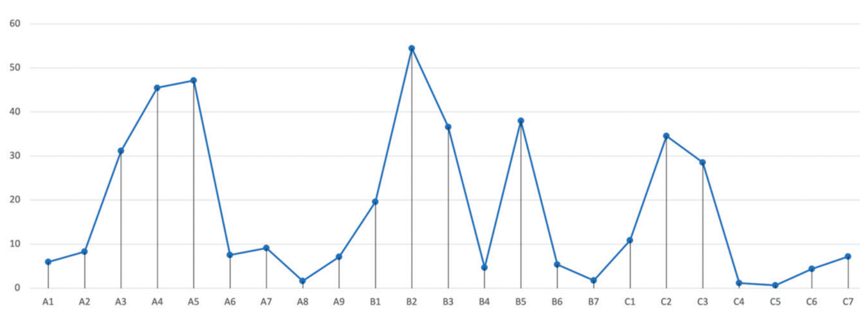

Figure 5. Betweenness centrality analysis of NMTLA.

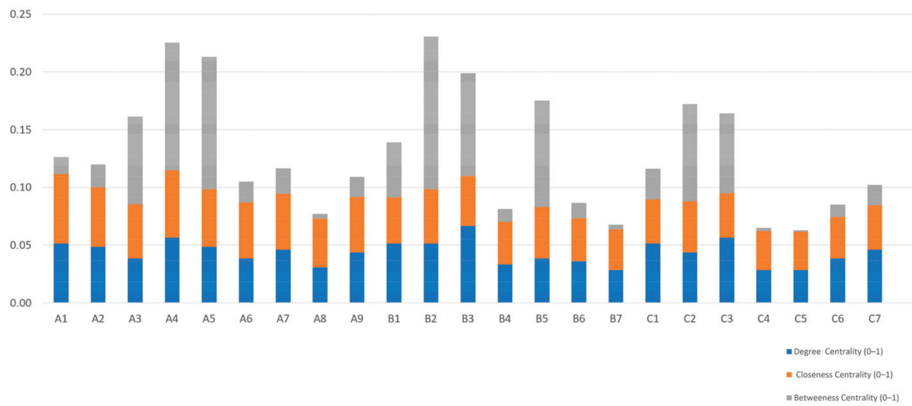

Figure 6. Comparison of degree centrality, closeness centrality, and betweenness centrality of NMTLA (the scales of all indicators are normalized between 0 and 1).

4. Discussion

4.1. Reflection on Categories of Current TLA

The research findings indicate that "Planting design", "Stormwater management and engineering", "Landscape visualization and analysis", "Information modeling (LIM and BIM) of landscape and building", "Urban greening and ecological restoration", "Landscape construction details and management", and "Landscape responses to climate change" are seven important categories in NMTLA. This result can be explained by recalling the development of LA discipline nowadays. Among the seven crucial categories of TLA, "Landscape construction details and management" and "Planting design", "Information modeling (LIM and BIM) of landscape and building", and "Stormwater management and engineering" are both practice-oriented technologies. They are closely connected to LA industry and could be utilized in every LA design project. In contemporary LA education, teaching students the professional skill that can be applied in work is an important task. Therefore, these technologies absolutely should be included in today's LA higher education, especially in the first 2 years of college, since they serve as the foundation of other advanced courses.

Among the seven most important categories of TLA, "Landscape visualization and analysis", "Urban greening and ecological restoration", and "Landscape responses to climate change" are more research-based technologies. They might not be very necessary to LA design practice, but they can inspire potential solutions to critical social and environmental issues through academic research. Therefore, in LA education, these categories of TLA should be involved in the curriculum, possibly in the form of independent study, thesis, seminar, or lab section. Moreover, "Urban greening and ecological restoration" have become more and more critical in LA discipline since Ian McHarg proposed the 'design with nature' theory in 1995. Meanwhile, the technologies of "Landscape responses to climate change" starts to receive increasing attention in both LA practice and research. These two categories of TLA integrate the knowledge and techniques of ecology, climatology, geography, botany, zoology, and other disciplines into LA. With much more explicit goals compared with other TLA, "Urban greening and ecological restoration" and "Landscape responses to climate change" could easily transform the technologies of other disciplines to the field of LA while combining LA research with LA practice. For example, water processing (hydrology), site transformation (climatology and geography), and vegetation application (botany) have become fundamental aspects of "Urban greening and ecological restoration" and "Landscape responses to climate change".

Considering that landscape design is a broad concept, none of the technologies of landscape design are isolated. For example, data from GIS, UAV imagery, AR, VR, landscape and building information modeling (LIM + BIM), landscape visualization, and algorithmic design and analysis will be adopted when it comes to the ecological restoration of water environments in design projects [134,135]. In general, the larger the scale of the design, the more complexity of the system, the greater number of technologies would be involved, and the more integrated the technologies are referred to. Each of these technologies affects and supports others in the whole TLA system, while designers have to realize the hierarchy and relevance of the system through the whole process of design. Designers should not only design with the view of history, culture, and aesthetics but also conceive, promote, and implement the design with the thinking of technology.

4.2. EFLA Based on NMTLA

By analyzing the degree centrality, closeness centrality, and betweenness centrality of 23 categories of TLA, an NMTLA can be developed. Based on the NMTLA, an EFLA can be proposed (Figure 7). In this EFLA, all categories of TLA can be summarized into four domains. The first category is core technologies of landscape design, such as "Planting design" and "Landscape visualization and analysis". Core technologies are indispensable in both LA education and practice. With high values of degree centrality and betweenness centrality, core technologies are able to affect and connect other technologies directly. The second category is applied technologies. Applied technologies indicate techniques from other disciplines that can be directly transformed into LA. Applied technologies, such as "UAV imaging and remote sensing", are scientific and objective. With higher out-degree than in-degree, applied technologies affect other technologies a lot and are less likely to be impacted by others. The third category is integrated technologies, which combine technologies in multiple other industries with the core technologies in LA according to the specific needs of landscape design. Integrated technologies show a low degree of centrality and tend to be impacted by other technologies. The fourth category is the specific technologies that meet specific circumstances and needs, with a low degree of centrality and betweenness centrality. Specific technologies are not universal in landscape design, but they are not trivial. For example, "Wildlife habitat conservation strategies" is not suitable for most of the practices of landscape design, but it is a critical meaning for the protection and restoration of the human ecological environment.

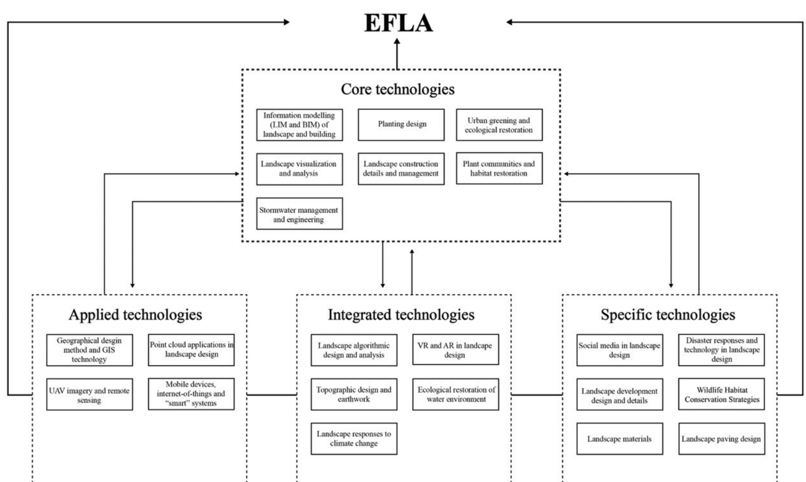

Figure 7. The summary of the EFLA model.

This EFLA suggests an appropriate use of different categories of TLA in LA higher education. Core technologies should be the focus of LA education and should be included in the first 3 years of college study. Since studio is the most important course for LA students, the learning of these core technologies can go with the studio or other basic courses.

For applied technologies, it requires students to have a fundamental understanding of LA then the techniques from other disciplines can be learned and applied in the contexts of LA. Therefore, applied technologies are not required only to be taught within the LA department but could also be taught in other departments or by teachers with different backgrounds. In this way, collaborative and interdisciplinary teaching and learning are necessary. A possible suggestion is to teach applied technologies in the form of elective courses and lab sections, where students can explore interdisciplinary knowledge spontaneously. Integrated technologies combine technologies in multiple other industries with the core technologies in LA according to the specific needs of landscape design. Therefore, learning integrated technologies requires LA students to understand the role of core technologies and applied technologies first. The instructors teaching integrated technologies should be authoritative in LA discipline while having some experience or resources in other fields. Considering this, seminars, lectures, thesis, and independent study are reasonable carriers of integrated technology teaching and learning. Finally, for the domain of specific technologies, considering its limited universality, courses related to these topics do not need to be complimentary in a common undergraduate curriculum. However, if students are interested in any of them, necessary elective courses and after-class tutorials introducing these technologies should always be available for students.

5. Conclusions and Limitations

With the goal of finding relationships among various categories of TLA and exploring their potential for LA education, this research first collected the data by applying Secondary Research to clarify the scope and categories of TLA. The second step was to apply expert interviews and NA to analyze the relationships among each technology in LA, then generate EFLA Based on data analysis of NMTLA. To build the NMTLA, this research identified 23 key categories through content analysis of secondary research. The expert interview and NA were then used to analyze and visualize the mutual influence and relationships among the categories. The NMTLA shows that “Planting design”, “Stormwater management and engineering”, “Landscape visualization and analysis”, “Information modeling (LIM and BIM) of landscape and building”, “Urban greening and ecological restoration”, “Landscape construction details and management”, and “Landscape responses to climate change” are seven important categories in NMTLA, they also can connect other categories together like bridges. On the other hand, “Wildlife habitat conservation strategies”, “Disaster responses and technologies in landscape design”, “Landscape paving design”, and “Social media in landscape design” are four technologies with limited universality.

Based on these findings, the study developed an EFLA which summarizes the twenty-three categories of TLA into four domains: core techniques, applied technologies, integrated technologies, and specific technologies. Inspired by the EFLA, this research proposed a series of suggestions for how to apply different categories of TLA in today’s and future LA education. For core technologies, this research suggests it to be taught in the first stage of college study and integrated with LA design studio course. For applied technologies, a possible suggestion is to teach applied technologies in the form of elective courses and lab sections, where students can explore interdisciplinary knowledge spontaneously. For integrated technologies, this research believes they should be taught after students have a comprehensive understanding of core technologies and applied technologies. Meanwhile, close communication and interaction with experienced instructors are important. This implies that seminars, lectures, thesis, and independent study are reasonable carriers of integrated technology teaching and learning. The domain of specific technologies has limited universality. Instead of setting related complementary courses, this research suggests that necessary elective courses and after-class tutorials introducing these technologies should be available for students.

The proposed NMTLA and EFLA in this research could explain, predict, and guide the expansion of the disciplinary boundaries of LA. They also contribute to the advancement and development of future LA higher education. The development of LA discipline and education relies on understanding and clarifying the related topics, techniques, and applications. TLA always changes with the progress of technology and the development of relevant disciplines. Therefore, keeping abreast of The Times to explore the function, potential, and limitations of various categories of TLA as well as the relationship among them will significantly benefit today's and future LA education. Building an NMTLA can potentially address the Sustainable Development Goals (SDGs) in LA education and industry, especially SDG 11 (Sustainable Cities and Communities) and SDG 13 (Climate Action). Among the 23 categories of TLA, 12 of them are closely related to SDGs. Categories such as "Stormwater management and engineering", "Urban greening and ecological restoration", and "Landscape responses to climate change" are important TLA that responds to SDGs. Discussing how to apply these categories of TLA in LA education also help inspire the ways in which LA discipline can contribute to the SDGs. The EFLA proposed in this research not only can be used in general LA higher education, but it also explores how to cultivate qualified landscape designers who can contribute to sustainable urban development in the future.

However, this research still has many limitations. The first is about the research scope and focus. The focus of this study is on LA education in the USA, as all the data and interviews are based on this context. Although the findings of this research can potentially be generalized to LA education worldwide, it's important to acknowledge that different countries and regions may have unique situations and cultural backgrounds that affect their LA education and practice. Therefore, this research is only a start rather than an endpoint of a related EFLA study. Further research should be conducted with consideration of LA education in various countries. The second limitation is about interview design and sample size. A total of 40 experts are the maximum sample size we can approach in this research due to the limited funding, resources, and time. However, a larger sample size is necessary to draw more valid conclusions. This problem needs to be addressed in future research if we expand the research scope to more countries and regions. At the same time, the interview design should be improved in future studies. The evaluation matrix in this research is straightforward but relatively arbitrary. Defining the correlation between categories of TLA as either "have no correlation" or "have correlation" is not enough. Diverse answers should be allowed and encouraged in future expert interview designs. The third limitation is the establishment of EFLA. The current framework is relatively conceptual and not comprehensive enough. Future research should enrich this EFLA by discussing the relationship between TLA and LA higher education in-depth.

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Study on the Integration of the Sustainable Development Goals in Management Disciplines in Chinese Universities: A Content Analysis

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Abstract: Under the guidance of the "Education 2030 Framework for Action", China's higher education is moving towards internationalization, and there is an upsurge in a movement to strive for the sustainable development of education. However, the level and condition of the integration of the Sustainable Development Goals in management disciplines in Chinese higher education are not well studied. In this study, the content analysis method was used to encode and analyze the curriculum standards of management disciplines in Chinese universities to provide empirical evidence regarding the sustainable development concept of higher education in China. We concluded the following: (1) In general, the SDGs are not embedded broadly and deeply in management disciplines in Chinese universities; however, SDG 8 (decent work and economic growth) is the most significantly relevant element, being integrated broadly in many programs and courses of management disciplines. (2) There is a diverse concentration of the integration of SDGs in different management disciplines.

Keywords: Sustainable Development Goals; higher education; management discipline; content analysis; China

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1. Introduction

As a transformative concept concerning the health and well-being of humankind and future generations, the connotation of "sustainable development" has become more enriched and has become a universally recognized development concept around the world. Since the 20th century, environmental problems have attracted extensive attention from all countries, among which global warming, acid rain, and ozone layer destruction have been the main causes. People have begun to consider how to attain sustainable development, balanced development, and scientific development (Li et al., 2022; Roberto et al., 2022) [1,2]. In 1980, the framework for the conservation of global natural resources was published [3], and it suggested that sustainable development should look into the underlying connections between nature, society, ecology, economy, and the process of using natural resources in order to achieve global sustainability.

Bai and Bai (2022) proposed that to ensure sustainable development, we must respect nature, be inclusive, and base it on practice [4]. Similarly, Zhou et al. (2021) found that we must follow objective laws, and we should not exhaust our resources at the expense of harming the environment to achieve development [5]. With the further deepening of this concept, the theme of education for sustainable development (ESD) can be put into practice. The global action plan of ESD points out that the existing plan cannot completely solve all the problems of sustainable development education [6]. Therefore, we must rethink the relationships between people, which is of vital importance to the implementation of ESD. According to Brissett (2023), education is the primary driver behind development and is crucial for fulfilling the other Sustainable Development Goals [7]. Archana and Ajai (2022) have advocated for the application of SDGs in education, and insisted that higher education should be updated to meet modern expectations and satisfy the demands of society and the environment [8].

From a global perspective, young students are not optimistic about the current knowledge of sustainable development, and there are still misunderstandings about the significance and implementation path of sustainable development (Biancardi, Colasante, D 'Adamo, 2023) [9]. Higher education in China has been moving more rapidly in the direction of sustainable development. Over the course of several years, the SDGs have had quite a positive impact on both the research and teaching in higher education institutes in China. More and more universities are integrating concepts such as sustainable development, green development, ecological civilization, etc., into various curriculums. However, there are few studies and no consensus on the question of whether and how the SDGs are integrated into Chinese universities.

In order to realize the current developments in promoting ESD and the integration of the SDGs into Chinese higher education, this paper uses the content analysis method to analyze the curriculum standards of management disciplines in Chinese universities, and then applies a frequency analysis to determine the extent to which the SDGs are integrated into management discipline courses in China. This analysis provides empirical evidence for the reform of higher education and lays the groundwork for creating a sustainable development education system in China.

Figure 1 shows the 17 Sustainable Development Goals.

Figure 1. The 17 SDGs.

2. Literature Review

Since the UN General Assembly adopted the program guidelines, research on education for sustainable development (ESD) has gradually grown in popularity. The SDGs have become a hot research topic, and many scholars have conducted in-depth research on the relationship between the SDGs and other activities, through which the content has expanded to the field of higher education. The majority of research studies agree that in order to improve college students' capacity for sustainable development, the higher education system should continually expand its integration and promote the notion of sustainable development. Education is essential for instilling in young people a sense of sustainable development and motivating them to take sustainable action (Qin, 2023) [10]. Jucelia and Teresa (2022) [11] and Nyberg and Wright (2022) [12] studied the differences in the degree of inclusion of the SDGs in journals, and concluded that the inclusion of the SDGs in journals is relatively uneven at present; thus, it is necessary to incorporate the SDGs into learning. To solve this problem, Berrone et al. (2023) provided a framework to combine the Sustainable Development Goals with the academic literature, making it possible to further promote sustainable development education [13].

Other scholars have studied the important factors affecting sustainable development education. Sigahi and Sznelwar (2022) found that different SDGs have different effects on the ability of Brazilian students, thus realizing a new blueprint for future education in Brazil [14]. Dudek (2022) explored the relationship between open education and the SDGs, and the main obstacles from the perspective of open education [15]. In higher education, Goncalves et al. (2022) found that sustainable development education can develop because strategic planning is consistent at all levels of colleges and universities [16]. It is worth mentioning that Paola et al. (2022) found that the partnerships between different interest groups must be involved in management, that is, must meet SDG17 (Partnerships for the Goals) of the Sustainable Development Goals [17].

Some scholars have studied the role of the SDGs from the perspective of talents needed by enterprises in the future, and Bapuji et al. (2020) studied how to improve social concern by using sustainable development education [18]. Koh et al. (2014) found that the SDGs can help improve social inclusion from the perspective of social inclusion [19]. In addition, different from the first two, Flammer et al. (2019) pointed out that the incentive mechanism in enterprises is also one of the ways for enterprises to enhance their sustainable development ability [20]. It is worth noting that Ziegler and Oliveira (2022) found that reverse thinking in enterprise management responded to unsustainability [21]. It seems that all these studies show that building a sustainable development target system is one of the major trends in the future.

There are some cases of applying the SDGs to universities abroad. Yang et al. (2021) designed an art project related to sustainable development and applied it to business, and found that it can improve students' eyesight and enhance their awareness of environmental protection [22]. Aravindaraj and Chinna (2022) applied the Sustainable Development Goals to specialized courses on the logistics supply chain and put forward improvement methods [23]. Mariem et al. (2021) effectively integrated the SDGs into subject education so that students could better acquire the knowledge related to the SDGs [24]. In order to further improve the application of the SDGs in teaching, Christopher et al. (2022) designed an interdisciplinary sustainable development course, which laid the foundation for the development of global sustainable development education [25].

The other three studies are also worthy of our attention. Unlike other scholars, Walter et al. (2023) studied the perspective of students to explore students' attitudes towards the SDGs [26]. Furthermore, Biancardi, Colasante, and D 'Adamo (2023) pointed out that young students are not optimistic about the knowledge of sustainable development [9]. Goralski and Tan (2022) paid more attention to the future trend of sustainable development, and they put forward that poverty theory will be an important trend of the SDGs in the future [27].

Judging from the development trends and research status abroad, the awareness of learning about the SDGs in developed countries is relatively mature. Generally, there are many successful cases and many mature experiences have been accumulated, forming an operation mode suitable for the sustainable development of their own universities. These experiences are worth learning about and applying to our country.

In China, domestic scholars' research on the SDGs has mostly remained in the initial stage. Yue and Chen (2022) pointed out that ecological civilization education will become the mainstream education [28]. Zhang et al. (2021) proposed that the study of ecological civilization should be included in higher education studies [29]. In addition, Yuan and Shen (2020), similar to the first two scholars, found that sustainable development education must be lifelong education [30]. Guan et al. (2023) highlighted that sustainable development education must strengthen top-level design [31].

The integration of sustainable development education into higher education is still in the theoretical stage and has not been put into practice. Based on the current growth in China, sustainable development education is evolving slowly. There has not been much research carried out on the SDGs' incorporation into China's higher education system, and therefore the issue is still unclear. As a result, the analysis of the degree to which the

SDGs are integrated into management disciplines at Chinese universities is helpful for the implementation of sustainable development education in China's higher education system and offers a theoretical foundation for the top-level design of the SDGs.

3. Materials and Methods

3.1. Data Acquisition and Analysis Methods

3.1.1. Content Analysis Method

Content analysis is a semi-quantitative research method. The essence of content analysis is the result of analyzing the change in all information, and it is the process of deducing accurate meaning from represented and meaningful words and sentences [32]. Specifically, this study systematically retrieved and collected the curriculum standards of management disciplines in higher education through the Internet. Then, the NVivo software was used to code the keywords and sentences, determine the categories, and calculate the frequency of the 17 SDGs to build a model to analyze the inclusion degree and characteristics of the SDGs of management disciplines in Chinese universities.

Content analysis can spread out the corresponding content, show readers' views on information, and present a new way of communication. Content analysis can make semi-quantitative analysis clearer and reduce the interference of subjectivity and uncertainty. By using this method, we can also reveal any hidden related content and accurately identify the quality of the content. Thus, this approach provides more detailed methods and results for semi-quantitative research.

The main advantage of content analysis is that it reveals the hidden facts and the internal logical structure of the text [33]. This study draws on the research framework of Huang [34], and through extensive reading of the literature and listening to experts' opinions, and after many discussions to form the standard test coding of management disciplines in Chinese universities, determines the coding framework required by the content analysis method.

3.1.2. Data Acquisition

Through reviewing the compulsory courses published by the Ministry of Education, this study collected the curriculum standards of relevant disciplines from the academic affairs offices, the public information for each major, and other documents on the official websites of universities. In addition to these documents, for the curriculum standards of relevant subjects not found on the official websites, this study used the curriculum standards of major universities obtained from MOOC platforms. After systematic searching, this study randomly sampled the curriculum standards of management disciplines in major universities from 2018 to 2022. First, the management disciplines were divided into six categories; then a certain number of curriculum standards were randomly selected from each category; finally, the final curriculum classification was formed, as shown in Table 1.

Table 1. Classification of 66 courses in management disciplines.

Subject Classification	Courses Selected from Different Disciplines in Chinese Universities
Management Science and Engineering	(1) Computer application foundation, (2) College physical education, (3) Ideological and moral cultivation and legal foundation, (4) College English, (5) Advanced mathematics, (6) Situation and policy, (7) Introduction to Mao Zedong thoughts and socialism with the theoretical system of Chinese characteristics, (8) The outline of the modern and contemporary history of China, (9) Basic principles of Marxism, (10) Economics, (11) Statistics, (12) Operational research, (13) Production operation management, (14) Marketing, (15) Accounting, (16) Financial management, (17) International finance, (18) Management information systems, (19) Organizational behavior, (20) Management decision models and methods, (21) Information management and information systems, (22) Engineering project management.

Table 1. *Cont.*

Subject Classification	Courses Selected from Different Disciplines in Chinese Universities
Business Administration	(1) Computer application foundation, (2) College physical education, (3) Ideological and moral cultivation and legal foundation, (4) College English, (5) Advanced mathematics, (6) Situation and policy, (7) Introduction to Mao Zedong thoughts and socialism with the theoretical system of Chinese characteristics, (8) The outline of the modern and contemporary history of China, (9) Basic principles of Marxism, (23) Management science, (10) Economics, (24) Technical economics, (18) Management information systems, (11) Statistics, (15) Accounting, (25) Intermediate accounting practice, (16) Financial management, (12) Operational research, (14) Marketing, (26) Economic law, (27) Introduction to the modern corporate system, (28) Corporate finance, (29) Human resource management, (30) Enterprise management.
Agricultural Economic Management	(1) Computer application foundation, (2) College physical education, (3) Ideological and moral cultivation and legal foundation, (4) College English, (5) Advanced mathematics, (6) Situation and policy, (7) Introduction to Mao Zedong thoughts and socialism with the theoretical system of Chinese characteristics, (8) The outline of the modern and contemporary history of China, (9) Basic principles of Marxism, (10) Economics, (23) Management science, (11) Statistics, (31) Agricultural economics, (32) Entrepreneurial management of agriculture-related enterprises, (33) Agricultural policy, (34) Agricultural product marketing, (35) Agricultural resources and environmental economics, (36) Introduction to agriculture.
Public Administration	(1) Computer application foundation, (2) College physical education, (3) Ideological and moral cultivation and legal foundation, (4) College English, (5) Advanced mathematics, (6) Situation and policy, (7) Introduction to Mao Zedong thoughts and socialism with the theoretical system of Chinese characteristics, (8) The outline of the modern and contemporary history of China, (9) Basic principles of Marxism, (37) Logic, (38) Introduction to law, (39) Introduction to sociology, (40) Political science, (41) Public management, (42) Public economics, (43) Psychology, (44) Public administration, (45) Public ethics, (15) Accounting, (46) Government budget management, (47) Public policy, (29) Human resource management, (48) Public relations, (49) Practical writing, (11) Statistics, (50) Theory and methods of social investigation, (51) Social security.
Library, Information, and Archives Management	(1) Computer application foundation, (2) College physical education, (3) Ideological and moral cultivation and legal foundation, (4) College English, (5) Advanced mathematics, (6) Situation and policy, (7) Introduction to Mao Zedong thoughts and socialism with the theoretical system of Chinese characteristics, (8) The outline of the modern and contemporary history of China, (9) Basic principles of Marxism, (52) Library science foundation, (53) Information resource management, (54) System analysis and design, (55) Modern information technology, (56) Document management and information analysis, (57) Information retrieval, (58) Information economics, (59) Intellectual property, (60) Strategic management, (61) Publishing, (62) Multimedia technology application.
Tourism Management	(1) Computer application foundation, (2) College physical education, (3) Ideological and moral cultivation and legal foundation, (4) College English, (5) Advanced mathematics, (6) Situation and policy, (7) Introduction to Mao Zedong thoughts and socialism with the theoretical system of Chinese characteristics, (8) The outline of the modern and contemporary history of China, (9) Basic principles of Marxism, (23) Management science, (10) Economics, (18) Management information systems, (11) Statistics, (15) Accounting, (16) Financial management, (14) Marketing, (26) Economic law, (63) Introduction to tourism, (64) Tourism economics, (65) Hotel management principles, (66) Tourism resources and development.

3.2. Analytical Framework

In this study, the management disciplines were divided into six categories, namely, Management Science and Engineering; Business Administration; Agricultural Economic Management; Public Administration; Library, Information, and Archives Management; and Tourism Management (see Table 1).

NVivo software was used to code the contents related to the 17 SDGs appearing in the curriculum standards. If SDG-related content appeared once in the curriculum standards, it was recorded as one, if it appeared twice, it was counted as two, etc. For example, in the course (66) Tourism resources and development, the phrase "enhancing awareness and ability to protect and develop tourism marine resources and forest resources" appears, which corresponds to SDG 14 (Life Below Water) and SDG 15 (Life On Land) in Figure 1. Therefore, it should be recorded once under SDG 14 and SDG 15.

Two researchers were enlisted to help with the coding of the curriculum standard materials in order to guarantee their accuracy and reliability. First, the two researchers were trained to clarify the coding rules and SDG-related contents, and then they independently coded the 66 collected curriculum standards of management disciplines in Chinese universities, during which the researchers did not interfere with each other. After coding, Cohen's kappa coefficient was used to test the consistency of the two researchers [35]. The calculation formula of Cohen's kappa coefficient is shown in Equation (3):

$$P_0 = \frac{1}{n}\sum_{i=1}^{g} f_{ii} \tag{1}$$

$$P_e = \frac{1}{n^2}\sum_{i=1}^{g} f_{i+}f_{+i} \tag{2}$$

$$K = \frac{P_0 - P_e}{1 - P_e} \tag{3}$$

where P_0 represents the proportion of agreement between the two researchers; P_e represents the expected agreement between the two researchers under chance; the K value is Cohen's kappa coefficient; n is the total number of samples; g is the total number of categories; f_{ii} is the number of correctly classified samples in each category; f_{i+} is the real number of samples in each category; and f_{+i} is the number of predicted samples in each category. If the K value exceeds 0.75, it can be considered that the coding of the two researchers is reliable. The calculated kappa coefficient was 0.921, which was greater than 0.75, indicating that the coding reliability of the two researchers was good.

4. Results

4.1. The Overall Analysis of the Integration of the SDGs in Management Disciplines in Chinese Universities

The coding results showed that the SDG-related contents appeared 461 times in 66 courses. The degree of integration of the SDGs in the management disciplines of Chinese universities is not balanced. For example, the content of SDG 13 (Climate Action) related to climate change only appears once, while the content of SDG 8 (Decent Work and Economic Growth) promoting economic growth and ensuring employment appears 63 times, as shown in Table 2. It is worth noting that the relevant contents of SDG 6 (Clean Water and Sanitation), SDG 7 (Affordable and Clean Energy), and SDG 16 (Peace, Justice, and Strong Institutions) all appear three times, that is, the common problems in international resources, including drinking water resources, clean and affordable energy, and global partnerships, are also rarely involved in the curriculum standards of management disciplines. It can be seen that the courses of higher-education management disciplines in China can basically cover all issues related to the SDGs. However, the courses pay more attention to individual social development goals, such as SDG 8 (Decent Work and Economic Growth) and SDG 3 (Good Health and Well-being), and less attention to goals related to vulnerable groups such as SDG 5 (Gender Equality) and SDG 2 (Zero Hunger).

Table 2. The frequency of curriculum standards corresponding to the SDGs.

SDGs	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Frequency	7	5	28	10	6	3	3	63	11	11	20	14	1	4	5	15	3

4.2. Analysis of the Standard Frequency of Public Courses Corresponding to the SDGs

As shown in Figure 2, only course (6) Situation and policy involves SDG 1 (No Poverty) and SDG 2 (Zero Hunger), and the curriculum standards of other public courses are not mentioned. The course (2) College physical education is the most important source for Chinese university students to study SDG 3 (Good Health and Well-being), and the words "Good Health and Well-being" are mentioned in the course (2) College physical education up to seven times. The course (2) College physical education is also the only course that focuses on SDG 6 (Clean Water and Sanitation). The course (2) College physical education is a basic compulsory course for university students as regulated by the state. It is not only an important form of school sports activity, but also a more common mass sports fitness activity. There is also a certain type of participant or subject who chooses to participate voluntarily in sporting activities in order to improve their physical and mental health. Under normal circumstances, the course (4) College English mainly teaches generally about the subject and is supplemented by other English appreciation and business English courses. Moreover, college English teaching is mainly concentrated in the first to the third year of college, which is an important transition period from high school life to college life. In order to provide high-quality education for university students, college English teaching should follow the principle of classified instruction and teach students in accordance with their aptitude to meet the actual needs of personalized teaching. Therefore, only the course (4) College English is involved in SDG 4 (Quality Education). For example, taking online courses as an example, college teachers select high-quality online resources and introduce them before class to guide students to think positively and stimulate students to be interested in learning. Through the wisdom tree, QQ group classes, and other platforms (the wisdom tree and QQ group classes are both online tools to provide a cross between school and online learning for students in China), online teaching interactions can be effectively realized. Students can use online learning materials to listen and learn repeatedly anytime and anywhere and can utilize them to check and fill in gaps. Compared with other the SDGs, SDG 7 (Affordable and Clean Energy), SDG 9 (Industry, Innovation and Infrastructure), SDG 12 (Responsible Consumption and Production), SDG 14 (Life Below Water), and SDG 15 (Life On Land) are not included in the public courses of management subjects in higher education. Teachers teach (5) Advanced mathematics, (1) Computer application foundation, (9) Basic principles of Marxism, and (4) College English, which provide direction for college students' future employment choices and help them broaden their employment options. Therefore, SDG 8 (Decent Work and Economic Growth) appears frequently in these courses. SDG 10 (Reduced Inequalities) appeared four times in total, including in (7) Introduction to Mao Zedong thoughts and socialism with the theoretical system of Chinese characteristics, (3) Ideological and moral cultivation and law, (6) Situation and policy, and (8) The outline of the modern history of China. These courses are all aimed at the welfare of the people, which will inevitably involve reducing inequality. SDG 11 (Sustainable Cities and Communities) and SDG 16 (Peace, Justice, and Strong Institutions) appear with the same frequency as the designed subjects. This is closely related to the similarities between the two topics. Only through the development of good and harmonious cities and communities can we build a more inclusive society. In many public courses, the research found that course (6) Situation and policy focuses on the SDGs via a wider range of topics, and it can also be said to be more integrated with the SDGs. (2) College physical education is more focused on health and well-being than other public courses.

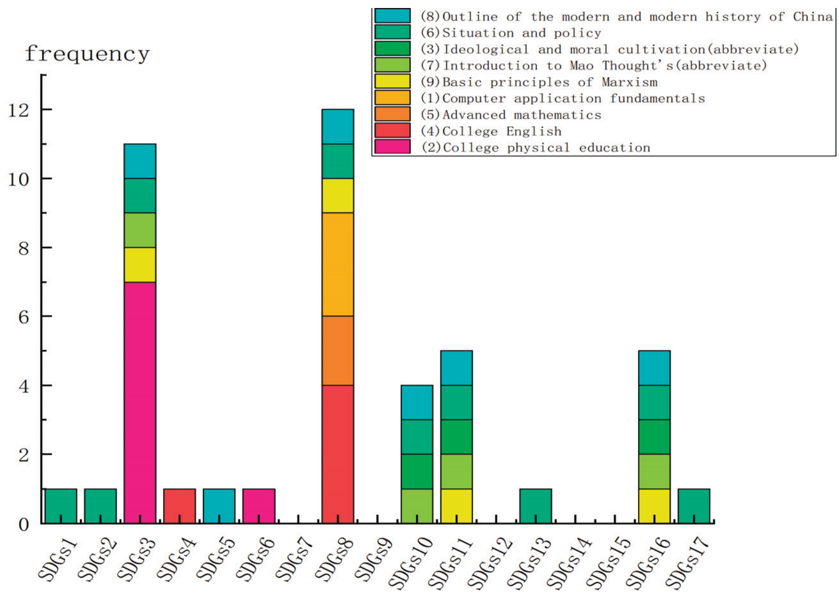

Figure 2. Inclusion of the SDGs in public courses of management subjects in higher education.

4.3. Analysis of the Frequency and Proportion of the Items of Each Major Course Corresponding to the SDGs

Figure 3 illustrates the extent to which, excluding public courses, each of the six majors is covered by the SDGs. SDG 8 (Decent Work and Economic Development), which is strongly tied to the employment-oriented orientation of universities, is related to the majority of management degrees. For instance, where Business Administration evaluates students' futures from the perspective of the sustainable development of firms, Agricultural Economic Management and Tourism Management place a greater emphasis on ecological environmental conservation. SDG 6 (Clean Water and Sanitation), SDG 8 (Decent Work and Economic Growth), SDG 12 (Responsible Consumption and Production), SDG 15 (Life On Land), and SDG 17 (Partnerships for the Goals) are mainly included in the course (23) Management Science, but in this course SDG content is rare. This also shows that (23) Management science majors lack the inclusion of the SDGs compared with other majors. Public management is the major with the highest frequency of SDG content out of the management disciplines, and it pays more attention to the development and stability of society. Among them, Library, Information, and Archives Management is the only program that provides students with quality education as the premise. It is characterized by breaking through the boundaries of the discipline and professional field to meet the needs of students' all-around development and personality development. This shows that the SDGs are not highly included in the courses set up by the six majors, which are more focused on employment. Among them, SDG 13 (Climate Action) is not included in the major courses, which is contrary to the overall development of students' bodies and minds, and there is a certain irrationality to this decision. SDG 13 (Climate Action) is a strategic approach for coping with global climate change and realizing carbon peak and carbon-neutral policies. It is also a major reason for the country to promote the construction of an ecological civilization and the "Blue sky project". Therefore, management disciplines in higher education should strengthen students' learning of new technologies, new ideas, and climate response measures; expand the "ecological niche" of higher education; break the "flowerpot effect"; enhance their "resistance and stability"; and achieve the Sustainable Development Goal of "integration and symbiosis".

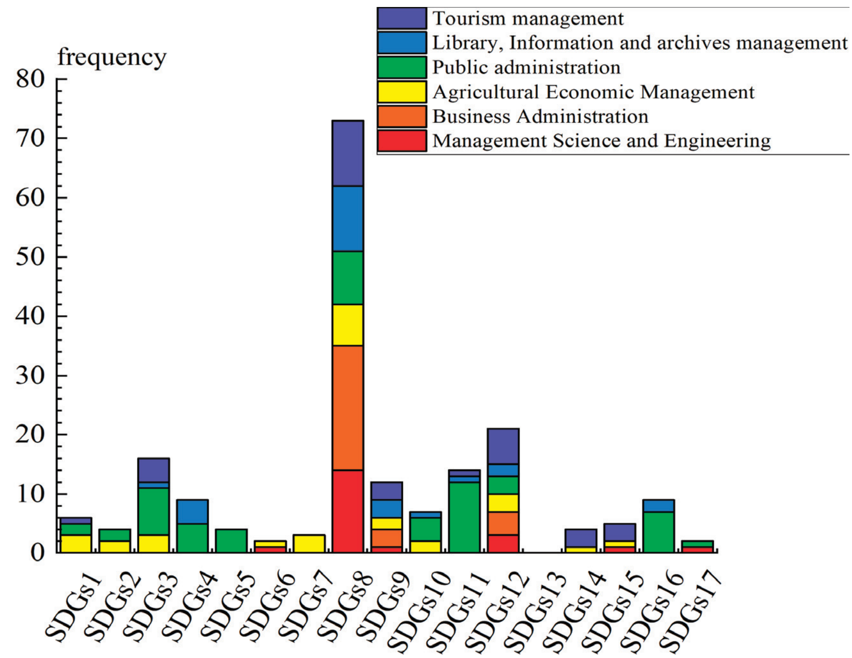

Figure 3. The degree of inclusion of the SDGs in the six major disciplines.

4.4. Analysis of the Subjects That Include the SDGs for Each Major

4.4.1. Financial Management Is the Main Field of Sustainable Development Education in Management Science and Engineering

The major of Management Science and Engineering has outstanding characteristics, such as talent training, but urgently needs to address social and economic development. The core goal is to cultivate students' scientific thinking, practicality, and engineering practice abilities. The four components of the curriculum system for Management Science and Engineering include the strategic objective of sustainable development, the legislation governing economic activity in support of sustainable development, a sustainable way of life, and social organization behavior. The course (16) Financial management takes finance and audit management as the main content, and risk management and value creation as the core values. The core goal of sustainable development education is to cultivate students' comprehensive quality of "understanding management, calculation, good financial management", and at the same time, cultivate students' innovation ability and social responsibility. It can be seen from Figure 4 that the frequency of addressing the SDGs in (16) Financial management is 13.04%, and the inclusion degree of other courses is around 8.70% and 4.35%. The SDGs involved in sustainable development education within Management Science and Engineering were concentrated, but the frequency of the SDG content was not high, as it only accounted for a total of 23 times. It is worth noting that SDG 1 (No Poverty), SDG 2 (Zero Hunger), SDG 3 (Good Health and Well-being), SDG 4 (Quality Education), SDG 5 (Gender Equality), SDG 7 (Affordable and Clean Energy), SDG 10 (Reduced Inequalities), SDG 11 (Sustainable Cities and Communities), SDG 13 (Climate Action), SDG 14 (Life Below Water), SDG 15 (Life On Land), and SDG 16 (Peace, Justice, and Strong Institutions) are all absent from the agenda, which indicates that these issues have not received much attention in the Management Science and Engineering profession.

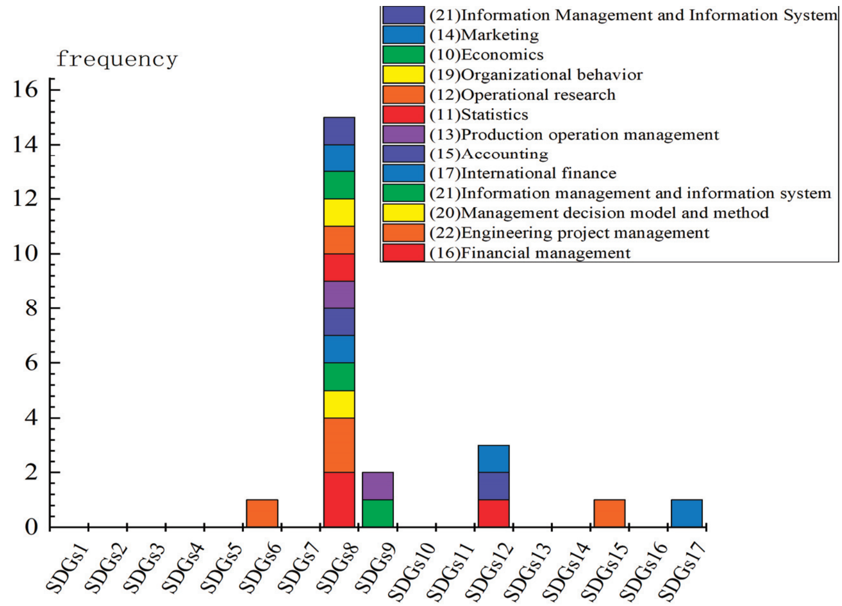

Figure 4. The degree of inclusion of the SDGs in Management Science and Engineering.

4.4.2. Financial Management Is the Main Field of Sustainable Development Education in Business Administration

Figure 5 shows that the education for sustainable development in Business Administration focuses on SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation, and Infrastructure), and SDG 12 (Responsible Consumption and Production), while the other 14 SDG issues occur at a frequency of 0. Economic globalization and the intensification of enterprise competition are the general trends of the world's economic development today. The negative impact of enterprise competition will continue to increase, and thus, the international community and governments of various countries are paying more attention to the sustainable development capacity of enterprises. Therefore, as the reserve talents of (30) Enterprise management, business management talents must pay more attention to the consciousness of "financial management and financial performance". However, while cultivating Business Administration talents, higher education should also pay attention to cultivating students' innovative ability, sustainable development ability, and international vision. The training mode of Business Administration professionals in the new era should focus on multidimensional, collaborative innovation and reform, such as interdisciplinary disciplines, diversified teaching methods, and the optimization of practical teaching.

4.4.3. Agricultural Resource and Environmental Economics Is the Main Field of Sustainable Development Education in Agricultural Economic Management

On 26 November 1993, the United Nations Environment Program (UNEP), an international academic institution, was formally established in Paris, France, to study and solve the main problems facing the international agricultural economy, such as poverty, waste management, and environmental health. The agency has made great contributions to promoting sustainable development and Agricultural Economic Management in various countries and regions around the world. As a major agricultural country, China actively participates in global sustainable development action. As the main field of education on the sustainable development of Agricultural Economic Management, (35) Agricultural resource and environmental economics involves a variety of topics, including water resource utilization, clean energy, employment, underwater life, terrestrial life, responsible consumption, production, etc. SDG content appeared six times, accounting for 21.43% of the Agricultural Economic Management courses, as shown in Figure 6. Compared with Business Administration and (23) Management science, the topics of the SDGs in (31) Agricultural economics and management were more widely included, and the SDG content appeared more frequently, at a total of 28 times. However, some issues were not covered. To meet the needs of China's agricultural economic development, sustainable development education activities aim to deepen students' understanding of China's national conditions, industrial characteristics, and sustainable development laws and apply them to the field of Agricultural Economic Management in a way that is both in line with those conditions and characteristics and that meets the advanced level of international practice. The development of Chinese higher education should continue in the direction of improving the quality of teaching and talent development, as well as cultivating students' overall quality.

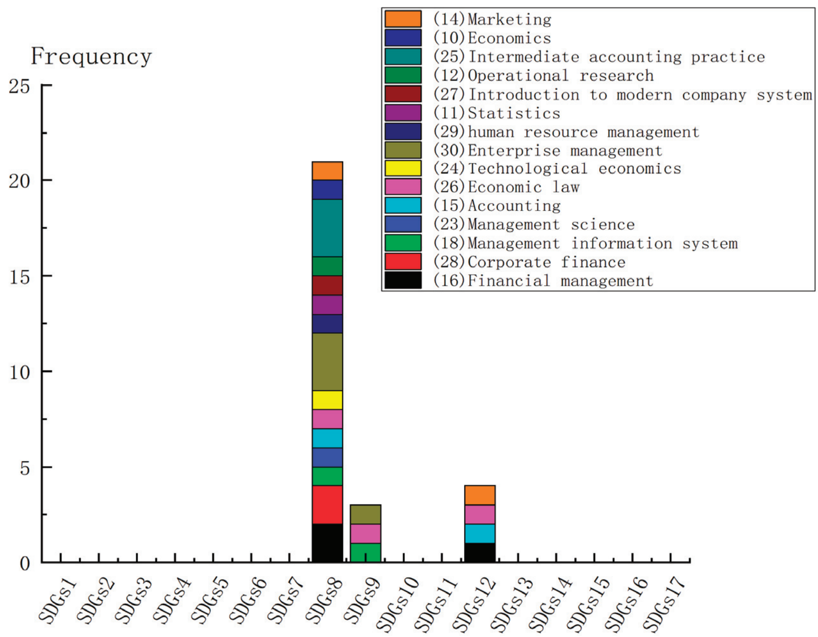

Figure 5. The degree of incorporation of the SDGs in Business Administration.

4.4.4. Social Security and Government Budget Management Are the Main Fields of Sustainable Development Education in Public Management

According to the content analysis, there are two SDG topics in the standard documents of the public management curriculum, which include (51) Social security and (46) Government budget management, as shown in Figure 7. The SDG content corresponding to the curriculum standards of public management majors appeared 61 times in total, among which (51) Social security and (46) Government budget management accounted for 14.75% (nine times) and 13.11% (eight times) of the total times, respectively, while the other subjects accounted for less than 10%. The courses (51) Social security and (46) Government budget management represent the main positions of sustainable development education for public management majors. It has always been the goal of the Communist Party of China to "realize the people's yearning for a better life". In the new journey of building a modern socialist country in an all-around way, we need to improve the service capacity of Public Administration departments and provide better, more efficient, equitable, and sustainable public goods and services to the people. The creation of the public management system in contemporary society also plays an essential and significant role in modern cities and government budget management systems. As a result, the foundation of public management in regard to the sustainable development of education is the improvement of social development and human welfare.

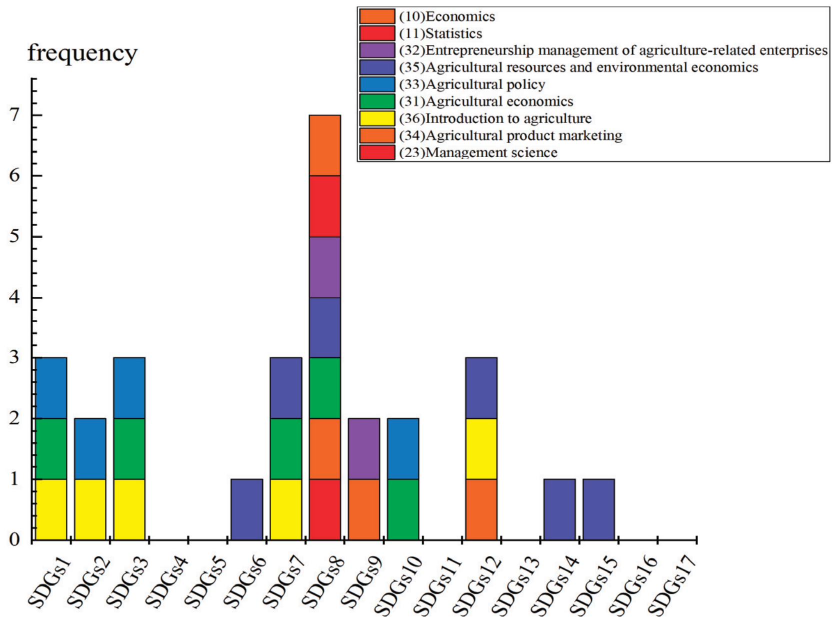

Figure 6. The degree of inclusion of the SDGs in agricultural economics and management specialty.

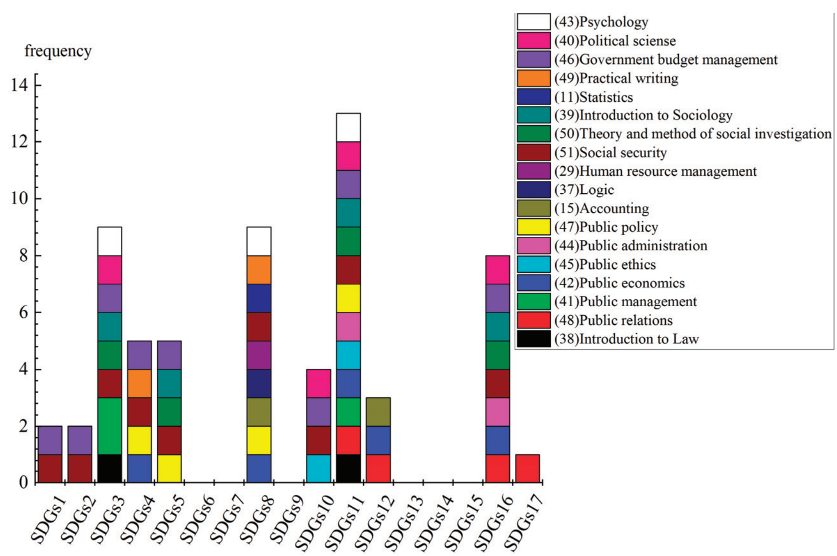

Figure 7. The degree of inclusion of the SDGs in public management.

4.4.5. Intellectual Property Is the Main Field of Education for Sustainable Development in Library, Information, and Archives Management

The strengthening of intellectual property protection in the Library, Information, and Archives Management speciality has strengthened the protection of intellectual property. According to statistics, there are 3.02 million trademarks in China, among which 133 are well-known trademarks (well-known trademarks account for 80% of the total number of registered trademarks). The State Intellectual Property Office has raised the number of trademarks and new plant varieties from 325 to 863. According to incomplete statistics, the number of trademarks in China has exceeded 17,000. At the same time, readers suffer damages as a result of numerous cases of infringement that take place every year. Therefore, the IPR curriculum standards focus on SDG 3 (Good Health and Well-being), SDG 8 (Decent Work and Economic Growth), SDG 10 (Reduced Inequalities), SDG 16 (Peace, Justice, and Strong Institutions), and other topics with a total frequency of four times, accounting for 16% of the total frequency found for Library, Information, and Archives Management courses, as shown in Figure 8. A noteworthy point is that the Library, Information, and Archives Management major is the only major that mentions quality education in all four courses. The major implements a teaching mode that focuses on improving students' reading ability, reading strategies, and reading skills, and continuously promotes education for sustainable development.

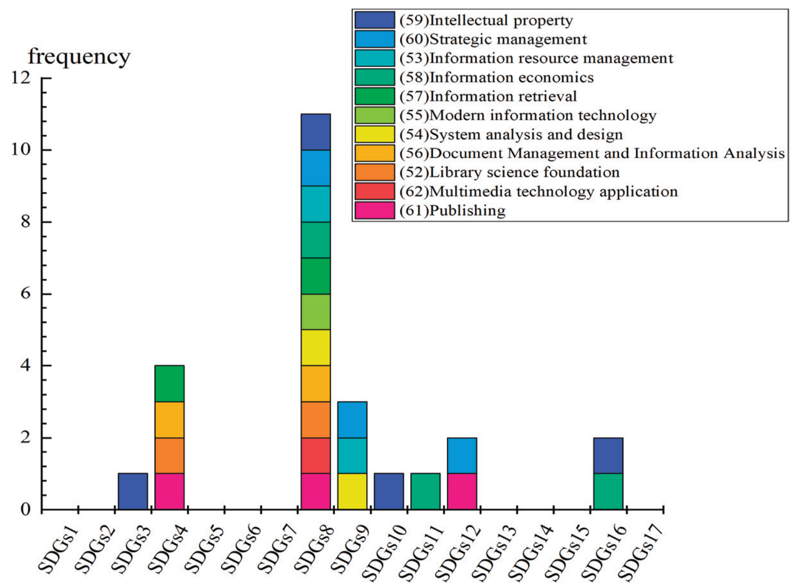

Figure 8. The degree of inclusion of the SDGs in Library, Information, and Archives Management.

4.4.6. Introduction to Tourism Is the Main Field of Education for Sustainable Development in Tourism Management

Tourism Management is meant to realize the harmonious coexistence between man and nature in tourism practices and is a process of constantly discovering, analyzing, and solving problems. The rapid development of China's tourism industry provides Chinese tourists with a new way of life, but also brings about many environmental problems. Therefore, the introduction of tourism pays more attention to the protection of the ecological environment. In-depth research on the theory of tourism resources is helpful to form a correct concept of tourism resource protection, rationally developing and utilizing tourism resources, and promote the sustainable development of tourism. The frequency of addressing other disciplines in Tourism Management was about three times, and the topics were scattered, but the content related to the SDGs was concentrated (see Figure 9). However, Tourism Management does not mention SDG 13 (Climate Action), even though it is among the management disciplines that should pay much attention to environmental protection. Why does this management discipline in universities not mention the issue of climate change regardless of whether it pays attention to environmental protection? This question is worthy of further investigation.

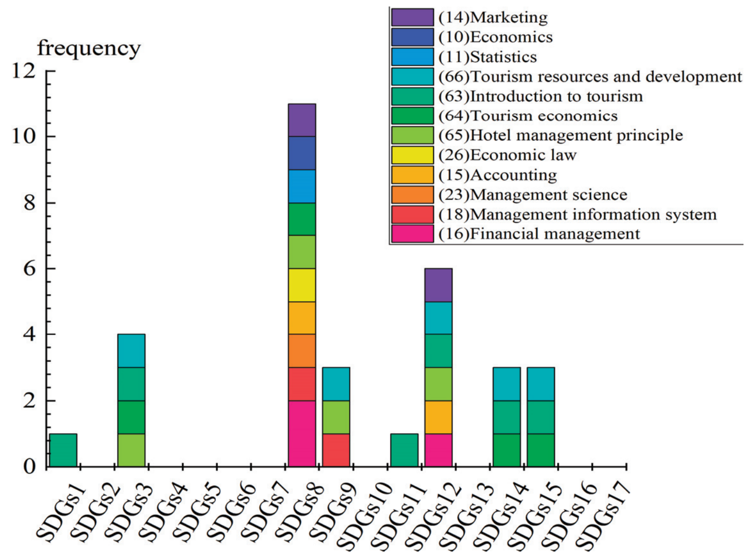

Figure 9. The degree of inclusion of the SDGs in Tourism Management majors.

5. Conclusions and Discussion

5.1. Balancing the Development of SDG Education in Management Disciplines

Although the SDGs have all been incorporated into management disciplines, many issues only appear in public courses and are not covered in professional courses, such as SDG 13 (Climate Action). The degree of the integration of the SDGs in management disciplines is still at a very early stage, and many issues related to the SDGs have not been integrated into programs and courses. Taking SDG 13 as an example, the content of SDG 13 includes urgent action to address climate change and its impacts. In 2021, the Chinese government issued the White Paper on China's Policies and Actions on Climate Change, which sets out China's new vision on climate change. It firmly establishes a sense of community, implements a new development philosophy, puts people first, and vigorously promotes carbon peaking and carbon neutrality as well as the synergy of reducing pollution and carbon emissions, thus pointing out the direction for actively responding to climate change. As the backbone for cultivating new green and low-carbon talents, Chinese universities should integrate SDG 13 into the higher education system to continuously promote the improvement of university students' mindset, knowledge, skills, and capabilities related to achieving sustainable development. Therefore, higher education curriculum reform and innovation must be sustainability-oriented, integrating the SDGs into course standards, and promoting the balanced development of sustainable development education in all majors. Furthermore, interdisciplinary research should be carried out among disciplines to cultivate the growth of new disciplines and better serve the goal of high-quality economic and social development in China. Finally, on the basis of the comprehensive consideration of the development trend in these disciplines, key subjects must support and plan to promote the balanced development of sustainable development education.

Only the balanced development of management disciplines can enable students to better cultivate their sustainable development abilities, make contributions to China's sustainable development education, and ultimately realize "moral cultivation".

5.2. Enriching and Merging Content into Public Courses and Professional Courses

The education model of Chinese higher education is based on professional courses and supplemented by public courses to jointly promote the healthy development of university students. The inherent model is utilized for different majors, and even though there are different professional courses that last for several years or even more than ten years, it has never changed. In the information age of rapid development, higher requirements have been put forward regarding the knowledge system of college teachers. Gone are the days when the traditional "bucket of water" could irrigate all students. Nowadays, college teachers are required to have "a pool of living water". They should not only have the knowledge system updated to modern day expectations, but also have the practical ability to nurture students continuously. According to an analysis of the SDGs' degree of inclusion and other features in Chinese colleges, both professional and (41) Public management courses are not sufficiently absorbing new information. In 2021, Huang found that the curriculum standards of 13 basic courses in primary and secondary schools in Macao mentioned the SDGS with a total frequency of 454 times [34]. However, the total frequency of including the SDGs in 66 management courses in Chinese universities was only 461 times. This also shows that the curriculum of Chinese universities does not incorporate the SDGs to a high degree.

Therefore, this study believes that strengthening the inclusion of new content in public courses and professional courses is conducive to the accurate matching of talent training needs and rapidly transforming them into real productivity; it is helpful for enhancing education and teaching standards further and addressing the public's increasing demand for better living conditions.

5.3. Based on the Subject Characteristics, the Knowledge System of the Sustainable Development Goals Is Formed

At present, the most respected Sustainable Development Goal in management disciplines in higher education in China is SDG 8 (Decent Work and Economic Growth). It exists in the curriculum standard of almost every course. This coincides with the concept of being "people-oriented" in the new curriculum reform. However, this is not the only goal needed for the future development of higher education in China. The key to meeting the goal of sustainable development is to cultivate some important abilities of students, such as their systematic thinking ability, anticipation ability, planning ability, and critical thinking ability. This cannot be achieved by only praising SDG 8. Therefore, higher education should be based on the characteristics of its own development, integrating other ideas related to the Sustainable Development Goals in the classroom and strengthening the linkage between disciplines after class to improve students' sustainable development ability. In the future, colleges and universities can also arrange and combine courses that address different Sustainable Development Goal topics in various disciplines so that students can obtain complete guidance on the Sustainable Development Goals, which will meet the career development needs of all kinds of talents and provide talent support for social and economic development. As a talent training base, colleges and universities are duty-bound to cultivate compound talents to meet the needs of society.

6. Limitations and Prospects

6.1. Limitations

Based on the curriculum standards of higher education management disciplines, this paper analyzes the degree to which they include the Sustainable Development Goals, but is restricted by its own cognitive level. This paper also had some limitations in the research process: First, in terms of research methods, this paper mainly adopted the content analysis method, the selection of curriculum standards was not comprehensive enough, and the collected data were subjective. The second limitation was the research content, which mainly focused on the research of sustainable development education theory, and the combination of theory and concrete practice was less examined.

6.2. Prospects

In order to solve the shortcomings of this study, the future development direction is put forward: Firstly, the selection of curriculum standards for higher education management should be expanded and more in-depth research should be conducted. Secondly, after developing a certain understanding of the Sustainable Development Goals addressed by various disciplines, we can put forward better teaching strategies through corresponding arrangements and combinations.

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sustainability

Article

Aligning Engineering Education for Sustainable Development through Governance: The Case of the International Center for Engineering Education in China

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Abstract: Engineering education plays a key role in the progress toward achieving the 17 Sustainable Development Goals (SDGs). However, engineering education faces many challenges worldwide, and the issues are becoming increasingly complicated because of the COVID-19 pandemic. To deal with these challenges and achieve the SDGs by 2030, governance that aligns engineering education and SDGs is badly needed. The International Center for Engineering Education (ICEE) has taken a series of governance actions to align engineering education and sustainable development. This research presents the contribution of these governance actions, analyzes the governance types and their relevance to the SDGs, and explores the key mechanisms of these governance actions and challenges. This research can provide useful information for the global community to understand China's participation in global engineering-educational governance and promote engineering education for sustainable development.

Keywords: engineering education; global governance; sustainable development; China

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1. Introduction

In 2015, the United Nations approved the 17 Sustainable Development Goals (SDGs) and the 2030 Agenda for Sustainable Development to achieve these goals. The 17 goals comprise a broad range of social, environmental and technological issues from poverty reduction, good health, industrial innovation, quality education, and gender equality, to the sustainable use of energy and clean water [1]. All 17 goals can be related to engineering and requires solutions rooted in engineering [2]. Engineering has a wide range of effects on human society and nature. It contributed to our ability to survive disasters and public-health challenges, to secure food and water, to communicate and travel, and to innovate and create new products and services [3]. Thus, engineering plays a central role in the creation of a more sustainable world. Given the crucial role that engineering has in shaping the development of our society, engineering education is critical for sustainability [2–5].

However, engineering education faces many challenges worldwide. First, the number of graduates in engineering fields has declined compared to other fields in the last 20 years, according to data from the UNESCO Institute for Statistics (UIS) [6]. "Escaping engineering" is becoming a common phenomenon. Decreasing numbers of students choose engineering as their major, and engineering graduates prefer to work in other fields such as business [2,7,8]. Second, gender inequality in the field of engineering is still present, and girls are not encouraged to become engineers in many places [9–13]. Third, the regional development of engineering education is unbalanced, and regional engineering capabilities vary greatly. The first UNESCO Engineering Report 2010 shows that there are 20–50 scientists and engineers per 10,000 people in developed industrialized countries, but developing countries have an average of just 5 scientists and engineers, while in poorer African countries this number drops to 1 or less [3]. Ten years later, this issue has not changed significantly. In Swaziland, for example, there is less than 1 engineering graduate for every 170,000 people; by comparison, in the United Kingdom, there is 1 engineering graduate for 1,100 people [2]. Fourth, new technologies brought by the Fourth Industrial Revolution (Industry 4.0), which include artificial intelligence, robotics, 5G networks, cloud computing, 3D-printing, blockchain, and digital healthcare, are becoming more complex and will change job types, career paths, and the ways in which people work [14]. This requires changes and innovation in the content of engineering education and a shift toward problem-based, project-, context-, and challenge-based learning [15–17]. Fifth, the spread of COVID-19 makes these challenges more difficult to solve, and poses new, additional challenges. For example, the large-scale use of remote learning has become very common since the outbreak of COVID-19. This enlarges the gap in the development of engineering education in different regions, since developing countries have poor digital infrastructures and ICT technology compared to developed countries. Moreover, the spread of COVID-19 also has a negative influence on the mobility of international engineering students and international exchanges and cooperation on engineering education. In order to deal with these global challenges, governance that integrates engineering education into sustainable development across the world is badly needed.

The concept of global governance was proposed initially to address global issues. To understand this concept, we need to clarify the meaning of governance first. Governance is the sum of the many ways in which individuals and institutions, public and private, manage their common affairs [18]. It is a part of human activity concerned with “creating the conditions for ordered rule and collective action” [19]. When this activity transcends the bounds of the nation-state and involves multiple actors in policy production and implementation on global, national, and local scales, the concept of global governance emerges [20]. As Rosenau states, “global governance is conceived to include systems of rule at all levels of human activity in which the pursuit of goals has transnational repercussions” [21]. The Commission on Global Governance defines global governance as “the formation of a series of formal and informal institutional arrangements through participation, negotiation and coordination by various actors, such as governments, various international organizations, and private or public institutions, to deal with the common challenges that mankind faced, such as ecological and environmental issues, to enhance the well-being of all human beings” [18]. Global governance relates to the interaction and collaboration between myriad entities emanating from various societal and professional orientations, which form networks to address issues that threaten local and global communities [22]. Global governance should be considered as covering the overlapping categories of functions performed internationally, including: information creation and exchange, the formulation and promulgation of principles, the promotion of consensual knowledge affecting general or particular issues concerning humankind, efforts to influence the behavior of states, and assistance in the advancement of human development [23]. Broader opinion can influence policy choices, and the interconnectedness of the world makes the idea of global governance important, exciting, and worthy [24].

The topic of global governance is important to scholars of world politics and economics. However, few efforts have been undertaken by education scholars to explore global educational governance in the last decade [20]. Global educational governance refers to actors, such as governments, international organizations, multinational companies, think tanks, and mass media, using participation, dialogue, negotiation, and cooperation to build consensus and construct a series of mechanisms or rules that can influence the development of international education. In recent years, a growing body of literature has focused on international organizations and their global governance activities in the educational area. International organizations have placed increasing emphasis on education, and they have become powerful actors in education [25]. UNESCO, OECD, and the World Bank are three important international organizations in the global education discourse and they have been repeatedly found to be the most relevant organizations in educational policymaking worldwide [26]. Researchers have identified the typology of international organizations' global governance activities in education based on the instruments that international organizations use. For example, UNESCO 's governing instruments include conventions (such as the Global Convention on the Recognition of Qualifications concerning Higher Education), educational concepts (such as Education for All and Lifelong Learning), conferences (Global Education Meeting), and research-based knowledge (Global Education Monitoring Report). UNESCO has been successful in garnering continuous support for its Education for All initiative since 1990 and has recently taken the lead in global educational reporting through its Global Education Monitoring Report (GEMR), its flagship publication [27]. The major global educational governing instruments developed by the OECD are "governing by numbers, governing by comparison, governing by example, governing by commensuration, governing by affection", etc. [28]. The World Bank is the largest funding and project-implementing institution in education in the world. Financial aid and scientific knowledge-sharing are the two major instruments that the World Bank using for global educational governance [29]. These governing instruments are categorized into two types: hard (coercive, or formal) and soft (normative, or informal) influence mechanisms. For instance, convention or regulation and funding are forms of hard power; and educational concepts or research knowledge are forms of soft power. Although it is difficult to empirically examine the differential impact of these types of governance, it seems that IOs are well placed to influence nation-states by forcing, paying, talking, persuading, pleading, and socializing [30]. Previous research has fully explored the types of international organizations' global governance activities in the field of education. However, there is a gap in the specific field of engineering education on which the global governance activities to align engineering education for sustainable development has not been as focused, especially in China.

China takes the implementation of the 2030 Agenda for Sustainable Development as a high priority and commits to promoting sustainable development in all areas [31]. Thus, China supported UNESCO to set up the International Center for Engineering Education (ICEE) in China in 2016, which is the only UNESCO Category II center named after engineering education. This international center aims to promote the concept of sustainable development in engineering education. It has taken a series of governance actions to align engineering education and sustainable development. The objective of this research is to present the contribution of these governance actions, analyze the governance types and their relevance to the SDGs, and explore the key mechanisms of these governance actions and the challenge of achieving the SDGs through global governance. This research can provide useful information for other countries or regions to promote engineering education for sustainable development.

Research questions:

1. What global governance effects does ICEE have on engineering education?
2. How do these governance activities relate to the SDGs?
3. What is the key mechanism of these governance actions and how do they help to meet the challenge of achieving the SDGs?

2. Methods

This study employs a qualitative methodology based on a case-study approach. A case study is an empirical method that investigates a contemporary phenomenon (the 'case') in depth and within its real-world context; such an understanding is likely to involve important contextual conditions pertinent to the case [32]. Therefore, it is advantageous to investigate the in-depth and detailed information on the effects of global governance actions on engineering education in the context of ICEE's practice.

2.1. The Case

This research focuses on the case of the International Center for Engineering Education under the auspices of UNESCO (ICEE). ICEE can be dated back to the educational research office of Tsinghua University, which was founded in 1979. This office then became the Center for Engineering Education, Tsinghua University, which was founded in 2008. Later, the Center for Engineering Education, Tsinghua University, became the China Academy of Engineering—Tsinghua University Center for Engineering Education, in 2014. The vision of ICEE is to build an equal, inclusive, developmental, and universally beneficial global engineering education community for the promotion of quality and equity in engineering education amongst all countries in the world. The mission of ICEE is to be a think tank for policy research, an incubator for high-caliber personnel, and an exchange-and-cooperation platform in global engineering education. As shown in Figure 1, ICEE pursues quality engineering education worldwide by building global networks, strengthening industry–university collaboration, and developing innovation-driven university education. The center focuses on talent cultivation in engineering for developing countries on the path of innovation-driven education and industry–university collaboration to support these countries in pursuing sustainable social and economic development, which will benefit individuals, local communities, countries, and the whole of humankind [33]. The organizational structure of ICEE includes the governing board, the advisory board, the executive committee, and four departments. As shown in Figure 2, the governing board is the decision-making body, the advisory board is the consultation body, and the executive committee is responsible for the regular operational and administrative affairs.

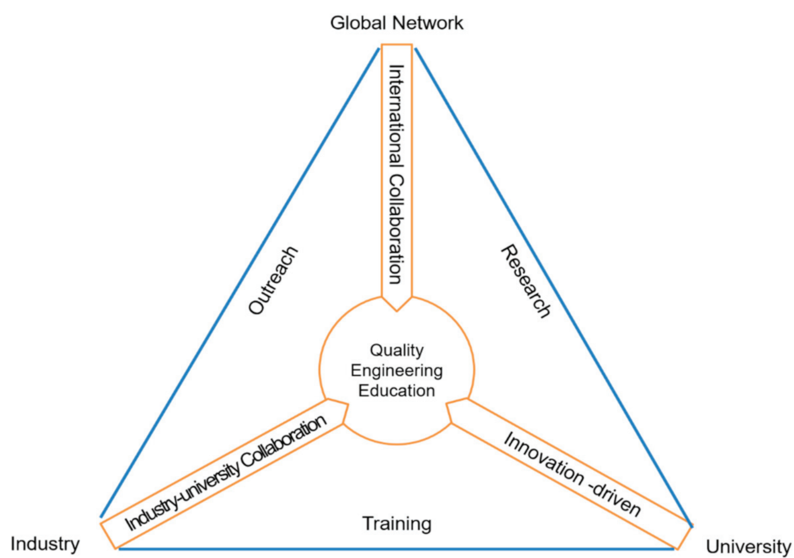

Figure 1. The mission of ICEE.

This paper reports on single-institution research, but this research and its contributions are notable for many reasons. As a Category II center of UNESCO, ICEE takes SDGs as its action framework, and it is committed to aligning engineering education with sustainable development. ICEE was proposed jointly by Tsinghua University and Chinese Academy of Engineering (CAE). Tsinghua University is one of the world's most prestigious universities and it is well known in the field of engineering education. China Academy of Engineering is a national consulting organization in engineering science and technology in China. It represents the capacity of engineering and engineering education of China. The various members of ICEE's governing board and advisory board are from Tsinghua university, China Academy of Engineering, China Engineering Education Accreditation Association, Massachusetts Institute of Technology, World Federation of Engineering Organizations, International Federation of Engineering Education Societies, Global Council of Engineering

Deans, Africa Engineering Education Association, European Society for Engineering Education, Engineering Academy of Japan, and other international institutions. ICEE shows the international cooperation of these organizations, which is a good example of effect of multi-agent synergetic governance on engineering education globally. ICEE is an important platform and window for China to participate in global engineering education governance through UNESCO. This research can help to understand China's participation in the global governance on engineering education.

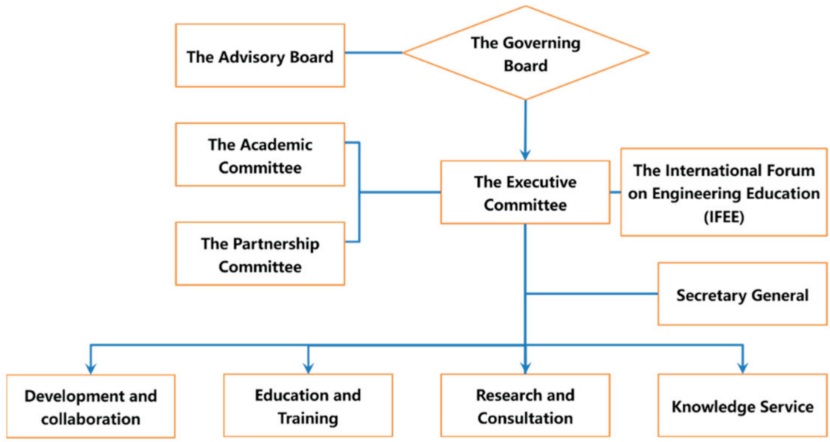

Figure 2. The organizational structure of ICEE.

2.2. Data Collection

Data were collected from documentation and text analysis. Documents play an explicit role in case-study data collection, and systematic searches for relevant documents are important [32]. In this research, the documentation includes public information from ICEE' websites or publications and inside information provided by ICEE. Large volumes of materials from ICEE were involved in this research, including annual reports, research reports, speeches, newsletters, meeting minutes etc. The time span of these research data ranges from 2019 to 2021. The documentation studied is presented in Table 1.

Table 1. Information about the documentation involved in this research.

Public Information	Inside Information
Newsletters	Annual reports
News	Work plan
Brochure	Research reports
Briefings of events and activities	Online learning project reports
Articles	Chronicle of events
Videos	International conference/Forum minutes
Speeches	Departmental meeting minutes

2.3. Data Analysis

Techniques for qualitative data analysis involve two cycles of coding. First-Cycle Coding includes elemental, procedural, and language analysis. Second-Cycle Coding is much more challenging; it includes pattern coding, focused coding, axial coding, and theoretical coding [34]. The data analysis focuses on effects of ICEE's global governance actions on engineering education and their connections with SDGs, and the key mechanism of these governance actions and the challenge to achieve SDGs through global governance.

All the ICEE documentation materials were organized, cleaned, and coded through the two cycles of coding using NVivo qualitative research software. In total, 338 documents (texts) and 2 h 7 min of videos were coded in this research. Through data analysis, we identified the typology of global governance activities of ICEE, sketched out their connections with SDGs, found the key mechanism of these governance actions and determined the challenges involved in achieving SDGs through global governance. The results of this analysis are discussed in detail in the following sections.

3. Results

The results from the case study and data analysis are presented in this section to answer the research questions. The typology of global governance in the field of engineering education is presented in Section 3.1. The connections of these governance actions with the SDGs are outlined in Section 3.2. In Section 3.3, the key mechanism of these governance actions is discussed and the challenges involved in achieving the SDGs through global governance are determined.

3.1. The Typology of Global Governance in Engineering Education

We found 3 categories and 14 codes based on the data analysis. The frequency of the codes and the details of the coding are shown in Table 2.

Table 2. Information about the coding process and results.

Categories	Codes (Frequency)	Raw Data (Source)
Governance actions (types)	Governance by ideas (28)	The idea of a global engineering education community rooted in the concept of a community with a shared future for mankind (research report: On the construction of the global engineering education community; minutes: The 2021 ICEE Governing Board and Advisory Board Meeting).
	Governance by standards (23)	ICEE completes the revision of the IEA standard for GAPC. (Annual report 2021).
	Governance by accreditation (31)	ICEE researchers contributed heavily to this process by, for example, establishing the internationally equivalent Chinese engineering education accreditation system, and research work on the rules and procedures of application, which provides guidance and suggestions for China joining in the Washington accord (news: ICEE has made important contributions to China Engineering Education's accession to the "Washington Accord").
	Governance by research (47)	With support from CAE, ICEE has carried out research on major strategic themes, such as "Engineering for Sustainable Development", "Research on the Demand for Engineering Science and Technology Talents and the Reform Strategy of Education Mode for Sustainable Development in the New Era", etc. (annual reports for 2019, 2020, 2021)
	Governance by conference (36)	The second international forum on engineering education was held in 2020 with the theme of "Environment and Sustainable Development" (news: The 2nd International Forum of Engineering Education IFEE 2020).

Table 2. *Cont.*

Categories	Codes (Frequency)	Raw Data (Source)
	Governance by knowledge services (35)	The engineering education knowledge service platform is a comprehensive, international, and non-profit online platform, which integrates data services, information services, and educational services to help people to obtain various educational resources in a one-stop framework (article: The implementation and development of the international program of computer micro-diploma—taking the practice during COVID-19 as an example).
Relevance to SDGs	SDGs (89)	Engineering for sustainable development (research reports, ICEE brochure, news, events)
	Sustainable development (77)	Engineering for sustainable development (research reports)
	Quality engineering education (43)	ICEE pursues quality engineering education worldwide (ICEE brochure, videos of ICEE promotional event)
	Engineering capacity (38)	ICEE aims to bridge the gap in regional engineering capacity (online-learning project reports, international conference/forum minutes).
	Partnerships (68)	In order to achieve the UN SDGs, ICEE consolidated partnerships and participated in global cooperation (annual reports for 2019, 2020, and 2021; news)
Key mechanism	Collaboration/ cooperation (85)	ICEE has continuously strengthened communications and cooperation with international organizations, academic institutions and business partners (Annual report 2019, 2020, 2021; departmental meeting minutes).
	Partner (72)	ICEE's close global partners, including UNESCO, IEA, WFEO, XuetangX, China Academy of Engineering, China Academy of Space Technology, China Harbour, etc. (ICEE website, annual report for 2021, news, newsletters).
	Global network (39)	ICEE constantly expands its visibility and influence by building global networks (work plans for 2019, 2020, and 2021).

3.1.1. Governance by Ideas

ICEE proposed the initiative of building an equal, inclusive, developmental, and universally beneficial global engineering education community. This idea is rooted in the concept of a community with a shared future for mankind. It is a community of belief, rules, actions, and interests, based on a consensus over the relationship between engineering education and the future development of mankind. With the principles of extensive consultation, joint contribution, and shared benefits, the global engineering education community will establish an efficient and equal cooperation mechanism, a flexible and diverse mobility mechanism, a universally beneficial governance mechanism, and an open resource-sharing mechanism. The cooperation mechanism generally involves establishing engineering education cooperation alliance, signing agreements, providing cooperation funds, creating cooperation platforms, exchanging scholars, and organizing conferences jointly. The mobility mechanism aims to improve the internationalization level of engineering education by establishing common standards and accreditation. The governance mechanism refers to the multi-agent synergetic governance model, which aims to achieve universally beneficial development. The open resource-sharing mechanism refers to establishing a global engineering-education database using information and communications technology, gathering large volumes of high-quality engineering-education resources. This resource-sharing mechanism is charitable and open for all.

3.1.2. Governance by Standards

ICEE has participated in the revision work of the International Engineering Alliance (IEA) Graduate Attributes and Professional Competencies (GAPC) as a core member since 2019. The GAPC profiles defined the expected outcomes for engineering-education programs and competencies for independent engineering practice for three professional tracks: engineer, engineering technologist, and engineering technician [35]. The GAPC framework is the basis of the three education accords and the four agreements. The three education accords are the Washington Accord, the Sydney Accord and the Dublin Accord. The four agreements are the International Professional Engineers' Agreement (IPEA), the APEC Engineer Agreement (APEC), the International Engineering Technologists' Agreement (IETA), and the Agreement for International Engineering Technicians (AIET). Through these accords and agreements, IEA established and enforces internationally benchmarked standards for engineering education and the expected competencies for engineering practice. The GAPC is recognized as a valuable international benchmark for engineering education by more than 30 countries. This revision work will have an important impact on the development of global engineering education in the next 10 years.

3.1.3. Governance by Accreditation

ICEE played an important role in the process of China joining in the Washington accord and the accreditation of engineering education in China. In 2005, China began to explore how to join in the Washington accord. Through the process of research, piloting, and full implementation, China became a full member of the Washington accord in 2016. ICEE researchers contributed significantly to this process by, for example, establishing the internationally equivalent Chinese engineering-education accreditation system, and conducting research on the rules and procedures of application, which provided guidance and suggestions for China joining in the Washington accord [36]. In 2006, only eight majors passed the accreditation. After China joined the Washington accord, the number of majors that passed the accreditation increased significantly. In 2020, 1600 majors passed the accreditation; they were distributed among 257 colleges and universities [37].

3.1.4. Governance by Research

ICEE aims to promote the development of engineering education and sustainable development through research. The most influential research project in which ICEE has participated is the "Engineering for sustainable development" report, the second UNESCO engineering report, which was officially released on World Engineering Day (4 March 2021). As one of the flagship reports of UNESCO, the engineering report is published in English, French, and Chinese, and its executive summary is published in English, French, Chinese, Russian, Spanish, and Arabic. The engineering report highlights the crucial role of engineering in achieving each of the SDGs and provides recommendations for governments, engineering organizations, academia and educational institutions, and industry to forge global partnerships and catalyze collaboration in engineering to deliver on the SDGs. The director-general of UNESCO, Audrey Azoulay, wrote in the preface of the report that "the report is an important milestone in the standard-setting work of UNESCO" [2]. ICEE also provides policy consultation on engineering education by research for the Chinese Academy of Engineering, the China Association for Science and Technology, the Ministry of Education, and other organizations or government departments.

3.1.5. Governance by Conferences

ICEE holds many international conferences about engineering education and sustainable development to share experiences and provide exchange opportunities for stakeholders in the field of engineering education. The international forum on engineering education

(IFEE), which is a major conference held by ICEE, aims to improve the quality of engineering education and achieve the SDGs by engaging engineers. To ensure the quality of engineering education, ICEE organized multiple online education seminars, dialogues, symposia, workshops and conferences after the outbreak of COVID-19 to share Tsinghua's experience of online education during the pandemic by working with Xuetangx, Global MOOC Alliance, and the Online Education Center of Tsinghua University. To align sustainable development in engineering education, ICEE also held the 2021 Engineering for Sustainable Development Symposium, which included discussions on the "Engineering for sustainable development" report.

3.1.6. Governance by Knowledge Services

ICEE provides engineering-education knowledge services for the public by working closely with Xuetangx and the International knowledge Centre for Engineering Sciences and Technology under the auspices of UNESCO. The engineering-education knowledge service platform is a comprehensive, international, and non-profit online platform, which integrates data services, information services, and educational services to help people to obtain various educational resources in a one-stop framework. The platform comprises massive information about engineering education, which includes research literature, policy documents, conferences, academic trends, accreditations, publications, engineering capacity, and online courses.

3.2. The Relevance of Governance Actions to the SDGs

The case analysis indicates that sustainable development is the core value of global engineering-educational governance. There is a strong degree of alignment between ICEE's governance activities and the SDGs. The correlations between the governance actions of ICEE and the SDGs are shown in Table 3.

Table 3. The relevance of the governance actions to the SDGs.

Governance Actions	Global Issues Addressed	Objective of the Actions	SDGs
Governance by the idea of a global engineering-education community	International cooperation on engineering education.	Build a wide and close global network	SDG 17. Partnerships for the goals
Governance by standards	Engineering education reform and innovation	Clarify what is the quality engineering education	SDG 4. Quality education
Governance by accreditation	The mobility of engineers	Quality engineering education-resource-sharing	SDG 4. Quality education
Governance by research	Aligning engineering education for sustainable development	To influence engineering-education policy	All 17 SDGs
Governance by conferences	International exchanges on engineering education	Provide a platform for global network to promote engineering education	SDG 4. Quality education SDG 17. Partnerships for the goals
Governance by knowledge services	Bridge the gap on regional engineering capacity	Promote the quality of engineering education in developing countries	SDG 10. Reduced inequalities

Governance by the idea of a global engineering-education community focuses on the international cooperation over engineering education, which is correlated with SDG 17. It aims to promote the development of engineering education worldwide through strong global partnerships and cooperation. ICEE calls on international organizations, governments, universities, enterprises, industry associations, engineering-education researchers and other stakeholders to build the global engineering education community together.

Governance by standards aims to lead engineering-education reform and innovation, which corresponds closely with SDG 4. The key objective of the standard revision work is to ensure that the new GAPC reflects contemporary values, such as sustainable development, diversity and inclusion, and ethics, and employer needs, as well as equipping the engineers/technologists/technicians of the future with the skills to incorporate the practices that advance the UN Sustainable Goals. The field of engineering education will be changed accordingly to meet the requirements of the new GAPC. This will include, for example, developing new pedagogies, such as problem-based learning, project-based learning, context-based learning, and challenge-based learning to support engineers' role in building a more sustainable and equitable world.

Governance by accreditation stimulated the reform of engineering education in China. This form of governance meets SDG 4. Student-centered and outcome-based education models are adopted in shaping a new version of the development of engineering education in China. Increasing numbers of majors passed the accreditation, which indicates that the quality of engineering education in China is improving continuously and that the internationalization of engineering education is heavily promoted. The international recognition of China's engineering education will motivate the mobility of its engineers overseas.

The objective of governance by research is to align engineering education for sustainable development, which can meet all 17 SDGs. ICEE commits to embedding the SDGs into its research projects. For example, in the second UNESCO engineering report project, ICEE proposed to UNESCO to add a sub-chapter to chapter 5 to reflect increasing interregional trends in engineering and to call for more future interregional cooperation for SDGs. The research projects funded by the Chinese Academy of Engineering focus on a wide range of topics within engineering education and sustainable development. Examples include: "Research on the Demand for Engineering Science and Technology Talents and the Reform Strategy of Education Mode for Sustainable Development in the New Era", "Talent Training Mode and Strategy in Key and Core Fields, such as AI.", "Engineering Education and International Cooperation in Post-Pandemic Era: Challenges and Countermeasures", "Database Construction for Engineering Education Development", "Training Strategy of Engineering Science and Technology Talents under the Carbon Peaking and Carbon Neutrality Goals", etc. These research projects are the basis of evidence-based policy making in engineering education in China.

Governance by conferences focuses on international exchanges on engineering education. It aims to support SDG 4 and 17 by enhancing mutual trust and expanding consensus though dialogue and consultation. The theme of the conferences held by ICEE is improving engineering-education quality and sustainable development. These conferences feature extensive numbers of participants. For example, the first international forum on engineering education was held in 2018, and its theme was "Innovation and Development of Engineering Education"; it focused on the Fourth Industrial Revolution and the innovative developments in engineering education in response to global challenges. More than 150 experts, scholars, and industry representatives from well-known universities, international organizations, academic groups, and enterprises from nearly 20 countries or regions participated in the forum [38]. The second international forum on engineering education was held in 2020, with the theme of "Environment and Sustainable Development", which included topics related to water ecology, climate change, health, sustainable technologies, and engineering education for sustainable development. A total of 1364 participants from 25 countries or regions and 38 institutions participated in the second forum [39].

Governance by knowledge services aims to bridge the gap on regional engineering capabilities, which will be helpful to achieve SDG 10. Based on the knowledge-services platform, ICEE provides micro-diploma online-learning projects for international engineering students from developing countries. Micro-diploma learning refers to a series of online courses that focuses on a certain professional theme; learners can obtain a certification in the form of a short-term project by passing exams based on the courses. From 2017 to 2020, 3,000 learners participated in the micro-diploma online-learning project, and 200 learners passed the exam and obtained the certification. A survey showed that the micro-diploma online-learning project was implemented well and that the international engineering students achieved expected learning outcomes, such as professional knowledge, improved problem-solving abilities, critical thinking, and innovation [40]. Although COVID-19 has led to the closure of large numbers of educational institutions for learners worldwide, this online learning project contributed a significantly to ensuring the sustainability of learning during the pandemic. This kind of high-quality education-resource-sharing bridges the gap in engineering capacity between developed countries and developing countries, which meets the goals of sustainable development.

3.3. The Key Mechanisms of Governance Actions and Challenges

The case analysis shows that collaboration is the key mechanism of global engineering educational governance. ICEE, as a high-level collaboration platform, has built a strong partnership that involves international organizations such as UNESCO and IEA, universities such as Tsinghua, academic consulting institutions such as CAE (Beijing, China), and companies such as XuetangX(Beijing, China). For example, the "Engineering for sustainable development" research project is not only a major academic achievement completed by ICEE in cooperation with UNESCO, but also a successful case of international cooperative research. The report was written and edited by more than 40 authors and multiple editors from over 30 international organizations and universities. The UNESCO Engineering Report is also a key strategic consulting research project of the CAE, with the participation of more than 10 CAE members.

These partnerships have their own advantages in the implementation of the SDGs. International organizations have a natural special-identity advantage. They exist beyond countries but also have close relationships with countries. They represent common human values and interests. International organizations play a key role in promoting the realization of the SDGs. For example, they support Member States in implementing the SDGs, as in UNESCO's action framework and platform for cooperation to promote international cooperation among the 193 Member States. UNESCO's five functions are as a laboratory of ideas, a setter of standards, a builder of capacity, a promoter of international cooperation, and a center of information exchange.

Universities also perform multiple functions, such as talent training, scientific research, social contributions, cultural inheritance and innovation, and international exchange and collaboration, that can provide knowledge and solutions for the implementation of the SDGs. Universities have an unshrinkable responsibility and should become leaders in a sustainable society. Tsinghua University, as a leading engineering university in China, commits to promoting sustainable development, and the implementation of the SDGs in Tsinghua University has achieved remarkable results. For example, in 2020 alone, there were 2317 courses, 20,665 campus events (lectures, workshops, exchanges, and other activities), 408 training projects with 55,557 trainees, and 10,059 patents related to the SDGs at Tsinghua University. Through XuetangX, high-quality engineering-education resources are shared with the entire country, and even the whole world. XuetangX features 62 million registered users and more than 3000 MOOCs. The courses that Tsinghua University provides for XuetangX cover all 17 SDGs.

Companies and engineering education have strong connections with each other. Companies, as employers, have the power to shape engineering education. They contribute to integrating sustainable development into the process of talent training. The China Academy of Engineering is an academic advisory institution for the government, and it has a powerful influence on policymaking. It can also contribute knowledge to the exploration and construction of a new model of global governance. The SDGs are committed to mobilizing the concerted action of multiple subjects to achieve common goals. The strong multilateral partnerships among international organizations, universities, companies, and other parties are the cornerstone of their collaboration. This is the key to achieving multi-agent synergetic governance.

However, collaboration, as the key mechanism of global engineering educational governance, is facing challenges. The diversified partnerships make it difficult to coordinate interests and different opinions, especially when national interests are involved in an international context. For example, there was a problem of map labels concerning territorial integrity in the second UNESCO engineering-report project, and it took significant time for the research team to solve it by using alternative figures to present their findings. When collecting global engineering-education data for the database construction, the problem of missing and inaccessible data arises. The emergence of COVID-19 has led to severe constraints on international exchange and collaboration broadly. As stated in ICEE's research reports, the epidemic will change the world structure and international situation; the competition in science and technology between countries is becoming tougher, and the mobility of international students in the science, technology, engineering, and mathematics (STEM) fields is restricted much more than before.

4. Discussion

There is a good range of typologies of global engineering educational governance for sustainable development. Overall, whether it is the proposal of the concept of an international engineering education community, the formulation of engineering education standards and the accreditation of engineering-education quality, research that serves evidence-based engineering-education policy making, conferences that provide platforms for cooperation network, or knowledge services aiming to bridge the global engineering-education development gap, the objective of these governance actions is to achieve the 17 goals of sustainable development by reshaping engineering education.

The governance activities discussed in this study can be divided into two categories. One is formal governance, which includes governance by standards and accreditation. The other is informal governance, which comprises governance by ideas, conferences, research, and knowledge services. Formal governance contributes to reshaping global engineering education through rules made by international organizations, and it requires governor to be official members of the accord or the agreement. Formal governance has a direct impact and greater binding force on the future development direction of engineering education and the improvement of engineering-education quality. Compared to formal governance, informal governance is an indirect approach to influencing the development of engineering education, which is also called soft governance or flexible governance. However, these governance activities face challenges to their implementation. For example, formal governance by standards and accreditation causes issues in the combination of internationalization and localization. Regulative and normative institutional pressures influence the decisions of engineering schools by requiring them to take visible action to demonstrate their conformity with global norms, while still pursuing local missions [41]. Informal governance by research faces the challenge of how to improve the mobility of scientific knowledge to expand its influence on policy making.

Diversified governance implies complex engineering-education issues and reflects the connections between the SDGs goals. It requires that entities adopt comprehensive and coherent strategies to deal with these issues. The governance activities described in this paper have different focuses. Governance by the proposal of building a global engineering-education community emphasizes the importance of collaboration in aligning engineering education and sustainable development. Governance by standards and accreditation introduces sustainable development into the assessment of engineering education quality and enhances the mobility of engineering students or engineers all over the world. Governance by research places particular emphasis on providing evidence for engineering-education policy makers. Governance by conferences stresses communication and information exchange in shaping engineering education. Governance by knowledge services focuses on higher-quality engineering-education resource-sharing. All these governance activities form a close governance network, which aims to deal with engineering educational issues precisely.

The case suggests that ICEE is an active participant in global engineering-education governance. This role is rooted in the following facts. China has promised to take the post-2015 development agenda as its mission, and work with others to promote global development. To guide and promote the implementation of the SDGs, China has formulated and issued a series of guidelines and policies to achieve the goals of sustainable development, which has included the following actions: issuing China's National Plan on the Implementation of the 2030 Agenda for Sustainable Development; the implementation of the SDGs has been embedded in the 13th Five-Year Plan, the 14th Five-Year Plan, and the national medium and long-term development strategy; and the Scheme of Constructing Innovation Demonstration Zone for implementing the 2030 Agenda in China was issued, and the Zone was established. As a responsible large developing country and a permanent member of the United Nations Security Council, China will stay committed to the implementation of the SDGs and integrate sustainable development not only with local development, but also with global development. China will always be a builder of world peace, a contributor to global development, and a defender of the international order. In this context, China, as an important participant, plays an active role in the global engineering educational governance [42]. The governance activities described in this research indicate that China has multiple roles in global engineering-education governance. These roles include the development of engineering education worldwide, contributing new approaches to the development of global engineering education, defending international engineering-education standards and rules of accreditation, providing high-quality engineering-education resources for the whole world, and constructing a collaboration-and-exchange mechanism for developing partnerships in engineering education.

The acceleration of the progress toward achieving the SDGs all over the world is the significant effect of ICEE's participation in global engineering-education governance. ICEE's governance activities meet the expectations of the commitment to implementing the SDG-acceleration actions, which were proposed at the 2019 SDG summit. Because of the COVID-19 pandemic, t progress towards the SDGs has slowed and become more challenging, according to the 2020 and 2021 SDG progress reports. The global community needs to unite more than ever and develop strong partnerships to ensure that no one is left behind. This is why China has to participate in global engineering-education governance. The experience of ICEE's participation shows that the multi-agent synergetic governance model, which involves international organizations, universities, companies, academic consulting institutions, and other entities, could enhance governance efficiency by developing a comprehensive and coherent strategy. Although this model of collaboration is facing challenges, this multi-agent synergetic-governance model provides a new path for building partnerships and accelerating progress toward the SDGs.

5. Conclusions

This research presents the image of China's participation in global engineering-education governance by mapping the governance activities of a typical case: ICEE. There is a good range of typologies of global engineering-education governance for sustainable development. The impact of ICEE's participation proves that the multi-agent synergetic governance model could enhance governance efficiency by designing a comprehensive and coherent strategy that contributes to accelerating progress toward achieving the SDGs. This research can help the global community to develop a full and deep understanding of China's participation in global engineering-education governance. However, the challenges described in this research have not been solved; this is the limitation of this research. Further research on global governance and the SDGs should address the fundamental imbalance in power and resources between countries [43].

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education sciences

Article

Key Aspects of Adolescents' Environmental Attitudes with a View to Transformative Education

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Abstract: The aim of this study is to gauge the environmental attitudes of adolescents in order to improve environmental education plans. To this end, the Attitudes Towards the Environment validated survey was applied to 346 adolescents (51% boys and 49% girls, mean age = 15.05) at secondary schools in Cordoba (Spain). A factor analysis (FA) was carried out using the FACTOR program, obtaining three factors: emotional, cognitive, and behavioral. The results of the FA exhibit excellent internal consistency, with an Omega coefficient of 0.916 and Cronbach's Alpha of 0.915, and adequate goodness of fit. The emotional factor results are good, as concern and responsibility towards the environment were notable. However, this did not translate into motivation to obtain further knowledge or to become involved in collective civic actions. The findings in this line give us information to review educational objectives and methodologies, for which emotional education is essential. Elements are proposed to encourage adolescents to adopt more proenvironmental attitudes so that the development of environmental awareness and concern in them is not undermined by frustration, and so that peer learning is present through dialogue and cooperative work, promoting an affinity for nature and the motivation to participate in collective civic activities.

Keywords: sustainability; adolescence; environmental education; ecological perspective; environmental attitude; formal education; nonformal education

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1. Introduction

One of the objectives of environmental education, according to Boyes and Stanisstreet [1], is to enable people to make informed decisions about their environmental behavior in order to protect the environment and nature. Since the 1970s, following the agreements contained in the Belgrade Charter, the result of the first International Seminar on Environmental Education, in 1975, new paradigms have been developed involving educating and enabling the public to make decisions allowing them to live in harmony and solidarity with everything around them and, according to the Treaty on Environmental Education for Sustainable Societies and Global Responsibility (Rio de Janeiro 1992), "Environmental Education is a political act, based on values, for social transformation" [2].

The Tbilisi declaration expounds that "Environmental Education must adopt a holistic perspective which examines the ecological, social, cultural and other aspects of particular problems. It is therefore inherently interdisciplinary" [3]. Our curricula often reflect archaic ideas about how the world should be, or used to be, rather than how it is today. It happens particularly with the climate destruction and the urgent need for environmental conservation [4]. Therefore, a transformative education that introduces new pedagogical elements in educational processes is necessary. Transformative education is based on learning "that aims to transform our existential understanding of humanity, including interrelationships both among humans and between humans and non-humans and the fundamentals of wellbeing" [5] (p. 1588). Ecopedagogy is one of the different pedagogies of transformative education, action-oriented through democratic dialogue to understand how environmental problems oppress the whole planet [6]. This way of understanding the world implies that environmental education, in a social context of crisis and continuous change, requires a multidisciplinary worldview. Bonil et al. [7] incorporate the principles of complexity theory into environmental education. The first is the systemic principle, according to which "the world is comprised of a large multidimensional network in which there are continuous relationships between elements located at different scales" [8] (p. 201). The second is the dialogic principle, which brings together apparently antagonistic elements to understand the complexity of systems, and the third is the hologrammatic one, which emphasizes the system's internal interaction.

The process of environmental awareness proceeds from this multidimensional vision and includes the affective dimension, composed of beliefs and values; the dispositional dimension, which represents personal attitudes; the cognitive dimension, where information and knowledge appear; and the active dimension, which has to do with proenvironmental behavior [8]. Along this line falls the concept of sustainability, where environmental and social justice issues are related [9]. According to Gericke et al. [10], sustainability is awareness of environmental phenomena produced by personal experiences, perceptions, beliefs, feelings, and actions [11].

This worldview and dimensions lead us to believe that environmental awareness is continuous, as reported by Kautish et al., and features different subscales, with its construction being based on three fundamental cornerstones [12]: knowledge, attitudes, and behavior [10,11]. When planning environmental education, the interrelation of subscales and dimensions must be taken into account. Some subscales with an important role are social approval for performing, or not, certain actions; belief in the efficacy of a behavior [13], concern, perception; and the intention to perform an action. Many studies conclude that awareness and concern for the environment are not necessarily reflected in conservationist behaviors, while emotional activity can influence them [14]. Others show that there is a gap between knowledge and proenvironmental behavior [15]. In addition, conduct may be more or less demanding in terms of modifying lifestyle patterns and, depending on the ease and comfort of modifying one's behaviors, it may be more likely to be carried out [1].

Often, attitude and willingness to perform a certain action are measured. Attitude influences the individual's behavior [16] and has often been used as an indicator of it. These values are determined by the biocentric dimension related to conservation, environmental protection, and risk control (preservation), and by the anthropocentric dimension, related to the use of natural resources (utilization) and associated with high-risk behaviors [17].

The active dimension is also measured from different angles. Action, from complexity theory, is defined as a method–strategy that is constituted as a continuous dialogue between theory and action [3]. As per Alisat et al. [18], often the term "behavior" is related to personal practices, but "taking action" goes a step further and is associated with participation in collective actions. Indeed, people who take collective action tend to have a strong environmental identity, with the environment playing an important role in their lives and constituting the motivation for their actions [19].

In studies on proenvironmental perception and behavior, behavioral intention is considered more than actual behavior [20]. Environmental perception consists of values and attitudes towards our natural environment and influences decisions to perform certain actions [21] and, thus, one's proenvironmental behavior [22].

A multitude of tools have been developed that measure different scales. They can be examined in greater depth in the literature review by Mónus [20]: connection with nature and environmental identity; selfish, altruistic, and biospheric value orientation; feelings and behavioral intentions; the subscales of affection and verbal engagement; environmental regulation; awareness of consequences; and many more. Although there is a wide variety of scales, there is no consensus as to which tools to use to measure meaningful environmental behavior [23], ecological behavior, or environmental actions. Some examples of widely used tools [20] are the New Ecological Paradigm; its revised version, the New Environmental Paradigm [24]; and the Ecological World View. NEP is especially useful for adults [25,26] and for environmental perception in children [27,28]. Other studies have evaluated the relationship between NEP and 2-MEV items in adolescents ages 10–16 [29,30].

Age and gender are sociodemographic factors that influence proenvironmental behavior. In fact, adolescents' climate change awareness can influence that of their families and friends, as shown in a study by Hiramatsu et al. [31], and vice versa [32]. Boyes and Stanisstreet [1] study how the cognitive basis is reflected in various behavioral factors, being potentially affected by education, concluding that there are students who perform actions when they are confident of their effectiveness in terms of environmental improvement. This is not true of all types of actions, however, as Rodriguez et al. [33] found that students aged 12 to 16 are willing to change habits when this is relatively easy, but not when the actions are more demanding [34]. There is a potential danger if environmental-awareness-raising begins before the receptivity stage, as people may suffer from environmental fatigue [35]. In relation to gender, girls have better scores than boys [36]—for example, in relation to environmental concern and believing in the effectiveness of actions [37], greater awareness of biospheric and altruistic values [38], and performing proenvironmental actions daily [1].

There are numerous environmental actions carried out in the educational field, but due to the specific context of this research, the educational innovation program called ALDEA, in which the educational centers of the study participate, is noteworthy. It is an environmental education program for the educational community developed by the Ministry of Education and Sports and the Ministry of Agriculture, Livestock, Fisheries, and Sustainable Development of the Junta de Andalucía. Its aim is to promote the integrated development of environmental education initiatives in the face of the current climatic emergency situation, the connection with nature and renaturalization of spaces, climate change, sustainable development, and the relationship between human beings and their social and natural environment that takes place in the educational centers of the city of Córdoba that have participated in this study [39]. Although this study does not intend to assess educational programs as ALDEA, some recurring obstacles can be highlighted, such as the lack of human resources and lack of time to develop it with quality.

As we have seen, attitude is a determining factor in environmental behavior, and its improvement should be an essential component of education. Thus, the aim of this study is to assess how the different components of environmental attitude influence secondary school adolescents, in order to improve environmental education plans and promote sustainability in formal and nonformal settings according to the most influential factors within the educational context. Regarding the serious environmental crisis, this type of research is essential for facing the current problems. In this sense, the study is focused on the near future, because knowing the environmental attitude of youths allows improving their education. These results will help to shape not only educational plans, but also the way environmental problems are conveyed and addressed, and the role of young people in their resolution.

2. Materials and Methods

2.1. Instrument

Based on the different variables and components mentioned above, this study will employ an instrument to evaluate the environmental attitudes or dispositional dimension [40] of young adolescents based on the concept of attitude advanced by W. Thomas and F. Znanieck in their work "The Polish Peasant in Europe and America", according to which the socioaffective component is composed of three factors [41–43]: the ideological or cognitive—that is, what is thought, ideas, knowledge, and convictions; the affective–emotional, which reflects concern for the environment; and the reactive–behavioral, or conative, related to action and thinking for or against, according to a personal norm in which responsibility for environmental problems is assumed and considered essential to take action. It also includes self-efficacy, regarding the ability to take actions to solve problems [44].

These three cornerstones of the socioaffective component coincide with the theory of complexity advanced by Bonil et al. [3] and what happens in the teaching–learning processes in science according to Sanmartí et al. [45], who posit that meaningful educational actions occur when the three dimensions are integrated and interconnected: what is done, thought, and felt.

The questionnaire designed and validated by Terrón et al. [46] was used to measure attitudes towards the environment in adolescents. It is a scale with 18 Likert-type items with five options: Don't agree/Never (1), Slightly agree/Almost never (2), Somewhat agree/Sometimes (3), Strongly agree/Quite a lot (4), and Totally agree/Always (5).

This scale was chosen because it meets the requirements of our study's population: designed for adolescents, written in Spanish, manageable number of items, and including both formal and nonformal situations ranging from personal to collective actions.

2.2. Sample and Data Collection

The sample comprised 346 people, 51% boys and 49% girls, aged 14, 15, and 16, with their respective percentages being 25%, 45%, and 30%. Data collection was carried out online in some classes, and in person in others, depending on the availability and preference of each school. The participants and school staff were informed and gave their informed consent before participating in the study.

2.3. Factor Analysis

The creators of the instrument [46] indicated the possibility of considering it unidimensional. They found five factors, but acknowledged their inconsistency and suggested that, in future research, empirical validity should be assessed using other factor analysis tests. Therefore, a semiconfirmatory FA was performed, applying ULS and direct Oblimin rotation, using the Factor program. After an analysis of goodness of fit, factor weights, and taking theory into account, we chose the three-factor model. The degree of adequacy for the factor analysis represented by the KMO was very satisfactory, with a value of 0.904, and with optimal internal consistency values—the Omega Coefficient being 0.916 and Cronbach's Alpha being 0.915. In addition, the distribution of items in three factors exhibits adequate goodness of fit. Table 1 shows the value of the factorial weights of each item. In the case of items 11 and 18, they are assigned to the factor whose factor weight is higher despite being included in other factors. However, item 17 is assigned to factor 3 for having theoretical coherence, although its factorial weight is lower. The distribution of items in three factors presents definitions of adequate goodness (GFI = 0.993; CFI = 0.991; NNFI = 0.990; RMSEA = 0.039 (0.0309–0.0396); RMCR = 0.0429).

Table 1. Results of the weights of the variables and the explained variance of each factor. The weights in bold are greater than 0.3 and assigned to the factor.

Items	F1	F2	F3
1. I wish there was a course on the environment in my academic program.		0.693	
2. I really want to participate in a class discussion about environmental conservation		0.466	
3. Working on a team in an environmental conservation activity makes me feel important.		0.521	
4. I would like to learn about the environment in all my courses.		0.821	
5. I wish more environmental conservation topics were covered in class.		0.725	
6. I think that more measures should be taken at my school in favor of environmental conservation.		0.330	
7. I like to learn through nature outings.	0.301		
8. It bothers me, during these outings, when litter is left outdoors.	0.639		
9. I would like to join an environmental conservation club or association that meets outside of class.		0.528	
10. I like to watch nature documentaries on television.			0.610
11. I would participate in a demonstration in favor of the environment.		0.307	**0.393**
12. I like to talk about the environment with my parents.			0.704
13. Nature conservation is one of my favorite topics.			0.732
14. I am concerned about the destruction of the environment.	0.838		

Table 1. *Cont.*

Items	F1	F2	F3
15. I admire volunteers who work for the environment.	0.576		
16. I feel responsible for environmental deterioration.	0.439		
17. Obtaining information about the environment is something I enjoy.	0.738	0.447	**0.384**
18. My behavior can help to improve the environment.	**0.603**	0.306	0.379

The development of the factors is balanced. Factor 1, the affective–emotional component, groups variables on civic, individual, and other people's actions, where feelings are generated in relation to environmental concern and responsibility. Environmental emotion is intrinsic to environmental concern, whose development predicts environmental behavior [47,48]. Factor 2, the cognitive component, includes items that define knowledge motivation actions in the formal sphere. This is acquired through different social agents to learn about environmental problems and act in an environmental way. Factor 3, the reactive–behavioral one, includes items on behavioral intention, defined as the willingness to perform an action, considered as the main predictor or the variable immediately preceding [42] a given behavior.

3. Results

The mean response for each item, as shown in Table 2, demonstrates a great diversity of results. First, the standard deviation is greater than 1 in all cases, which indicates that there is great heterogeneity in the responses, such that the mean is indicative but not conclusive.

Table 2. Descriptive statistics and reliability measures.

Items	M	SD
F1. Emotional and affective. Alpha = 0.80; Omega = 0.80.	**3.87**	**0.12**
7. I like to learn through nature outings.	3.67	1.16
8. It bothers me, during these outings, when litter is left outdoors.	4.13	1.04
14. I am concerned about the destruction of the environment.	4.10	1.02
15. I admire volunteers who work for the environment.	3.95	1.12
16. I feel responsible for environmental deterioration.	3.02	1.13
18. My behavior can help to improve the environment.	3.74	1.11
F2. Cognitive. Alpha = 0.84; Omega = 0.84.	**3.19**	**0.10**
1. I wish there was a course on the environment in my academic program.	3.17	1.06
2. I really want to participate in a class discussion about environmental conservation.	3.03	1.16
3. Working on a team in an environmental conservation activity makes me feel important.	3.03	1.12
4. I would like to learn about the environment in all my courses.	2.65	1.12
5. I wish more environmental conservation topics were covered in class.	3.21	1.03
6. I think that more measures should be taken at my school in favor of environmental conservation.	3.47	1.05
F3. Reactive and behavioral. Alpha = 0.83; Omega = 0.83.	**2.69**	**0.12**
9. I would like to join an environmental conservation club or association that meets outside of class.	2.19	1.06
10. I like to watch nature documentaries on television.	2.66	1.30
11. I would participate in a demonstration in favor of the environment.	2.60	1.32
12. I like to talk about the environment with my parents.	2.59	2.45
13. Nature conservation is one of my favorite topics.	2.54	1.19
17. Obtaining information about the environment is something I enjoy.	2.97	1.16

With the SPSS Statistics 25 program, we analyzed the data in search of significant differences in the gender variable according to the factors. Based on the Kolmogorov–Smirnov test, the distribution of the sample is normal, but the Levenne test indicates that the data should be considered nonparametric. The results show that there are significant differences in the three factors and that girls had better scores.

To conduct a more exhaustive analysis of the significant differences, we performed the same operations taking all the items. Significant differences occur in 9 items, equally distributed between the three factors, with girls having better results than boys in all the items except number 10. In Factor 1, the items deal with environmental concern (Item 18), admiration for other people who protect the environment (Item 15), and awareness of personal responsibility for environmental deterioration (Item 16). In Factor 2, the significant differences are found in Items 1, 4, and 5, where the desire to work more on environmental issues in the subjects is expressed. Finally, in Factor 3, Item 10 appears, where boys have a better score than girls, which refers to enjoying watching documentaries on television. The greatest difference is found in Item 11, F3, indicating that girls are more willing than boys to participate in demonstrations.

4. Discussion

The environmental attitude questionnaire in adolescents offered by Terron et al. [46] was replicated in the city of Cordoba with a similar sample size, but it is not possible to make major comparisons with respect to the original questionnaire for several reasons. The first is due to the factor analysis method used, and the second is because the study focuses on the Item Response Theory (IRT) developed by George Rasch [49].

The semiconfirmatory analysis carried out with the FACTOR program yielded three factors in tune with the socioaffective component on which the survey is based. The variables that predict a person's ecological behavior are knowledge, concern, values, and behavioral intention [34,50,51]. Transformative learning goes beyond the development of the mind [52]. In fact, critical thinking is related to the concept of "reflective learning", made up of three components: "identify and challenge assumptions; be aware of how context influences thoughts and actions; and develop and explore alternatives to existing ways of thinking and living" [53] (p. 257).

The affective component in relation to environmental responsibility and concern presents good numbers, constituting a good starting point, since once the affective system is activated, preventive action is much more likely [54]. Despite this, and the fact that many studies have shown that emotions play a central role in behavioral decision-making [55], this fact is not reflected in educational interest, and even less in behavior, confirming that knowledge is not the only element that influences environmental action [56]. Furthermore, [57] report that there is a slight decline in social responsibility values among adolescents. The reason for this disconnect between the affective, cognitive, and behavioral aspects is worth pondering. To do so, we will delve deeper into the subscales present in the factors.

The emotional factor includes items related to activities in nature and the emotional reaction generated by seeing deterioration wrought by other people. In relation to well-being in nature, some studies have shown a link between positive experiences in nature during childhood and proenvironmental attitudes [58]. This could be an element that also influences adolescents. Along this line, the findings of Krettenauer [59] confirm that proenvironmental attitudes and behaviors in adolescents improve with increasing exposure to and contact with nature. Yanniris [60] confirms the link between contact with nature and outdoor experiences during childhood with the environmental concern of adults. Meanwhile, evaluative emotions towards others, such as anger or indignation when seeing others violate a moral norm, are strong predictors of proenvironmental behavior. In addition, young people are receptive to other people's attitudes and behaviors towards the environment [61].

The environmental attitude survey focuses on the cognitive factor in the formal sphere: environmental courses, mainstreaming environmental issues in all subjects, teamwork in nature activities, etc. In this aspect, transformative learning reaches the deepest levels of knowledge to give way to transformative action that helps to achieve the Sustainable Development Goals [62]. Taking into account that today's students live in an era of globalized digitalization, schools must incorporate these sources and media (mass-media, social networks, etc.) where much of the information and knowledge is stored and accessed [61,62]. Transformative learning involves our understanding of our relationships with other humans and with the natural world [63,64].

The last component is behavioral. The action dimension, essential in transformative learning, implies the development of informed choices at personal, social, and political levels [65,66]. In other studies, it has been common to refer to proenvironmental actions that are carried out on a daily and individual basis. However, the Attitudes Towards the Environment survey that we applied focuses, on the one hand, on the motivation to learn formally, and, on the other, on voluntary participation in collective associations or actions. In the first place, there is a limited tendency to search for information, interest in discussing environmental issues outside the school environment, or in talking about environmental issues with their families. This fact is negative since the interpretation of the problem is the initial phase of the decision to seek information [67]. Thus, these data indicate a low-risk perception of environmental problems, and perception of risk is an element precipitating behavioral change [68], including, specifically, information seeking. Expanding information and knowledge contributes to awareness of the future impacts of current actions and is a key step to realizing that current actions and policies have long-term environmental consequences [54]. It is valuable to consider the findings of Mead et al. [69], who observed that adolescents who perceive grave risks due to climate change are more likely to seek information on their own than those who do not, and that parental influence is also key. In this regard, it is noteworthy that the only item where boys had higher scores was, precisely, motivation arising voluntarily to continue their education. However, environmental understanding does not translate in a simple way into an emotion that, in turn, generates action [70]. Students do not always understand the effectiveness of actions [71] or are not prepared to understand their impacts on health [72]. Sometimes, the actions proposed cannot be carried out by those in the age ranges in question, as the capacity to perform them has not been developed. In the words of [71], there is a risk that too much exposure to discouraging issues such as global warming may generate feelings of helplessness and demotivation to act for change [73]. A transformative pedagogy should contribute to the development of analytical skills related to the context of students [54]. At the beginning, we mentioned environmental fatigue in education, which may be related to the low scores in Factors 2 and 3; hence, highlighting the importance of educating students in how to use the media so that their learning contributes to a critical, selective, and active reception of all the information they receive through mass media.

In relation to the second focus of the behavioral component, the lowest figures were, precisely, on items involving civic behaviors that promote collective efforts with higher-profile actions and, therefore, ones of greater social cost [18]. While critical thinking and reflection is an essential prerequisite for transformative learning to occur, it is not by itself sufficient unless it results in transformative, sustainable, and responsible action [64]. Sometimes, the actions proposed cannot be carried out by those in the age ranges in question, as the capacity to perform them has not been developed. In the words of [71], there is a risk that too much exposure to discouraging issues such as global warming may generate feelings of helplessness and demotivation to act for change [70]. The contrast between the respondents' support for actions led by others, such as volunteer work on conservation issues, with a mean of 3.95, clashes in a striking way with participating directly in a demonstration, at 2.60, or being part of an association, which had the lowest score of 2.19. The greatest difference between genders came in one of the three items with the lowest scores: participating in a demonstration, where the score was 0.62 higher in girls. A study of the young Russian population found that although the majority indicated that environmental problems are acute and that the environmental situation in their city is worse than that of others, many were not willing to take responsibility for proenvironmental practices [64]. Although, as we have already mentioned, women tend to present better results in terms of their civic attitudes. In the same study by Shutaleva et al. [64], young women tend to think that everyone must comply with environmental standards. Tindall et al. [74] analyzed the contradictory effects, deducing that women are more participative, concerned, and committed, but are more limited by gender roles, restricting their activism.

Environmental activism [75] is a subtype of environmental behavior [23]. In fact, as Walsh [6] affirms that relational approaches to transformative education—in addition to advancing transformative learning—are key to supporting social justice goals. In contrast to this idea, other findings analyze how "individual characteristics are better predictors of proenvironmental behavior than environmental activism" [75] (p. 184). Nevertheless, according to Curtis, "students are learners, consumers, and citizens, and thus potential activists, able to mobilize political action to advocate for a cleaner environment and fairer societies" [76] (p. 10). Along these lines, Clayton [19] perceives that change happens individually, by performing individual acts. Dono et al. [75] call this type of action "personal practices", entailing an individualization of the problem [18]. However, the importance of encouraging activism should be emphasized since collective actions play a key role in tackling environmental problems by combining a series of specific skills and abilities by which the individual becomes environmentally engaged [75]. International volunteering programs of proenvironmental practices seem to be effective since they can positively influence the acquisition of behaviors such as the habit of separating waste in Cambodian students after volunteering on environmental cleanup in another country [77]. Continuing with the idea of collectivizing actions, it should be taken into account that young people may feel overwhelmed by the difficulty of solving distant and complex environmental problems individually [78], and participation in collective forums channels this frustration. One way to enhance civic action is through education in media usage, especially the digital realm [79], as this can foster the development of competencies crucial to active, engaged, and participatory citizenship.

Therefore, any educational plan must contemplate civic collective actions that promote environmental activism. In this regard, the findings found by Robinson et al. [28] confirm the importance of emotional intelligence in young people in relation to proenvironmental behavior and attitudes, being much higher in adolescents able to manage, identify, and control their own and others' emotions. They conclude that the role adolescents will play in the management of environmental problems as part of an active, decision-making populace is of vital importance, with the connection between proenvironmental attitudes and behaviors during this stage of evolutionary development being very important. Therefore, in addition to promoting critical thinking, students should also be encouraged to have heartfelt and sincere experiences, enhancing skills and values such as affection and empathy [80].

On the other hand, the objective of experiential learning [60] puts the focus on the students' experience in finding solutions to real-life problems that affect local communities and is more effective in changing behaviors than knowledge-based learning. Further, Mezirow [81] defines transformative learning as problem solving by "defining a problem or by redefining or reframing the problem." In this aspect, "the importance of keeping the local, but recognizing the global, is also an integral part of ecopedagogies" [5] (p. 9). Environmental education today plays an influential role in harmonizing the relationship between people and nature as a path for the survival of humanity [66]. Carmi et al. [56] suggest that, to foster environmental sensitivity, it is important to act in nonformal settings, while Stevenson et al. [82] cite the presence of other factors to encourage adolescents to expand their knowledge of climate change and invoke Vygotsky's theories to highlight the importance of generating informal learning forums, such as discussion groups or group project work, where interaction between students encourages dialogue and debate, with learning being more effective in this way than with direct instruction by teachers.

The interdisciplinary nature of Environmental, Sustainability, and Global Citizenship Education is a challenge to the current educational system where the curriculum is organized into subjects that require "a kind of education that would encourage interdisciplinary cooperation and synthesis in its teaching and learning practices." [60] (p. 8). As Odell et al. indicate [52], an element of transformative learning is questioning the frameworks in which education operates and aligns with the elements of transformative learning.

5. Conclusions

The improvement of environmental attitudes in adolescents is an educational challenge; so, it is necessary to reconsider our methodologies and perspectives through which to generate transformative educational processes. To this end, it is important to take into account the affective component through a more heartening presentation of the actions that can be carried out, both at a personal level and as a society. The analysis carried out of young adolescents' attitudes towards the environment at secondary schools in the city of Cordoba offers some conclusions in this regard.

This research study concurs with the findings of other studies containing arguments asserting the importance of exposing youth to these problems and solutions, showing them how they are related to their lifestyles and how change improves their leisure time, health, and peer relationships. It is important to promote knowledge and awareness of environmental issues. Acting in one's immediate environment constitutes an opportunity for youth to appreciate their transformative power regarding environmental issues. This points to the need for educational interventions to link environmental commitments to their personal daily, lives—that is, not only formal settings, but also nonformal and informal ones. Combined with this idea, it is essential to carry out more activities in nature, integrating them into relationships between peers to make them socially rewarding.

We conclude by pointing to the importance of some elements that should be taken into account in future transformative environmental education interventions. Firstly, incorporate external educational agents in the formal sphere. This translates into, on the one hand, the greater prevalence of extracurricular activities, educational programs, and/or awareness campaigns by other social agents within schools where the formal and nonformal spheres complement each other and serve as support when it comes to achieving the objectives of the programs, dedicating more time to it, but in a shared way with the teaching staff and other institutions. On the other hand, this leads to incorporating activities with families through school groups such as PTAs and alumni associations, etc., which can also come from the agents mentioned above. Secondly, encouraging group work, debates, and forums for dialogue among equals, both inside and outside the classroom. This entails carrying out more experimental and experiential teaching–learning processes, with global analyses of the environmental situation, but seeking local solutions that can be developed by the students in a participatory, collective, and open-air way. Finally, emotional education should be considered in a transversal way, as it prevents possible frustration in the face of the potentially overwhelming environmental challenges of today and tomorrow, so that people can avoid resignation and channel their energies into transformative, collective actions, keeping in mind the idea of transformative education: "think globally, act locally". The aim is to turn frustration and indignation into motivation to find alternatives that can be carried out by young adolescents in their daily lives and to encourage youth to organize and become transformative agents. In short, the aim is to promote community schools open to different socializing and influential agents in adolescents' educational processes, establishing communicative and educational strategies in relation to environmental problems, avoiding paralyzing catastrophism and encouraging transformational attitudes.

Once the methodological keys to improve environmental education for adolescents are known, it is necessary to review and evaluate the scope of environmental education programs specifically in order to integrate improvements and to give continuity to the achievements.

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Research on the Current Situation of Employment Mobility and Retention Rate Predictions of "Double First-Class" University Graduates Based on the Random Forest and BP Neural Network Models

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Abstract: The economic development of various regions is influenced by high-quality population mobility. The research object of this article is the employment mobility data of "Double First-Class" university graduates from 2014 to 2019; the subsequent analysis is based on these data. First, this paper summarizes the current state of university graduates' employment mobility. Second, this paper employs the fixed-effect model and PCA method to conclude that economic factors are the primary factors influencing university graduates' employment mobility. Finally, based on the nonlinear, small sample, and high-dimensional characteristics of university graduates' employment mobility data, this paper employs the random forest and BP neural network methods to build a prediction model for university graduates' employment retention rate. The results show that the BP neural network model outperforms the random forest model in terms of prediction accuracy. The BP neural network model can accurately predict the employment retention rate of "Double First-Class" university graduates, which can guide the reasonable mobility of university graduates and provide a reference for government universities and individuals to make decisions.

Keywords: double first-class; random forest; BP neural network; prediction; graduates; university; employment; mobility

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1. Introduction

Since China implemented the university entrance examination policy to increase enrollment, a growing number of people have obtained a higher education. The rapid expansion of higher education, in the context of increasing privatization of education, does not necessarily increase upward mobility in society but rather increases educational inequality. In China, the mismatch between higher education and the labor market, as well as social mobility stagnation, are common [1]. The labor market in China is marked by structural contradictions; supply-side reforms have resulted in a large number of job transfers; scientific and technological progress has influenced the labor market, and rising labor costs have stifled labor demand and employment quality. University graduates are much more mobile than non-university graduates, a difference partly because university graduates are more sensitive to employment opportunities in other fields [2].

Give priority to the development of education, accelerate the construction of first-class universities and first-class disciplines, and realize the connotative development of higher education, according to the report of the Communist Party of China's 19th National Congress. Simultaneously, it is necessary to eliminate the flaws in the system and mechanisms that impede labor and talent mobility, so that everyone has the opportunity to realize their development through hard work. The disparity in regional labor force quality is a significant factor influencing the uneven development of regional economies [3].

According to the human capital theory, high-quality human capital is the core element that affects the development of the industrial structure, which in turn affects the development of the entire economic level. This paper studies the employment mobility of high-quality human capital, which has guiding significance for economic development.

Push and pull theory is one of the important theories used to study floating population and immigration. It believes that in the case of the market economy and free population mobility, the reason for population migration and immigration relocation is that people can improve their living conditions through relocation. Thus, the factors that improve the living conditions of immigrants in the inmobility areas become the pull force, and the unfavorable socioeconomic conditions in the outmobility areas become the push force. Population migration is accomplished under the combined action of these two forces. What factors will affect the employment migration of university graduates, and what trend will the employment migration of university graduates show in the future: these are all issues worth exploring.

Combined with previous research results, this study further improves the related research in terms of research objects, research methods, and research ideas. First of all, the research object of this study is the employment geographical mobility of graduates from 147 "Double First-Class" universities. Graduates of "Double First-Class" colleges and universities belong to high-quality human capital, and the mobility of high-quality human capital is the core factor affecting economic development. This study further refines the classification of high-end talents, filling the gaps in this research field. Secondly, this paper uses the method of econometrics and the method of PCA to analyze the influencing factors of the employment mobility of "Double First-Class" university graduates and draws consistent conclusions. Finally, in terms of research ideas, this paper first analyzes the characteristics and influencing factors of the employment mobility of "Double First-Class" university graduates, and then uses 22 influencing factors to conduct a comparative study of the prediction methods. The employment retention rate in this paper refers to the proportion of graduates from "Double First-Class" colleges and universities who remain employed in the places where they are studying.

This paper creates a database of university graduates' employment mobility based on the principle of data availability using the employment quality report data of "Double First-Class" university graduates in 26 provinces from 2014 to 2019. This article attempts to answer the following questions: What is the current status of employment mobility for graduates from "Double-First-Class" universities? What factors affect the employment mobility of graduates from "Double-First-Class" universities? The article normalizes complex data and uses PCA to reduce the dimensionality of multidimensional data. Comparing the random forest and BP neural networks, which method can more accurately predict the retention rate of "Double First-Class" university graduates?

The research results show that there are regional differences in the employment mobility of graduates from "Double First-Class" universities. Graduates from economically developed regions tend to stay in local employment, and graduates mainly move into the eastern regions for employment. Economic factors and educational factors are the main factors affecting the employment mobility of graduates from "Double First-Class" universities. Finally, through a comparative analysis of the prediction models, it was found that the PCA-BP neural network can more accurately predict the employment retention rate of "Double First-Class" university graduates.

The structure of this paper is as follows: Section 2 presents an overview of the related literature. Section 3 describes the current situation of employment mobility of graduates from "Double First-Class" universities. Section 4 discusses the factors that affect the employment mobility of graduates from "Double First-Class" universities. Section 5 uses PCA to reduce the dimensionality of the complex data, and then compares and analyzes the random forest and BP neural network methods to reveal which method can more accurately predict the retention rate of graduates' employment mobility in "Double First-

Class" universities. The final section summarizes the research results and provides policy recommendations.

2. Literature Review

This paper compares and analyzes the random forest and BP neural network methods for predicting the employment retention rate of "Double First-Class" university graduates in 26 provinces and cities.

2.1. The Connotation of "Double First-Class" Construction

"Double first-class" construction is another key construction project implemented by China in the new era of higher education development after the "985 Project" and "211 Project" [4]. First-class universities and disciplines of the world are referred to as "Double First-Class". There are 137 "Double First-Class" universities in the first batch, including 42 world-class universities (36 in class A and 6 in class B) and 95 world-class discipline universities. The "Double First-Class" construction is predicated on the development of first-class disciplines. The foundation of first-class disciplines is superior discipline knowledge, and the foundation of discipline development is human creativity. First-class disciplines have outstanding academic leaders and teams, adequate academic funding, and advanced scientific research equipment, as well as outstanding academic accomplishments and talent development quality. First-class universities and first-class disciplines are critical drivers of knowledge discovery and scientific and technological innovation, a source of advanced ideas and excellent culture, a foundation for cultivating all types of high-quality talent, and a critical support for economic and social development [5].

In the specific construction tasks, in addition to building a first-class faculty, they also stipulate the cultivation of top-notch innovative talents, the improvement of the scientific research level, the inheritance of excellent culture of innovation, and the promotion of achievement transformation. This is the difference between the "Double First-Class" construction and the "211 Project" and "985 Project". The "Double First-Class" construction highlights the important task of cultivating top-notch innovative talents [6]. The "Double First-Class" construction aims to implement dynamic monitoring, and the implementation of dynamic management is a good innovation mechanism.

2.2. Graduate Employment Migration

Firstly, domestic and foreign scholars have conducted a lot of research on the characteristics of university graduates' employment mobility. Generally, individuals with higher levels of human capital are more geographically mobile [7,8]. Most scholars have conducted research on the geographical location of places of study and employment [9,10], and the most important employment locations for graduates are still large and medium-sized cities [11].

Secondly, researchers have analyzed the relevant influencing factors from different perspectives. According to the push and pull theory, the factors that affect the mobility of talents can also be called the factors that attract the mobility of talents. In different eras, different economic development environments, and different political and cultural backgrounds, the influencing factors of talent attraction have gradually shown differentiated characteristics in relation to influencing mechanisms and effects. Generally speaking, income level, per capita GDP, unemployment rate, urban amenities, educational structure and university quality all affect graduate migration [12–15].

2.3. Forecast Methods

This paper begins by employing a principal component analysis (PCA) to reduce the dimensionality of multiple data sets. A principal component analysis is a multivariate statistical analysis technique that replaces the original variable with a linear combination of the original variables to form an uncorrelated comprehensive variable on the premise of preserving the original variable's information with the least possible loss [16,17]. This eliminates the correlation between the original variables, reduces the network dimension, and facilitates data sorting and calculation [18,19].

The machine learning method [20], the PDE model [21], system dynamics [22], the exponential smoothing forecasting model [23], the grey model [24], random forest [25–28], and neural network [29–32] are the main tools used in population forecasting research. The majority of scholars utilize gray models, random forests, and neural networks [33]. The gray model research object is for unknown information or small samples, with a small sample size requirement [34]. It accomplishes its goal of accurately describing and comprehending the real world by generating, developing, and implementing some known information. Random forest is a statistical learning theory that has a high prediction accuracy, is tolerant of outliers and noise, and can identify abnormal collection points and compare and delete them [35,36]. In addition, it can assess the significance of each predictor's impact on the classification [37]. Similar to the human brain, the neural network model is capable of approximating a large number of complex nonlinear functions [38,39]. The neural network is one of the machine learning algorithms that imitates the functioning of human neurons to predict various events by continuously fitting nonlinear functions [40].

The BP artificial neural network is a multi-layer forward neural network based on the error back-propagation algorithm (Back-Propagation) developed by Rmenlhart, McClelland, and others [41]. The superiority of BP lies in its high simulation function, which can effectively correct errors through repeated learning of the network and can circumvent the expert scoring link in traditional evaluation, thereby minimizing the impact of subjective factors on the results [42]. Unlike general mathematical regression, the nonlinear operation of BP can better comprehend the relationship between variables and simultaneously incorporate the influence of hidden variables on the overall results into the calculation process [43]. The BP neural network can realize any nonlinear mapping between input and output, so it has the widest range of applications in pattern recognition, risk assessment, and adaptive control, among others [44].

To sum up, there are still two main deficiencies in the previous studies: first, the comprehensive and systematic analysis of the influencing factors of talent attractiveness is not enough; the second is the lack of a quantitative analysis of complex data on the influencing factors of talent attractiveness. This paper examines the factors influencing the employment mobility of university graduates from six main perspectives, tallies 22 relevant data indicators, and examines the factors influencing the employment migration of university graduates comprehensively. This paper primarily uses the random forest and neural networks to predict university graduates' employment retention rate. These two models are utilized more frequently for population prediction. However, given that the development of population size is affected by many factors, the limitations of using a single model for forecasting are inevitable, and the application of combined models in forecasting has gradually been welcomed by scholars. This paper analyzes the PCA-random forest and PCA-BP neural network models. The improved model has a higher accuracy and a better effect when dealing with uncertain factors.

3. Status Quo of Employment Migration of "Double First-Class" University Graduates

3.1. Regional Differences in Employment Mobility for "Double First-Class" University Graduates Exist

Based on the availability and completeness of data, this study calculated the number of graduates, the number of graduates entering each province, and the number of graduates leaving each province from 2014 to 2019 in 137 "Double First-Class" universities in 26 provinces in China.

As shown in Figure 1, the number of university graduates in each province increased annually from 2014 to 2019, and the number of university graduates was correlated with the province's native population and economic growth. Generally speaking, provinces with larger populations have a greater proportion of graduates. There were relatively more graduates from the populous provinces in the eastern and central regions, and relatively few graduates from the western regions. Figure 1 shows that the employment mobility of university graduates presents a clear regional imbalance.

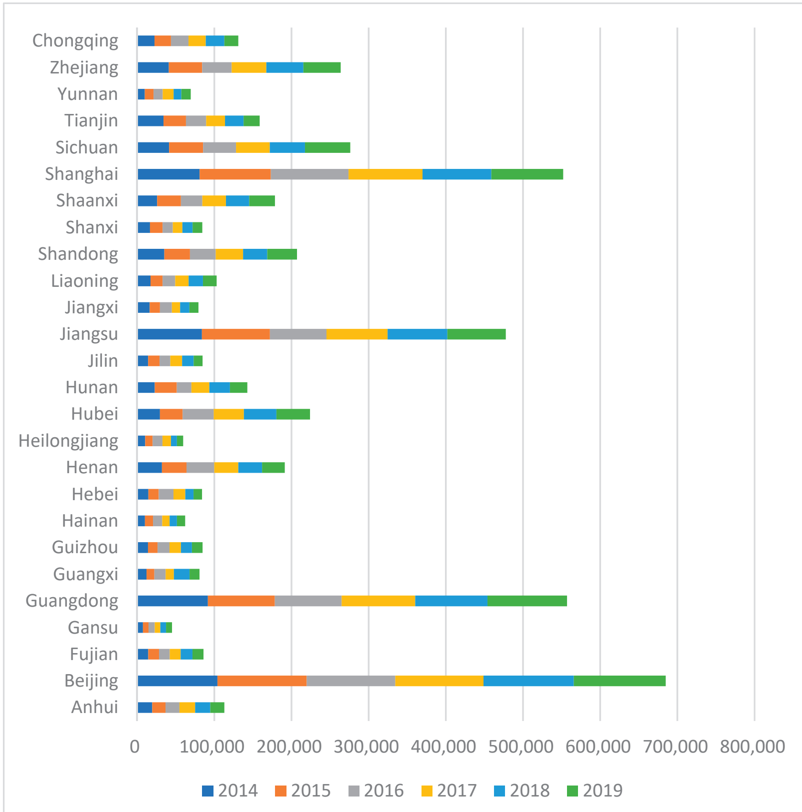

Figure 1. The number of graduates from "Double First-Class" universities in each province after migration from 2014 to 2019.

3.2. The Employment Mobility of "Double First-Class" University Graduates Is Sticky

Based on Figure 2, it can be seen that the employment mobility of "Double First-Class" university graduates showed a strong stickiness. Beijing, Guangdong, Guangxi, Henan, Jiangsu, Shandong, Shanghai, Yunnan, and Zhejiang's "Double First-Class" university graduates were relatively sticky, and the proportion of graduates staying in local employment was more than 50% each year. The proportion of graduates from Heilongjiang, Jilin, Liaoning, and the western regions of "Double First-Class" universities staying in local employment was relatively small. The conclusion is that "dual first-class" university graduates in the central and eastern regions were more sticky when it came to choosing a place of employment, whereas "Double First-Class" university graduates in the west and northeast regions were less sticky.

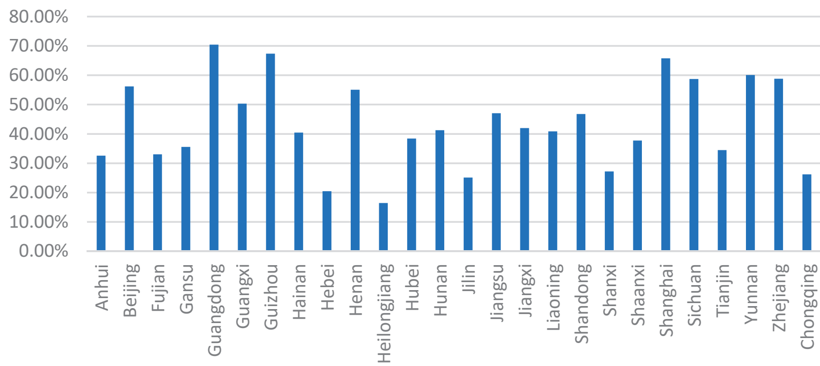

Figure 2. "Double First-Class" university graduates staying in the local employment ratio chart in 2019.

Guangzhou, Shanghai, Guizhou, Zhejiang, Yunnan, and Henan were the top six provinces where graduates of "Double First-Class" universities stayed employed locally, and the proportions were 72%, 71%, 61%, 60%, and 59%. The proportion of graduates from "Double First-Class" universities staying in employment in this province was closely related to geographic location and climate. The eastern and central plains and the provinces with suitable climates for survival retained more population. The employment rate of "Double First-Class" university graduates in their places of study was also related to the province's economic development level. In general, economically developed provinces can retain a greater number of graduates for local employment. Due to a lack of educational resources in the western provinces, the "Double First-Class" universities recruited relatively few students from the province and generally attracted more students from other provinces to study. Frequently, a region's openness is also a factor in determining whether university graduates remain in local employment. Students from less developed areas typically attend school and work in their communities.

3.3. The Employment Mobility of "Double First-Class" University Graduates Exhibits Concentration

Through the statistics of graduate employment quality reports in universities, we obtained the employment mobility rate and number of migrants from each college province to province. This paper counted a total of 676 province-to-province mobility paths of "Double First-Class" university graduation from 2014 to 2019. Figure 3 is a diagram of the main mobility paths with a graduate employment mobility rate of more than 2% in the "Double First-Class" universities, with a total of 167 routes. This paper used ECHARTS to generate a visualization of graduate employment mobility paths. It can be seen that the employment of "Double First-Class" university graduates was concentrated in Beijing, Guangdong, Shanghai, Zhejiang, and Jiangsu. As one can see, graduates of "dual first-class" universities preferred to work in economically developed provinces. On the one hand, these students possess cutting-edge theoretical knowledge, science, and technology, as well as the ability to find work in economically developed cities. On the other hand, these cities offer graduates a plethora of employment opportunities, relatively high wages, and a broader development platform.

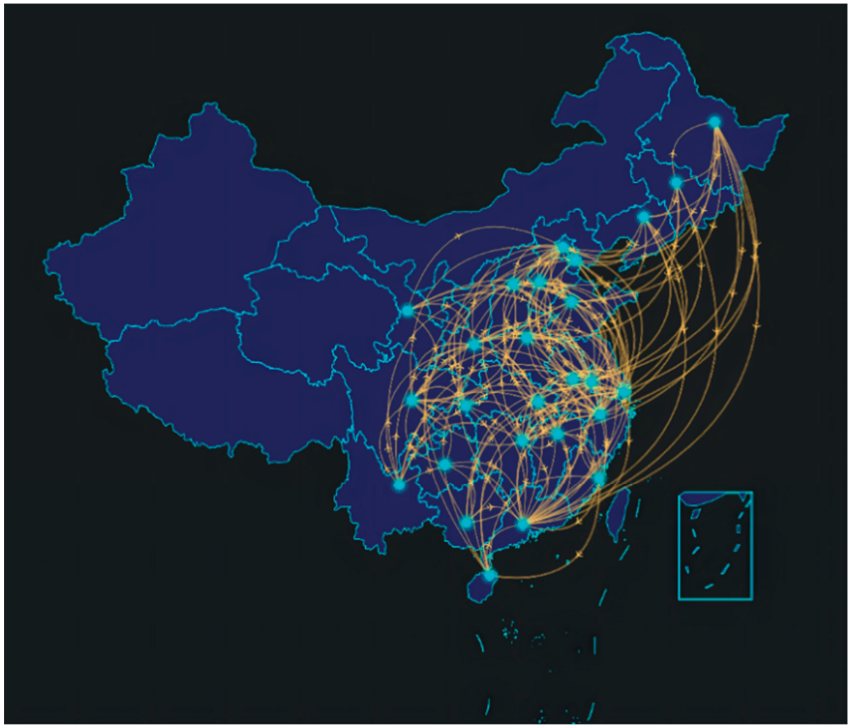

Figure 3. "Double First-Class" university graduates' main mobility path diagram (In the figure, the point represents the provincial capital cities, and the line represents the direction of population migration from provinces to provincial).

4. Analysis of Influencing Factors of Employment Mobility of "Double First-Class" University Graduates

4.1. Fixed-Effects Model Building

Based on the above data, this paper used panel data from 2014 to 2019 to study the factors influencing the employment mobility of university graduates. Panel data models included a mixed regression model, a random effect model, and a fixed-effect model. In this paper, through the Hausmann test, the fixed-effect model was used to analyze the factors affecting the employment mobility of university graduates.

$$lnY_{it} = \alpha_0 + \beta_1 lnG_{it} + \beta_2 lnW_{it} + \beta_3 lnH_{it} + \beta_4 lnT_{it} + \beta_5 lnS_{it} + \beta_6 lnP_{it} + \delta_c + U_{it} \quad (1)$$

In Equation (1), i denotes the province, t denotes the year, as the constant term; α_0 is the constant term. lnY_{it} indicates the logarithm of the number of university graduates' mobility. lnG_{it} represents the logarithm of GDP per capita [45]. lnW_{it} represents the logarithm of the average wage [46]. lnH_{it} represents the logarithm of the average sales price of commercial housing [47–49]. lnT_{it} represents the logarithm of the local financial expenditure on science and technology [50]. lnS_{it} represents the logarithm of the educational level [51], expressed by the number of ordinary primary schools and the number of higher education schools. lnP_{it} represents the logarithm of a series of control variables [51,52], expressed in terms of public service level, choice of urban road area per capita, number of beds in medical and health institutions, and Internet broadband access users. U_{it} is the error term. δ_C represents the city's unobserved fixed effects [52], the city's customs, history, landscape, and ecological environment. Since it cannot be observed and may be associated with independent variables, the model needed to be processed by first-order difference processing. The latter model was:

$$\Delta lnY_{it} = \lambda_1 \Delta lnG_{it} + \lambda_2 \Delta lnW_{it} + \lambda_3 \Delta lnH_{it} + \lambda_4 \Delta lnT_{it} + \lambda_5 \Delta lnS_{it} + \lambda_6 \Delta P_{it} + \Delta U_{it} \quad (2)$$

After model processing, the urban fixed effect δ_c was eliminated. In Equation (2), ΔlnG_{it} represents the difference between the logarithmic current period of per capita GDP and the previous period. ΔlnW_{it} represents the logarithmic current period of the average salary of urban employees and the difference between the previous period. ΔlnH_{it} represents the average commercial housing sales price of the number of a current phase difference between the previous period. ΔlnT_{it} represents the difference between the logarithmic current and the previous period of the local fiscal expenditure on science and technology. ΔlnS_{it} represents the difference between the logarithm of the number of ordinary institutions of higher learning and the number of ordinary primary schools in the current period and the previous period. P_{it} represents the variation of per capita urban road area, number of beds in medical and health institutions, and Internet broadband access users. ΔU_{it} represents the difference of the error term.

4.2. Variable Description

The data used in this study were calculated from the Graduate Employment Quality Report of the "Double First-Class" universities in 26 provinces and cities in Eastern, Central, and Western China from 2014 to 2019, the annual data of university graduates in each province published on the website of the Ministry of Education, and the data of China Statistical Yearbook and statistical yearbook of each province.

Through the statistics of the employment mobility data of graduates from "Double First-Class" universities in each province from 2014 to 2019, the employment mobility database of graduates from "Double First-Class" universities in each province was established. Due to a data shortage for "Double First-Class" universities in some provinces, this article counted the employment mobility of "Double First-Class" university graduates in 26 provinces and cities. This paper selected 22 groups of data that affect the employment mobility of university graduates in six aspects: economic level, industrial structure level, urban development level, science and technology education level, living environment, and quality of life. Table 1 summarizes all the variables used in this paper.

Table 1. Variable descriptive statistics.

	Variable Name	Obs	Mean	Std. Dev.	Min	Max
Economic level	GDP	156	29,668	21,393	3449	107,987
	Average wage	156	59,527	29,675	25,202	164,563
	Commodity house price	156	8677	6268	3629	37,420
	Unemployment rate	156	3.173	0.647	1.300	4.500
Industrial structure level	Rationalization of industrial structure	156	1.431	0.789	0.704	5.234
	Advanced industrial structure	156	0.861	0.307	0.251	1.757
	High-tech industrial structure	156	0.147	0.103	0.0222	0.468
	Producer service industry structure	156	2.266	0.726	1.381	5.049
Urban development level	Fixed asset investment	156	14,686	8812	1689	37,664
	Fiscal decentralization	156	6.102	2.602	3.150	14.89
	Urbanization rate	156	0.599	0.119	0.400	0.896
	FDI/GDP	156	0.0217	0.0170	0.000385	0.126
Science and technology education level	R&D full-time equivalent	156	106,560	131,806	1779	642,490
	Science and Technology Fiscal Expenditure	156	16,061	18,089	1238	116,879
	Number of regular high schools	156	95.15	34.46	17	167
	Number of elementary schools	156	6460	4573	698	25,578

Table 1. *Cont.*

	Variable Name	Obs	Mean	Std. Dev.	Min	Max
Living environment	Road mileage per square kilometer	156	1.081	0.447	0.304	2.115
	Number of medical and health beds	156	28.07	15.00	3.450	64.01
	Harmless treatment of domestic waste	156	24,740	19,377	3880	134,543
Quality of Life	Internet access users	156	12,066	8371	1203	38,016
	Number of performing arts groups	156	507.8	524.2	39	2859
	Number of people participating in pension insurance	156	1430	1029	224.9	5392

To prevent problems with collinearity and endogeneity, the following variables were picked for fitting when the panel fixed effects model was used. According to the above model, the explained variable was the number of university graduates in each province after the migration; the core explanatory variable was economic factors, including per capita GDP (Pergdp), the average wage of urban employees (Wage), and the average sales price of commercial housing (House); explanatory variables were local financial expenditure on science and technology (Tech), number of ordinary universities (Univer), number of ordinary primary schools (Prim); other control variables were the per capita urban road area (Road), the number of beds in medical and health institutions (Health), and the number of Internet Broadband Access Users (Net). In this paper, the variance expansion factor was used to test the data. The average value of the variance expansion factor VIF of each variable was 6.28, and the VIF of each variable was less than 10. There was no collinearity in the above data.

4.3. Empirical Analysis

Model I–Model VI were the regression results of increasing variables in turn. Model VII was the regression result using the instrumental variable method to test the endogeneity of the model.

According to Table 2, it can be seen in Model I that the number of beds in medical institutions and the number of Internet broadband access users were both significant, indicating that medical care and the Internet had a significant impact on the mobility of university graduates. According to Model II, after adding the variable of education level, the result shows that the number of ordinary universities was significantly positive at the 5% level. This shows that the richness of higher education resources affected the employment of university graduates. Higher education resource-rich provinces attract more university graduates.

Table 2. National regression model.

Dependent Variable	Model I	Model II	Model III	Model IV	Mode V	Model VI	Model VII
	Number of University Graduates after Migration in Each Province						
(Pergdp)				1.5550 ***	1.6446 ***	1.6782 ***	2.8055 *
				(3.39)	(3.03)	(3.08)	(1.83)
(Wage)				−0.7835 **	−0.6687	−0.6524	0.4577
				(−2.31)	(−1.45)	(−1.41)	(0.31)
(House)					−0.1435	0.4958	−1.2683
					(−0.38)	(0.21)	(−1.29)
(House_sq)						−0.0345	
						(−0.30)	
(Tech)			0.2803 **	0.1703	0.1652	0.1642	0.1215
			(2.53)	(1.65)	(1.61)	(1.61)	(0.56)
(Univer)		1.8275 **	1.7631 **	1.5173 ***	1.4563 ***	1.4181 **	2.3227 **
		(2.77)	(2.77)	(2.95)	(3.03)	(2.70)	(2.37)

Table 2. *Cont.*

Dependent Variable	Model I	Model II	Model III	Model IV	Mode V	Model VI	Model VII
	Number of University Graduates after Migration in Each Province						
(Prim)		−0.2154	−0.4432	−0.7075 **	−0.7205 **	−0.7071 *	−1.0944 ***
		(−0.61)	(−1.24)	(−2.15)	(−2.17)	(−2.03)	(−2.70)
(Road)	0.1377	0.1381	−0.0142	−0.3225	−0.3614	−0.3755	−0.3731
	(0.52)	(0.70)	(−0.07)	(−1.22)	(−1.09)	(−1.16)	(−0.74)
(Health)	0.9721 **	0.6609	−0.1039	−0.4356	−0.4046	−0.4598	−1.2901
	(2.16)	(1.19)	(−0.16)	(−0.56)	(−0.53)	(−0.56)	(−0.96)
(Net)	−0.2027 *	−0.3181 **	−0.2888 **	−0.3883 **	−0.4090 **	−0.4176 **	−0.7672 *
	(−1.77)	(−2.38)	(−2.42)	(−3.46)	(−3.18)	(−3.31)	(−1.84)
(Constant)	3.2375	1.0818	9.2633	11.9025 *	11.5202 *	8.8332	8.3677
	(0.92)	(0.17)	(1.40)	(1.84)	(1.87)	(0.77)	(0.80)
Observations	156	156	156	156	156	156	130
Number of provinces	26	26	26	26	26	26	26

Note: *, **, *** mean significant at the levels of 10%, 5%, and 1% respectively, and the number in parentheses is the "t" value of the estimated coefficient.

Model III was the addition of variables related to the level of technological innovation, and the results show that local fiscal expenditures on science and technology and the number of universities were both significantly positive. Among them, for every 1% increase in local financial science and technology expenditures, the number of university graduates' mobility to the province increased by 0.2803%, which was statistically significant at the 5% level. This proves that the more local finance invests in science and technology, the more university graduates it can attract. The higher the level of technological innovation in a place, the more high-quality talents it attracts. Areas with a high level of technological innovation provide a good employment platform, technical support, and sufficient funds for high-quality talents.

According to Model IV, after adding the relevant variables of economic factors, the results show that per capita GDP, average wages, number of higher education schools, and elementary schools were all significant. This shows that after controlling for other variables, the level of economic development and education have a significant impact on the employment mobility of university graduates. With a higher level of economic development in the region's living standards, wages are high, which meets the pursuit of high-quality talent to higher economic conditions. However, the number of its primary and secondary schools' coefficients was negative, indicating that fewer primary schools attract more university graduates instead. The possible reason is that the school districts where there are many elementary schools have relatively more houses, and the age of university graduates ranges from 20 to 30 at the time of employment. Most of them are relatively young and do not have children. Therefore, the attractiveness of basic education to university graduates is insufficient.

According to Model V, after adding the housing price factor, the results show that the average salary and the average housing price were not significant, and the per capita GDP, the number of universities and schools, the number of primary schools, and the number of Internet users were significant. When housing costs were taken into account, the attractiveness of wages for university graduates' employment diminishes significantly. This demonstrates that housing prices have a "crowding out effect" on university graduates' mobility. High housing costs increase the cost of living for recent graduates, while high wages detract from their attractiveness. After including the average house price's square term in Model VI, the average house price's square term was negative, indicating an inverted U-shaped relationship between the average house price and university students' employment mobility.

Model VII employed the instrumental variable method to eliminate the model's endogeneity. The observations were reduced to 130 by making the first-order lags of GDP per capita, the first-order lags of average wages, and the first-order lags of average house prices as instrumental variables. The regression results show that the per capita GDP, the number of universities, the number of primary schools, and the number of netizens were all significant, which was consistent with the original model V.

5. Prediction of the Employment Mobility of Graduates from "Double First-Class" Universities

Figure 4 is a mobility chart of the prediction of the retention rate of "double first-class" university graduates. This paper used the following steps to predict the employment retention rate of "Double First-Class" university graduates:

- Normalization of original data;
- Use of PCA to reduce the dimension of the data, and reduce the data from 22 dimensions to 9 dimensions;
- Random forest model prediction results;
- BP neural network model prediction results;
- Comparative analysis model and prediction accuracy.

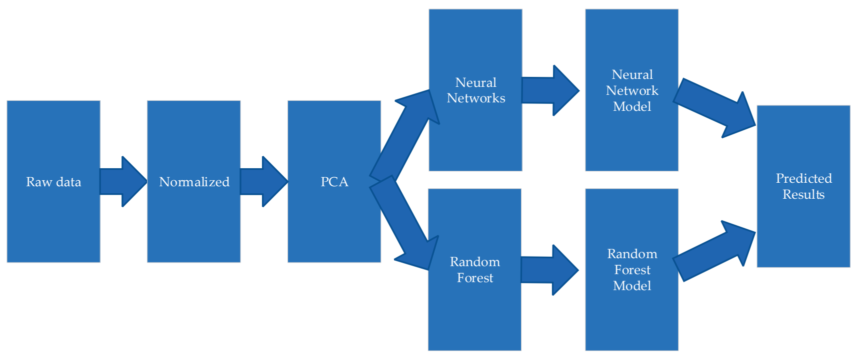

Figure 4. Mobility chart of the forecasting employment retention rate of "Double First-Class" university graduates.

5.1. The Principle of PCA

Through the statistics of the geographical mobility data of the employment of graduates "Double First-Class" universities in each province from 2014 to 2019, this paper established a database of graduate employment mobility of "Double First-Class" universities in each province. Due to the lack of data statistics in individual provinces, this paper counted the employment mobility of graduates from "Double First-Class" universities in 26 provinces and cities, including 22 parameter indicators.

This paper utilized the Z-score standardization method to normalize the data to eliminate the prediction error caused by the various dimensions of the early warning indicator data. This method provides the original data's mean and standard deviation to standardize the data. The processed data adhere to the normal distribution with a mean of 0 and a standard deviation of 1, and the transformation function is:

$$x^* = \frac{x - \mu}{\sigma} \tag{3}$$

where μ is the mean of all sample data and σ is the standard deviation of all sample data.

Since the input data have too many dimensions, an excessive number of irrelevant x inputs can easily result in the overfitting of the model during training. We used the PCA dimensionality reduction method to reduce the data from 22 dimensions to 9 dimensions to improve the experimental efficiency. PCA (Principal Component Analysis) is a common data analysis method that is frequently used for dimensionality reduction in high-dimensional data and can be used to extract the data's main feature components [53]. The primary goal of dimensionality reduction is to find a representation of the data with fewer dimensions that retain as much information as possible [54]. PCA is a technique for multivariate statistical analysis [55]. It replaces the original variables with a linear combination of the original variables to form an uncorrelated comprehensive variable under the premise of ensuring the minimum loss of information of the original variables, thus removing the correlation between the original variables [56]. Utilizing the concept of dimensionality reduction, the PCA method can comprehend the primary contradiction of the research problem, simplify the complex problem, and enhance the research efficiency [57].

Assuming that a certain thing is composed of m indicators, which are represented by $E_1, E_2, \ldots, E_m$, respectively, and the m indicators form an m-dimensional random vector, $E = (E_1, E_2, \ldots, E_m)'$, let q be mean value of the random vector E. The random vector E can be transformed into a new comprehensive variable by a linear transformation, which is represented by W. Thus, the new comprehensive variable can be linearly represented by the original variable, which satisfies the following formula:

$$W_1 = q_{11}E_1 + q_{12}E_2 + \ldots + q_{1m}E_m \tag{4}$$

$$W_2 = q_{21}E_1 + q_{22}E_2 + \ldots + q_{2m}E_m \tag{5}$$

$$W_n = q_{n1}E_1 + q_{n2}E_2 + \ldots + q_{nm}E_m \tag{6}$$

In the equation: The coefficient q_{ij} is calculable using the following principles:

(1)
$$q_{i1}{}^2 + q_{i2}{}^2 + \ldots + q_{im}{}^2 = 1\ (i = 1, 2, \ldots, m) \tag{7}$$

(2) W_i is linearly independent of W_j ($i \neq j$; $i, j = 1, 2, \ldots, n$);

(3) W_1 is the one with the largest variance among all linear combinations of $E_1, E_2, \ldots,$ Em; W_2 is the one with the largest variance among all linear combinations of $E_1, E_2, \ldots, E_m$ that are not related to W_1; W_N is the one with the largest variance among all linear combinations when $W_1, W_2, \ldots W_{N-1}$ is uncorrelated.

The new variable indexes $W_1, W_2, \ldots W_N$ determined in this way are called the first principal component, the second component, . . . , and the nth principal component of the original variable indexes $E_1, E_2, \ldots, E_m$, respectively. Among them, the variance of W_1 accounts for the largest proportion of the total variance, and the variances of $W_1, W_2, \ldots W_N$ decrease in turn. When analyzing practical problems, it is common practice to select the first few largest principal components, which not only reduces the number of variables but also captures the main contradiction of the problem and simplifies the relationship between variables. In this paper, the fit method of PCA was used to train all training data, resulting in the trained PCA model.

Figure 5 depicts the ranking of factors affecting the employment mobility of university graduates after dimension reduction using PCA. It can be seen that economic level factors, including the regional GDP, wages, the average sales price of commercial housing, and the unemployment rate of each province and city, were the primary factors affecting the employment mobility of "Double First-Class" university graduates. The result after PCA for the gross regional product was 0.3178, the result after PCA for wages was 0.2561, and the result after PCA for the average sales price of commercial housing was 0.1088. The level of industrial structure, including the rationalization of industrial structure, the advanced level of industrial structure, the level of high-tech industrial structure, and the level of the industrial structure of producer services, was a secondary factor affecting the employment migration of "Double First-Class" university graduates. The result of PCA after the rationalization of industrial structure was 0.0442, the result after PCA of advanced industrial structure was 0.0400, the result after PCA of high-tech industrial structure level was 0.0343, and the result of industrial structure level of producer service industry after PCA was 0.0321.

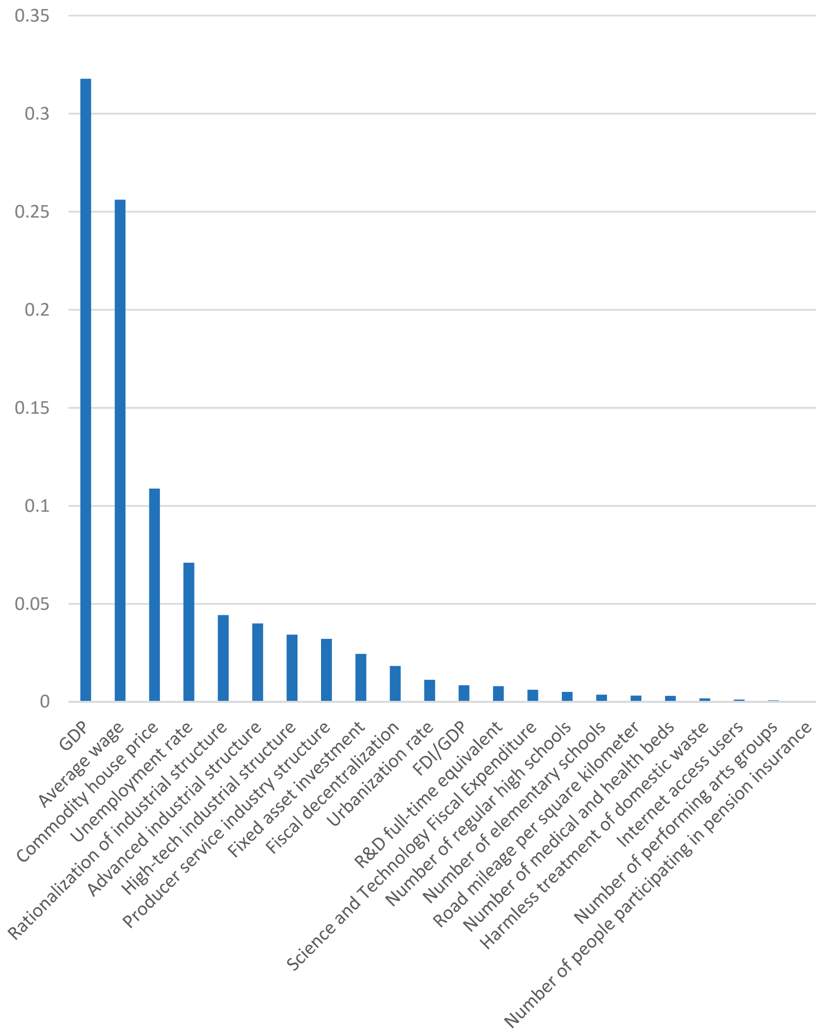

Figure 5. Ranking of each influencing component after PCA.

The impact of urban development level, scientific and technological education level, living environment, and quality of life on the employment mobility of "Double First-Class" university graduates was relatively small. Therefore, it can be concluded that the ranking of the importance of each principal component after PCA was consistent with the previous results using the fixed effects model. Economic factors were the most important factors affecting the employment mobility of graduates from "Double First-Class" universities.

5.2. Random Forest Prediction Model

Random forest is a statistical learning theory proposed by Breiman in 1996 [58]. It uses the bootstrap resampling method to extract multiple samples from the original sample, models each bootstrap sample as a decision tree, and combines the predictions of multiple decision trees to obtain the final prediction result through voting [59]. The random forest has excellent tolerance for outliers and noise and is not susceptible to overfitting. A random forest is a natural tool for nonlinear modeling. It only requires the continuous training of sample data [60]. It is ideally suited for application problems involving irregular multi-constraint conditions and missing data. This method overcomes the disadvantages of indirect, time-consuming, and inefficient information and knowledge acquisition caused by traditional forecasting methods and lays the groundwork for the practical application of forecasting [61]. It is currently one of the most popular frontier research fields in data mining and bioinformatics, and it has been successfully implemented in medicine, economics, and management, among other fields [62].

The principle of the random forest is as follows.

First, set the original sample set T, where the sample size is N, and use the Bootstrap sampling method to extract K sample sets from the sample set to generate random vector decisions.

Second, a decision tree model $\{h\ (x, \theta_i),\ i = 1, \ldots, k\}$ is established for evaluating the influencing factors of talent attraction in first-tier cities by using the random vector sequence i distributed independently, where the matrix x is the independent variable.

Finally, after k rounds of training, a regression tree model sequence $\{h_1(x), h_2(x) \ldots, h_k\ (x)\}$ is obtained. For any given new sample, its prediction result is the average summary of the results of k rounds, and its formula is:

$$H(x) = argmax \sum_{i=1}^{k} I(h_i(x) = Y) \quad (8)$$

In the classification model, h_i represents a single decision tree in the classification model; $H(x)$ is the random forest combined classification model; Y is the output target variable.

The random forest data processing procedure is as follows:

(1) In this paper, Bootstrap sampling was used to randomly select N training subsets from the original training set for 22 influencing factors, with the size of each training subset being approximately two-thirds of the original training set. After many repeats, there are always some samples that cannot be drawn; these samples form M out-of-bag data sets, which serve as the test sample set of random forest.

(2) At each node of each decision tree, randomly select m variables as alternative branch variables, where the number of randomly selected variables is less than the number of original variables, and then select the optimal branch according to the branch goodness criterion.

(3) Each decision tree begins recursive branching from the top down, and the minimum size of the leaf node is set to five. Based on this as the termination condition for the growth of the regression tree, a random forest model is generated from the generated decision tree.

The final output of the algorithm is implemented by the majority voting method. A test sample will be classified based on the randomly constructed N decision subtrees, the results of each subtree will be summarized, and the classification result with the most votes will be the final output of the classification algorithm [63].

The results from Table 3. show that the number of random forest trees was set to 10, 50, 100, and 500, respectively, and the maximum depth of trees was set to 10, 50, and 100, respectively. When the number of trees in the random forest was 10 and the maximum depth of trees was 50, the value of the loss function MSE was 0.1799 and the value of MAE was 0.1463. When the number of trees in the random forest was 50 and the maximum depth of trees was 50, the value of the loss function MSE was 0.1761 and the value of MAE was 0.1443. When the number of trees in the random forest was 100 and the maximum depth of trees was 50, the loss function MSE was 0.1794 and MAE was 0.1461. When the number of trees in the random forest was 500 and the maximum depth of trees was 50, the metric value of the loss function MSE was 0.1782, and the metric value of MAE was 0.1454. It can be seen that when the number of trees in the random forest was 50 and the maximum depth of the trees was 50, the minimum value of MSE was 0.1761, and the value of MAE was also the minimum 0.1443. At this time, the prediction accuracy of random forest was the best. These values were the results obtained after dimensionality reduction using PCA. The loss function obtained without PCA dimensionality reduction was relatively large.

Table 3. The number and depth results of different tree nodes in random forest.

Number	**10**	**10**	**10**	**50**	**50**	**50**	**100**	**100**	**100**	**500**	**500**	**500**
Depth	**10**	**50**	**100**	**10**	**50**	**100**	**10**	**50**	**100**	**10**	**50**	**100**
MSE	0.1806	0.1799	0.1866	0.1785	0.1761	0.1801	0.1795	0.1794	0.1804	0.1792	0.1782	0.1802
MAE	0.1469	0.1463	0.1523	0.1457	0.1443	0.1468	0.1464	0.1461	0.1469	0.1460	0.1454	0.1467

5.3. BP Neural Network Model

BP neural network is also called an error backpropagation neural network [64]. The BP algorithm's learning process consists of two parts: forward propagation and backward propagation. The direction of forwarding propagation is the input layer-hidden layer-output layer. Each neuronal layer influences the neurons in the next layer [65]. The error is calculated by subtracting the net-work output from the sample's expected output. If the error does not meet the threshold, backpropagation is carried out. It propagates forward after returning layer by layer along the original path, adjusting the weights between each neuron. This process is repeatedly looped until the error reaches a predetermined threshold, at which point propagation ceases [66,67]. Figure 6 shows the structure of the PCA-BP neural network.

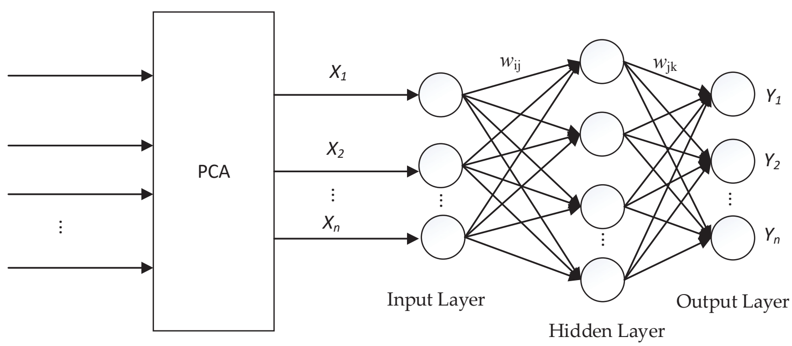

Figure 6. Structure of the PCA-BP neural network.

General algorithmic operations of the BP neural network:

Let the input vectors be X_1, X_2, X_3, ... , X_n; the corresponding expected output vectors are Y_1, Y_2, Y_3, ... , Y_n; w_{ij} and w_{jk} are the connection weights from the input layer to the hidden layer, and the connection weights are from the hidden layer to the output layer, respectively; n and m are the number of input nodes and the number of output nodes, respectively.

(1) Assign random values in the interval [−1, +1] to the connection weights w_{ij}, w_{jk} and the thresholds a, b;

(2) According to the input vector X, the connection weight w_{ij} from the input layer to the hidden layer and the hidden layer threshold a, the hidden layer output T is calculated.

$$T_j = f\left(\sum_{i=1}^{n} w_{ij}x_i - a_i\right),\ j = 1,2,3,\ldots,l \tag{9}$$

In the equation, l represents the number of nodes in the hidden layer; f represents the activation function of the hidden layer, and the activation function is defined as l is the number of nodes in the hidden layer; f is the activation function of the hidden layer, and the activation function is $f(x) = \frac{1}{1+e^{-x}}$

(3) According to the hidden layer output T, weight $w_{ij,}$ and threshold b, through the transfer function, the actual output value C of each unit of the output layer is output;
(4) According to the expected input $Y(Y_1, Y_2, Y_3, \ldots, Y_n)$ and the actual output value C, the correction error e of each unit of the output layer is calculated;

$$e_k = Y_k - C_k, k = 1, 2, 3, \ldots, m \tag{10}$$

$$W_{ij} = w_{ij} + \mu T_j(1 - T_j)x_i \tag{11}$$

$$W_{jk} = w_{jk} + \mu T_j e_k \tag{12}$$

where: $i = 1, 2, 3, \ldots, n$; $j = 1, 2, 3, \ldots, l$; $k = 1, 2, 3, \ldots, m$; μ is the learning rate.

$$a_j = a_j + \mu T_j(1 - T_j),\ j = 1,\ 2,\ 3, \ldots, l \tag{13}$$

$$b_k = b_k + e_k,\ k = 1,\ 2,\ 3, \ldots, m \tag{14}$$

(5) Determine whether the global error meets the specified accuracy requirements and whether the number of iteration steps exceeds the specified number of steps. If true, the algorithm terminates; otherwise, it returns.

As shown in Table 4 and Figure 7, the loss function MSE in the training set had a value of 0.6977 at the 1st epoch and decreased to 0.1274 at the 100th epoch. The value of the MAE metric was 0.6778 and decreased to 0.1064 at the 100th epoch. The lowest MSE and MAE values were recorded at the 100th epoch. In the validation set, the value of the MSE loss function at the 1st epoch was 0.1484 and decreased to 0.1159 at the 100th epoch. The value of the MAE metric was 0.1239 and decreased to 0.0921. The lowest MSE and MAE values were recorded at the 100th epoch.

Table 4. Loss function (MSE) and quality metric (MAE) values of the training and validation set.

Epoch	Training Set		Validation Set	
	MSE	MAE	MSE	MAE
1	0.6977	0.6777	0.1484	0.1239
2	0.1643	0.1364	0.1411	0.1164
3	0.1595	0.1332	0.1400	0.1160
4	0.1573	0.1314	0.1392	0.1155
5	0.1560	0.1304	0.1385	0.1150
6	0.1549	0.1295	0.1378	0.1146
7	0.1539	0.1288	0.1372	0.1143
8	0.1533	0.1282	0.1367	0.1140
9	0.1527	0.1277	0.1362	0.1137
10	0.1521	0.1272	0.1358	0.1135
...	...	...	...	...
90	0.1301	0.1088	0.1159	0.0930
91	0.1298	0.1085	0.1158	0.0928
92	0.1295	0.1083	0.1158	0.0927
93	0.1292	0.1080	0.1158	0.0926
94	0.1289	0.1078	0.1158	0.0926
95	0.1287	0.1076	0.1158	0.0925
96	0.1284	0.1073	0.1158	0.0924
97	0.1282	0.1071	0.1158	0.0923
98	0.1279	0.1069	0.1158	0.0922
99	0.1277	0.1066	0.1159	0.0922
100	0.1274	0.1064	0.1159	0.0921

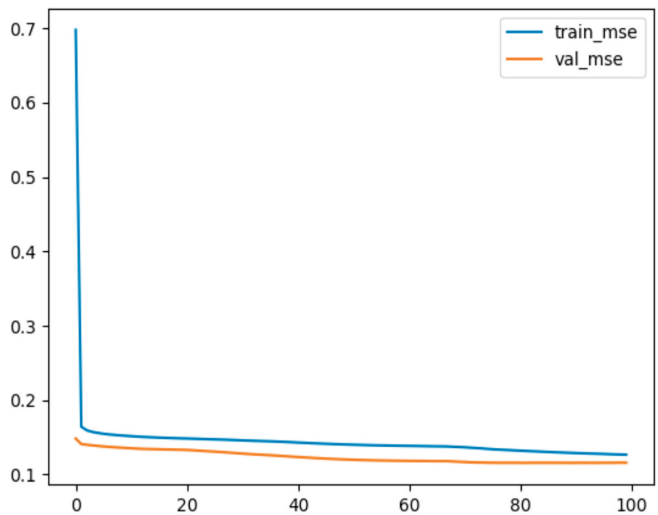

Figure 7. Comparison of loss functions for the training and validation sets.

As shown in Table 5 and Figure 8, after dimensionality reduction using PCA, the loss function MSE in the training set had a value of 0.3319 at the 1st epoch and decreased to 0.1137 at the 100th epoch. The value of the MAE metric was 0.2833 and decreased to 0.0873 at the 100th epoch. The lowest MSE and MAE values were recorded at the 100th epoch. In the validation set, the value of the MSE loss function at the 1st epoch was 0.2085 and decreased to 0.1152 at the 100th epoch. The value of the MAE metric was 0.1811 and decreased to 0.0943. The lowest values of MSE and MAE were recorded at the 96th epoch—0.1151 and 0.0940, respectively. The results indicate that the loss function (MSE) and quality indicator (MAE) values of the training and validation sets were not significantly different, and the PCA-BP neural network model can accurately predict the employment retention rate of "Double First-Class" university graduates.

Table 5. Loss function (MSE) and quality metric (MAE) values of the training and validation set after PCA.

Epoch	Training Set		Validation Set	
	MSE	MAE	MSE	MAE
1	0.3319	0.2833	0.2085	0.1811
2	0.2097	0.1789	0.1286	0.1015
3	0.1617	0.1315	0.1315	0.1107
4	0.1553	0.1277	0.1255	0.1032
5	0.1534	0.1250	0.1252	0.1047
6	0.1521	0.1239	0.1238	0.1036
7	0.1511	0.1228	0.1233	0.1034
8	0.1503	0.1219	0.1230	0.1031
9	0.1495	0.1212	0.1228	0.1030
10	0.1489	0.1206	0.1227	0.1028
...	...	...	...	...
90	0.1167	0.0890	0.1156	0.0941
91	0.1164	0.0888	0.1155	0.0941
92	0.1161	0.0886	0.1154	0.0941
93	0.1158	0.0883	0.1154	0.0941
94	0.1154	0.0882	0.1152	0.0940
95	0.1151	0.0880	0.1152	0.0940
96	0.1148	0.0878	0.1151	0.0940

Table 5. *Cont.*

Epoch	Training Set		Validation Set	
	MSE	MAE	MSE	MAE
97	0.1145	0.0877	0.1152	0.0942
98	0.1142	0.0876	0.1152	0.0942
99	0.1140	0.0874	0.1152	0.0943
100	0.1137	0.0873	0.1152	0.0943

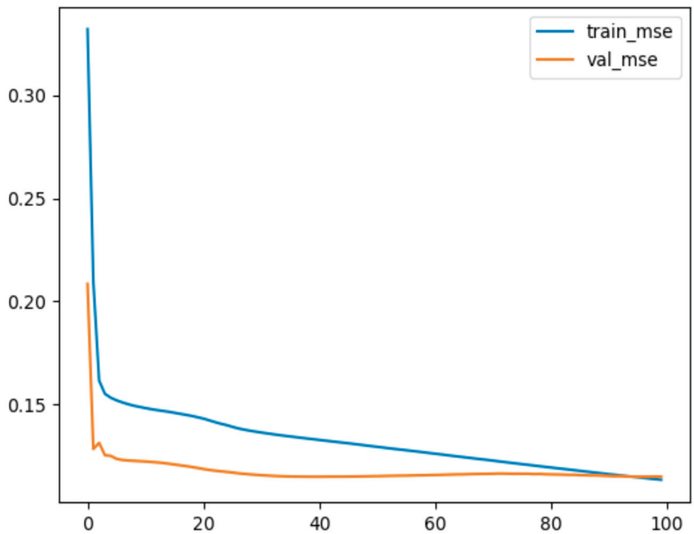

Figure 8. Comparison of the loss functions on the training set and validation set after PCA.

To conclude the above, after dimension reduction via PCA, the minimum loss function (MSE) obtained by the random forest model was 0.1761, whereas the minimum loss function (MSE) obtained by the BP neural network model was 0.1137. The prediction accuracy obtained after using PCA to reduce the dimension was better, and the loss function was relatively small. Comparing random forestry and BP neural network revealed that the BP neural network model provided a more accurate prediction of the employee retention rate of "Double First-Class" university graduates, whereas the relative prediction accuracy of the random forestry model was low.

6. Conclusions and Policy Implications

This paper took the employment mobility data of graduates from "Double First-Class" universities in various provinces from 2014 to 2019 as the research object and counted the panel data on the employment mobility of graduates from "Double First-Class" universities in 26 provinces and cities, with a total of 156 groups. According to the availability of data, this paper counted the employment mobility data of graduates from "Double First-Class" universities for 6 years. There were regional differences in the employment mobility of graduates from "Double-First-Class" universities.

Most graduates stayed in their places of study for employment, and they tended to focus on large cities such as Beijing, Shanghai, and Guangzhou. Economic factors were the main factors affecting the employment mobility of graduates from "Double First-Class" universities. Due to the small number of data years, the large fluctuations in the number of influencing factors, and the existence of certain correlations between indicators, traditional linear prediction methods may not have been able to predict correctly. PCA can effectively remove the correlation between data and reduce the input of indicators, which is conducive to sorting and calculation, but it cannot reflect the nonlinear relationship between indicators, and cannot directly predict the unemployment rate of university graduates.

Through transformation, this method can reduce the dimensionality of the original high-dimensional data without sacrificing much data information, i.e., map it into a low-dimensional space. The experimental results demonstrated that, compared to a random forest, a BP neural network can reduce the number of input nodes while preserving the information's integrity and avoiding the phenomenon of correlation and information overlap among various influential factors. The accuracy of the BP neural network predictions was greater than that of a random forest prediction model. This method accurately predicted university graduates' employment retention rate.

This paper gives the following suggestions on how to improve the attractiveness of each province to high-quality talents: First of all, the housing prices in first-tier cities in my country are generally relatively high, and the salary income of university graduates cannot bear the price of high housing prices. Although Beijing, Shanghai, Guangzhou, and Shenzhen have excellent public services and good educational resources, high housing prices are still an important factor for university graduates to consider when choosing a place to work.

Second, strengthen the financial science and technology expenditure, and improve the ability of scientific and technological innovation, especially in the central regions, most of which are located in the plain area, and have had a large population since ancient times. However, rich population resources cannot promote the sustainable development of the economy, and the lack of high-quality talents will lead to insufficient scientific and technological innovation capabilities. Relying on the talent introduction policies formulated by various regions in recent years, at the same time improving the ability of scientific and technological innovation, increasing the employment of high-tech industries, and attracting university graduates to settle down for a long time with the advantage of housing prices, they can effectively deal with the problem of lack of high-quality talents. Enhance scientific and technological innovation capabilities, thereby promoting the development of the entire economic level.

Finally, rationally distribute educational resources and improve education levels. For the central region, the enhancement of basic education is the key to attracting talents. Most of the central regions attract high-quality talents who can settle down for a long time. The improvement of basic education can effectively attract high-quality talents to settle in the region. As for the western region, most of the regions lack higher education resources; therefore, improve the educational equity in the western region, increase the investment in higher education resources, and cultivate more talents to serve the local area.

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Post-Graduate Geographical Education in China: Can Talents Meet the Need of Sustainable Development?

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Abstract: As widely acknowledged and targeted in Transforming Our World: The 2030 Agenda for Sustainable Development, talents education and training is an important measure to systematically solve the problem of economically, societally, resource, and environmentally sustainable development, and so as the post-graduate geographical talents education and training. Whether post-graduate geographical talents education and training can meet the need of sustainable development is an increasingly significant issue in geography science. Therefore, from the perspective of population scale, education quality, and education input, taking Chinese post-graduate geographical education as an example, the paper empirically investigated the spatial differentiation and talents production mechanism. With the support of spatial analysis tools by ArcGIS and GeoDa software, the strong inter-regional differentiation and imbalance characteristics of post-graduate geographical talents education were detected, outlining a general east-west geographical pattern in China. Moreover, the spatial production mechanism of post-graduate geographical talents has its own global and national scale, regional comprehensive and province-related characteristics, and production of the talents education and training in human geography, physical geography, and cartography. GIS also has its own focuses and demands.

Keywords: post-graduate geographical talents education; sustainable development; degree authorization; talent education and training; quality education

1. Introduction

Due to different advantages and demands, different countries and organizations have their different cultivating and training curricula and developing directions for geographical talents to meet economically, societally, resource, and environmentally sustainable development under the background of globalization. German geography began to emphasize the strengthening of systematic geography in the 1970s, and its basic structure of the spiral geography curriculum was formed [1]. Meanwhile, German geography paid attention to strengthening the understanding of geopolitics [2]. France geography is no longer confined to the field of geography, but transcends disciplinary boundaries to form a multidisciplinary and integrated trend, while emphasizing the development of students' abilities and achieving sustainable educational development [3]. Korean geography will pay more attention to regional geography in the future [4]. Japanese geography pays attention to sustainable development and to forming one axis of the main content of the subject "Chiri Sogo" [5].

Indonesian geography has integrated the environment and sustainable development into the social science, natural science, geography, and biology in the modern times [6].

Since the reform and opening up in China, the post-graduate geographical education has educated and trained a number of research-oriented talents for the sustainable utilization of national or local resources and the environment, territorial spatial planning and management, and economic and social construction. The smooth implementation of the Fourteenth Five-Year Plan for National Economic and Social Development of the People's Republic of China and the Outline of the Long-range Goals to 2035 and China's National Plan on Implementation of the 2030 Agenda for Sustainable Development calls for the establishment of a sound land–sea coordination system for territorial spatial planning, natural resource assets, and ecological environment governance. Therefore, geography science has been endowed with a new task and responsibility for its regionality and comprehensiveness [7]. The key task is to educate and train different types of post-graduate geographical talents that can solve the problems of economically, societally, resource, and environmentally sustainable development in China's land–sea surface system. Therefore, the main goal of geographical post-graduate education with innovative ability is to provide excellent talents for the sustainable development of the country and the coordinated development of the local economy, society, and resources and environment [8]. The optimization of the layout and quality of post-graduate geographical education institutions have become the academic focus in China [9,10].

Scholars' research on the post-graduate geographical education remains in its overall development period in China, and because of the primary stage of development, there is a gap among the current situation of geographical education in China. Moreover, there is no systematic study of the common and different geography science education in China and there is no study of their distribution characteristics. Therefore, the aim of the paper is to reveal the regional characteristics of post-graduate geographical talents by sorting out the orientation of education in Chinese institutions. Furthermore, this paper also aims to reveal the nature of geographical distribution through the coupling between the distribution of geographical education institutions and the distribution of natural allocation to help optimize the spatial production pattern and characteristics of post-graduate geographical education in Chinese institutions, and provide references for similar countries.

2. Literature Review

In recent years, international scholars' research of geographical talents education mainly focused on European and American countries. In 2011, W. Brian Whalley et al. studied British and American geographical traditions and emphasized the universality of geography and related skills training [11]. In 2017, M. Duane Nellis argued that the impact of new technologies, changes in curriculum structures, and local policies contributed to the new learning model in the United States [12]. In 2008, Ron Johnston studied the research achievement of the ACC, the largest group of academic geographers in the United States. They mainly focused on a defined subset of the discipline and undertook relevant academic activities. Their goal was to show the most important work done by American geographers in the past decade [13]. In 2008, Hay studied the role of the International Network for Learning and Teaching in Geography for Higher Education (INLT) in the production of geographical knowledge; introduced British and American educational models; and strengthened existing unequal social relations [14]. In 2006, Henry Wai-Chung Yeung studied the approach to shape the economic geography of higher education institutions in the unique development environments of China and Singapore, arguing that the economic geography approach requires the localization of the curriculum [15]. In 2002, after the systematic study of tourism geography in Chinese universities conducted by Baosteel, there was still a large gap between Chinese scholars and those in North America [16]. In 2018, Mitchell studied the professional development direction of GIS talents and emphasized the importance of building a well-structured professional development [17]. In 2019, Liu

R et al. argued that GIS has become a universal tool in geography and other fields, and studied the impact of GIS on human geography students [18].

However, the time spent on research concerning Chinese geography is still very short. In 2021, Junxi Qian studied the development of geography from the period of reform and opening up [19]. Different from the geographical paradigm of English-speaking countries, China has identified two kinds of tension: between natural science and social science orientations, and between applied knowledge and critical/reflexive knowledge [20]. In 2019, Sun et al. discussed the development of the geography of higher education in China during 1904–1949, and summarized the differences in geography in China and the special role of geographers studying abroad by taking geography institutions, curricula, and teachers as indicators [21]. In 2015, Guosheng Han studied the current teaching situation of tourism geography in Taiwan, China, based on the content analysis of 60 teaching syllabuses, which is helpful for international tourism geography circles to have a better understanding of China's tourism geography education [22]. In 1982, Chunfen Li studied the progress of university geography education in the People's Republic of China from 1949, which made achievements in establishing professional geography institutions, training teachers and geographers, and publishing geography textbooks [23]. In 2007, Xiaojian Li, Yunfeng Kong, and Baoyu Peng, combined with data and a survey of 20 geographical universities, elaborated on the characteristics of the development of geography in higher education in China since 1980, and the development was very optimistic [24]. Although the development of several fields was unbalanced, the overall trend was expanding. In 2019, Ran Liu et al. conducted a standardized spatial thinking ability test (STAT) and found that Geographical Information System (GIS) has become a common problem-solving tool in the field of regional research [18]. In addition, Chinese students performed better in spatial reasoning ability and showed higher spatial cognition in problem solutions and Boolean logic [25]. In 2006, Ada Lo studied the tourism geography and reviewed the history of hospitality and tourism higher education in Hong Kong [26].

3. Materials and Methods

Spatial autocorrelation is generally used to express the heterogeneity and spatial cluster characteristics of spatial elements, and positive spatial autocorrelation is the propensity for regions or locations that really are close together to have comparable values, which is most typically found in practical circumstances [27]. In order to explore the spatial characteristics of post-graduate geographical education institutions, the GeoDa, whose version is 1.16 by Dr. Luc Anselin and his team from America in 2013, bivariate spatial autocorrelation analysis method exists to analyze the spatial correlation of post-graduate geographical education institutions.

3.1. Data Collection

According to the affiliation, post-graduate geographical education institutions can be divided into three categories: regular university affiliated to a certain government, the University of Chinese Academy of Sciences, and a research-institution-affiliated certain unit of the government from the China Post-Graduate Admission Information Network (https://yz.chsi.com.cn/) (accessed on 20 August 2020). There are a total of 89 post-graduate geographical education institutions. The map of China was geo-coded from the Baidu Map (https://map.baidu.com/) (accessed on 2 September 2020). The attribute data, mainly including the name of each province, and the number and structure of geographical post-graduate talents, the scale of population, the quality of population, and the input of education were added to province in ArcGIS, whose version is 10.2 by Environmental Systems Research Institute, Inc. from America in 2013.

3.2. Spatial Weight Matrix Construction

The spatial weight matrix is the spatial arrangement between different spatial objects, which usually defines a binary symmetric spatial weight matrix W to express the interdependence relationship in the space [28], and GeoDa is used to construct the spatial weight matrix for population scale, education quality, and educational input. The calculation method is shown in Formula (1).

$$W = \begin{vmatrix} w_{11} & w_{12} & \cdots & w_{1n} \\ w_{21} & w_{22} & \cdots & w_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ w_{n1} & w_{n2} & \cdots & w_{nn} \end{vmatrix} \tag{1}$$

Among them,

$$w_{ij} = \begin{cases} 1, \textit{ When district county I is adjacent to district county I} \\ 0, \textit{ When district county I is not adjacent to district county I} \end{cases}$$

Special note: when I = j, w_{ij} = 0.

It is not hard to find that the matrix W is symmetric, that is, W^T = W.

3.3. Bivariate Spatial Autocorrelation Analysis

Spatial dependence, spatial correlation, or spatial autocorrelation between spatial statistics and geolocation-related data can compensate for the deficiency of traditional quantitative statistical analysis [29]. Therefore, the bivariate spatial autocorrelation method was adopted to study the correlation between the distribution of geography education institutions in universities and the population scale, education quality, education input in different provinces, and the coupling was analyzed.

$$\mathrm{I} = \frac{n \times \sum_i^n \sum_j^n W \times (x_i - \overline{x})\left(y_j - \overline{y}\right)}{\left(\sum_i^n \sum_j^n W_{ij}\right) \times \sum_i^n (x_i - \overline{x})^2} \tag{2}$$

where n is the number of sample lattices, x_i, y_j are the attribute values of i or j or region, $\overline{x}$ is the mean of all the points, and W_{ij} is the weight matrix to measure the relationship between spatial things, which is a generally symmetric matrix.

* Data for Hong Kong, Macao, and Taiwan are missing, and the figure is gray and blank.

4. Results

4.1. The Type and Scale of Post-Graduate Geographical Talents Education

According to the China Post-Graduate Admission Information (https://yz.chsi.com.cn/) (accessed on 20 August 2020), there are three types of post-graduate geographical talents education institutions in China: (1) The first type is regular university which is affiliated to a certain government, which can be divided into the university under the ministry of education (or other ministries), the university under the provincial people's government, and the university under the local government in accordance to the affiliation relationship. Meanwhile, the affiliation relationship determines the funding channel to universities as well as its belonging. Moreover, by the end of 2020, 85 Chinese universities can grant the master degree in geography, and 33 of them can grant the doctor degree in geography. (2) The second type is the University of Chinese Academy of Sciences, which is characterized by the integration of science and education, and aims at educating and training high-level and high-quality innovative and entrepreneurial talents with less than a thousand of admitted masters and doctors annually. This includes the Institute of Geographical Sciences and Natural Resources Research, Nanjing Institute of Geography and Limnology, Northeast Institute of Geography and Agroecology, Institute of Mountain Hazards and Environment, Northwest Institute of Eco-Environment and Resources, Xinjiang Institute of Ecology and Geography, Institute of Soil Science, Guangzhou Institute of Geochemistry, Institute of Tibetan Plateau Research, Yantai Institute of Coastal Zone

Research, Aerospace Information Research Institute, Innovation Academy for Precision Measurement Science and Technology, College of Resources and Environment, and School of Future Technology. (3) The third type is a research institution, which is affiliated to certain unit of the government, that includes the Chinese Academy of Forestry, Beijing Research Institute of Uranium Geology, and Chinese Academy of Meteorological Sciences. These institutions educate and train post-graduate talents in geography in the industrial field with less than a hundred of admitted masters and doctors annually.

4.2. The Spatial Distribution of Post-Graduate Geographical Talents Education

In 2020, there are 85 universities authorized to grant the master degree in geography (Table 1). Beijing has eight of them, and Hubei, Jiangsu, and Shanxi each has six of them. Meanwhile, Shandong, Jilin, Guangdong, Henan, and 12 other provinces and cities each has 3–5 of them. Moreover, Anhui, Shanghai, Hainan, Heilongjiang and other 14 provinces and cities each has 1–2 of them. However, Tibet has no university authorized to offer post-graduate programs in geography. Among the 85 universities, 79 of them have first-level disciplinary authorization for the master degree in geography, and the other five universities have second-level disciplinary authorization for the master degree in geography, which include Huaqiao University, China University of Mining and Technology, Shanxi University, Xi'an International Studies University, and Sichuan Agricultural University. There are four universities in Beijing with authorization for the doctor degree in geography (including the University of Chinese Academy of Sciences). Meanwhile, there are two universities in Jiangsu, Hubei, Guangdong, Shaanxi, Yunnan, Gansu, and a university in Hunan, Shandong, and 17 other provinces with authorization for the doctor degree in geography. However, there is no university in Shanxi, Sichuan, Zhejiang, Guangxi, Hainan, Ningxia, and Xizang provinces with authorization for the doctor degree in geography.

Table 1. Spatial distribution of geographical education institution authorization for the master degree or the doctor degree in geography in China, excluding Hong Kong, Macao, and Taiwan regions.

Region	Institution Authorization for the Master Degree	Institution Authorization for the Doctor Degree	Region	Institution Authorization for the Master Degree	Institution Authorization for the Doctor Degree
Beijing	8	4	Hunan	2	1
Jiangsu	6	2	Anhui	2	1
Hubei	6	2	Xinjiang	2	1
Shaanxi	6	2	Tianjin	2	1
Shandong	5	1	Hebei	1	1
Sichuan	4	0	Guizhou	1	1
Jilin	4	1	Heilongjiang	1	1
Henan	3	2	Guangxi	1	0
Guangdong	3	2	Inner Mongolia	1	1
Yunnan	3	2	Liaoning	1	1
Gansu	3	2	Shanghai	1	1
Zhejiang	3	1	Hainan	1	0
Shanxi	3	2	Ningxia	1	0
Fujian	3	1	Qinghai	1	1
Jiangxi	3	1	Xizang	0	0
Chongqing	3	1			

Data Sources: https://yz.chsi.com.cn/ (accessed on 20 August 2020).

4.3. The Bivariate Spatial Autocorrelation Analysis of Post-Graduate Geographical Talents Education

Spatial autocorrelation is an analysis method to study whether the value of a certain position in space is related to the value of its adjacent position and the degree of correlation. The local spatial autocorrelation measure (LISA) can reveal the spatial autocorrelation of adjacent regions within a local region. The LISA cluster diagram and significance map were obtained by GeoDa software 1.16 (20 October 2020) for 64-bit Windows. The Figures 1–6 show that there were three clusters between population scale, education quality, education input, and post-graduate geographical talents education in China, which showed significant spatial similarities and differences.

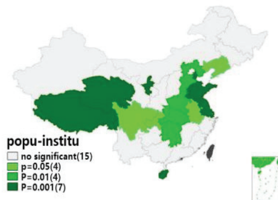

Figure 1. Local significance of population scale. (Data Sources: China education statistical yearbook, statistical yearbooks of provinces and cities, the sixth national census.)

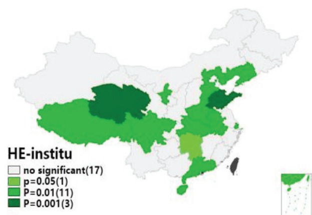

Figure 2. Local significance of education quality. (Data Sources: China education statistical yearbook, statistical yearbooks of provinces and cities, the sixth national census.)

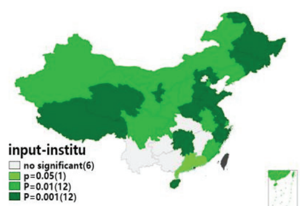

Figure 3. Local significance of education input. (Data Sources: China education statistical yearbook, statistical yearbooks of provinces and cities, the sixth national census.)

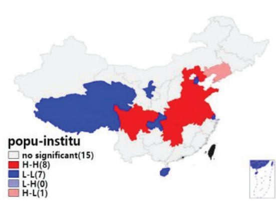

Figure 4. Local incremental clustering of population scale. (Data Sources: China education statistical yearbook, statistical yearbooks of provinces and cities, the sixth national census.)

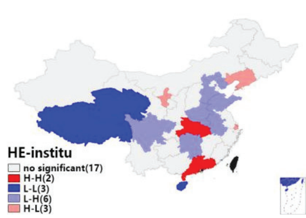

Figure 5. Local incremental clustering of education quality. (Data Sources: China education statistical yearbook, statistical yearbooks of provinces and cities, the sixth national census.)

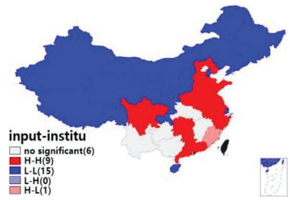

Figure 6. Local incremental clustering of education input. (Data Sources: China education statistical yearbook, statistical yearbooks of provinces and cities, the sixth national census.)

4.3.1. The Significant East-West Difference between Population Scale and Education

According to the analysis of the population scale of each province and the post-graduate geographical talents education institutions in China (Figures 1 and 2), it shows significant east-west difference.

There is an H-H cluster which means a large population with high education levels around Hebei, Shandong, Jiangsu, Henan, Anhui, Hubei, Hunan, and Sichuan province in the east of China. There is a significant correlation between population scale and geographical education institutions, among which Shandong and Jiangsu province are the most significant. Meanwhile, post-graduate geographical education in Shandong and Jiangsu province is well developed, and there are high-level talents education and training centers and basic conditions for professional research, allowing independent education and training of talents to meet the needs in economically, societally, resource, and environmentally sustainable development. Furthermore, there was an L-L cluster having less population and poor educational levels around Ningxia, Chongqing, Qinghai, and Tibet in the west of China. Although it has the support of national policy, the population scale is still in the low levels and cannot meet the basic conditions of high-level education and training, and the research direction is limited.

4.3.2. The East-West Difference between the Education Quality and Education

According to the analysis of the education quality of each province and post-graduate geographical talents education in China (Figures 3 and 4), it shows east-west differences.

There is an H-H cluster with a large population and high education levels around Guangdong and Hubei province in the east of China. Guangdong province has been developing rapidly in recent years and is located in the coastal region, bordering Hong Kong and relying on Hong Kong's education advantage to attract a large number of talents to promote the concentration of talents. Meanwhile, Hubei province has 66 colleges and universities, relying on Xiangyang, Yichang, Huanggang, Enshi, and other cities to establish a sound education network, forming its own advantages in talent attraction. Moreover, there is an L-H cluster that has a smaller population, but there are relatively good educational resources around Hebei, Shandong, Henan, Anhui, Hunan, and Sichuan province. Among them, Shandong provinces is the representative, whose number of net outflows of population has a certain impact on the quality of young people. Under the great pressure of exam-oriented education in Shandong province, students choose to study in the other province, leading to a large number of brain drains, which also caused the Shandong talents dilemma now. In recent years, economic development ranked in first place, but the development of education has not been fully planned, resulting in weak overall talents education and training and a fragile ecological environment and the need for professional talents to serve local sustainable capacity construction. Furthermore, there is an LL cluster with a smaller population and poor educational resources in Qinghai and Tibet in the west of China, whose geographical location is one of the main influences.

4.3.3. The Southeast-Northwest Difference between Education Input and Education

According to the analysis of the education input of each province and the post-graduate geographical talents education in China (Figures 5 and 6), it shows south-north differences and east-west differences.

There is an H-H cluster which means a large population with high education levels around Hebei, Shandong, Henan, Anhui, Jiangsu, Zhejiang, Guizhou, Guangdong, Sichuan province in the east of China. These have developed economies with a high investment in education, and have a sound education system. Moreover, there is an L-L cluster with a smaller population and poor educational resources around Heilongjiang, Jilin, Liaoning, Inner Mongolia, Shanxi, Shaanxi, Chongqing, Ningxia, Gansu, Qinghai, Xinjiang, Tibet, Tianjin, Shanghai, and Hainan province, generally in the north and west of China, with lower education investment. Although, in recent years, the north and west region of education investment has showed a rising trend among regions, the spatial pattern of education investment does not change its situation, and its input is still at the lower level in China with low attraction to talents, low population cluster ability, and few geographical education institutions [30].

5. Discussion

5.1. The Characteristics of Post-Graduate Geographical Talents Education

The educating and training orientation of post-graduate geographical institutions in China has its own characteristics, which are influenced by factors such as geography teacher's capability, resources and environment location, history of human activities, and laboratories and field observation stations.

5.1.1. The Global and National Scales' Characteristics in the Universities Directly under the Ministry of Education

A total of 22 universities directly under the Ministry of Education in China are authorized to grant post-graduate degrees in geography, of which 11 are authorized to grant doctor degrees in first-level disciplines (Table 1) and nine are authorized to grant master degrees in first-level disciplines. To sort out the post-graduate programs of geography in universities directly under the Ministry of Education, the education and training direction of master/doctoral students in the same university is the same. Therefore, the three second-level geography disciplines of physical geography, human geography, and geographic information system are used to compare the master/doctoral degrees in different universities, to summarize the overall characteristics of the education and training of post-graduate geographical talents in universities directly under the Ministry of Education of China.

The educating and training direction of physical geography post-graduate talents in universities directly under the Ministry of Education mostly focuses on the evolution of the physical geography environment on a global scale (Table 2). Meanwhile, universities also maintain the research characteristics of China's regional resources, environment, and disaster management. Beijing Normal University, Lanzhou University, and Shaanxi Normal University, as representatives of universities in northern China, focus on the research of landform and soil, water and soil conservation, and environmental changes in arid areas; southern universities such as Nanjing University and Sun Yat-sen University focus on hydrology, water resources, water environment, and drainage basin or coastal zone resources and environment; East China Normal University (ECNU) takes the physical geographical process of delta cities as the core direction, forming the research characteristics of the relationship between cities and estuaries and coasts; Southwest University has formed a world-class karst research system.

Table 2. The direction of geographical post-graduate education in universities directed by the Ministry of Education.

University	Physical Geography	Human Geography	Cartography and GIS
Peking University	Land science and resource management, global environmental change and ecosystems, resource and environmental information systems, river basin comprehensive planning and managing	Urban Geography, Economic Geography, Urban and Regional Planning, Tourism Geography and Urban Recreation Space Planning, Landscape Planning and Design	GIS structure and technology, Spatial data distributed computing, Intelligent Processing and Understanding of Spatial Information, GIS Modeling, Digital Earth/Cities, Spatial Information Engineering, Theory and Method of Spatial Information Mobile Application
Nanjing University	Surface process and global ecological environment evolution, land hydrology and water resources utilization, soil and land resource utilization	Land Planning and Management, Tourism Geography and Planning Culture, and Landscape Geography	Geography and GIS Theory, Digital Map and Applied Map Science, Planning and Resource Environmental Information Engineering, Virtual Reality Project
Lanzhou University	Geomorphology, environmental archaeology and historical climate, the present environmental processes, soil and geochemistry, tree ring climate and ecology, use of natural resources, ecological environment impact	Human Activities and Environmental Changes, Ecological Economy and Resource Environment Management, Urban Environment and Urban Planning, Tourism resources' employment and program	Mechanism remote sensing, Land Surface Processes, Hydrologic remote sensing, Quantitative Remote Sensing, GIS Environment Modeling, Space-time modeling theory and application of atmospheric environment remote sensing
Sun Yat-sen University	Environmental change and natural disasters, environmental assessment and planning, evaluation and utilization of natural resources	Regional and Sustainable Tourism Development, Regional Development and Urban and Rural Planning, Land resources exploit	Spatial Analysis and Intelligent Understanding, High performance geo-computation, Digital Earth and Smart City, Modeling and Application of Geographic Information System
Wuhan University	Water resources and water ecology, river-basin development, climate change and its environmental effects, surface processes and environmental evolution	Urban Geography and Urban Research, Economic Geography and Industrial Planning, Regional Development and Urban and Rural Planning, Resource Environment and Sustainable Development	GIS Software Development and Engineering Application, geographic information visualization and virtual reality technology, Digital Map Engineering, Digital Areas and Cities, Massive Spatial Data Access Technology, Earth-observing technology
Southwest University	Karstology and environmental change, urban landscape and disaster landscape, land use and soil environment	World Economic Geography, Land Use and Land Planning	Remote sensing of ecological environment, Urban remote sensing, Mapping Technology and Method
Beijing Normal University	Climate change and eco-environment response, natural geography in arid areas, environmental evolution, regional disaster	Urban geography and planning, regional analysis and planning, Globalization and Geo-Setting, Cultural Geography	Remote Sensing Mechanism, Remote Sensing Quantitative Retrieval, Analysis and Application of Remote Sensing Information, Geographic information analysis
East China Normal University	Urban landscape and environment, natural risk assessment and prediction, delta process, environmental evolution, global change	Economic Geography and Regional Innovation, Urban geography and urban economy, World Geography and Geopolitics, Political geography and administrative divisions, Cultural Geography and Local Development	Remote sensing science and application, GIS, Geo-computation, Map mapping and Visualization

Table 2. *Cont.*

University	Physical Geography	Human Geography	Cartography and GIS
Northeast Normal University	Synthetic physical geography, biogeography, climate change and regional responses, soil geography	Regional Economic Geography, Urban Geography and International Economic and Trade Geography of Urban and Rural Planning	Remote Sensing Information Analysis and Application Model, GIS theory and application development, Hyperspectral and Polarized Light Remote Sensing, Quantitative geography, Modern Cartography
Central China Normal University	Natural Resource Exploitation and Utilization, Ecological environment, Tourism Resources and Environment	Historical Geography and Healthy Sustainable Development, Regional Development and Urban and Rural Planning, Land resources exploit	Geographic Information Engineering, Geographic Information Science, Geographical simulation
Shaanxi NormalUniversity	Environmental evolution and man-land relationship, Global change and natural disasters, Land resources and land price assessment, Wind-blown sand dynamics	Population and health geography, Tourism Geography and Scenic Area Planning, Urban and Regional Research	Thematic Mapping, Resource and environment remote sensing, Digital Map and Geographical Modeling

Data Sources: https://yz.chsi.com.cn/ (accessed on 15 September 2020).

The educating and training direction of human geography post-graduate talents in universities directly under the Ministry of Education mostly focus on economic geography, urban geography, tourism and cultural geography, and land use planning technology and methods (Table 2). Peking University, East China Normal University, Sun Yat-sen University, and Northeast Normal University have formed their own characteristics in the fields of economic geography and urban geography. Beijing Normal University has strong capability in cultural geography and financial geography, while Nanjing University has advantages in land resources and land planning. The international influence of ECNU in world geography is becoming increasingly significant. The post-graduate education of human geography in universities directly under the Ministry of Education focuses on the theory and method of human-economic geography and its application in economic and social construction and attaches great importance to the contribution of geography to urban and rural planning, land use planning, tourism planning, population policy, and community governance.

The education and training direction of the geographic information system post-graduate talents in universities directly under the Ministry of Education attaches great importance to interdisciplinary integration with surveying and mapping, remote sensing, ecological environments, computers, and other disciplines and has been applied to social and economic construction, ecological and environmental change monitoring, and other fields of daily life. Wuhan University was the earliest research institution engaged in geographic information system, remote sensing, and surveying and mapping in China. It has leading advantages in this discipline, with rich research directions and strong practicability (Table 2). Peking University highlights the principles, methods, and applications the of geographic information system, Beijing Normal University focuses on remote sensing and geographic information system based on resource and ecological data, Nanjing University highlights the application of remote sensing in the ecological environment and territorial spatial planning, and Lanzhou University attaches great importance to the study of arid areas based on GIS. In general, the disciplines of geographic information science of each university are different, and the advantages of their respective theories, regions, and industries are highlighted to educate and train information geography post-graduate talents actively to meet future needs.

5.1.2. The Regional Comprehensiveness Characteristics in Provincial Normal Universities

Provincial normal universities are funded by the local financial support of the provinces under their administration. As an important part of China's higher education system, they aim to serve the economic and social development of the region and focus on educating and training high-quality talents for the region. There are 32 provincial normal universities in China with doctoral programs in geography, and 11 universities have doctoral programs in geography, including Nanjing Normal University, Capital Normal University, and Fujian Normal University. Except for Anhui Normal University, all of them are first-level doctoral programs. Combining with a provincial normal university geography graduate education scheme, the Nanjing Normal University, Capital Normal University, Capital Normal University, and Harbin Normal University geography are selected to summarize subject characteristics of provincial normal university graduate education in geography (Table 3).

Table 3. Main orientation of geography post-graduate education in provincial normal universities.

University	Physical Geography	Human Geography	Cartography and GIS
Nanjing Normal University	Quaternary Geology, Environmental Change and Global Change, Ground process and geomorphology simulation	Rural Geography and Urban and Rural Development, Tourism Geography, Resource and energy development, utilization and sustainable development, Geopolitics	Spatial Structure and Mechanism of Geographic Information; The acquisition, modeling, processing, processing, expression and application of geographic information; Spatial cognition theories, Simulation of Cognitive Law of Geographical Space
Capital Normal University	Water and soil environmental process and restoration, Ecological Environment and Regulation	Industrial development and spatial layout, Urban Development and Its Spatial Structure, Regional and Urban Planning	3D spatial information acquisition and expression, Water Resources Management Information System of Remote Sensing Technology and Geoscience Application
Hunan Normal University	Mechanism of River—Lake Interaction in Dongting Lake Basin, Sustainable Utilization of Land Resources in Typical Subtropical Areas, Environmental Geochemistry and Ecological Restoration	Urban Geography and Regional Sustainable Development, Regional Development and Urban and Rural Planning, Regional Economy and Regional Planning	Resource and Environment information system, Geospatial Modeling and Analysis, Remote Sensing Monitoring and Assessment of Resources and Environment
Harbin Normal University	Synthetic Physical Geography, Biogeography and Ecological Restoration, Soil Ecology	Regional Economic Geography, international economic geography, region and urban development	Quantitative Remote Sensing, Spatial Analysis and Environmental Remote Sensing, intelligent information mining

Data Sources: https://yz.chsi.com.cn/ (accessed on 15 September 2020).

The post-graduate Program of Physical Geography in Provincial Normal University focuses on local resources and environmental conditions. Fujian Normal University and Hunan Normal University focus on regional characteristics, which focus on the geographical advantages of Fujian and Taiwan as well as the regional characteristics of humid subtropical zone, subtropical climate, and the mechanism of river and lake action in the Dongting Lake basin. Meanwhile, Harbin Normal University focuses on black soil and forest ecology. Moreover, Capital Normal University focuses on environment and water resources management in urban and urbanized areas, and Nanjing Normal University focuses on land surface processes and resource utilization in monsoon environments. In general, the education and training of physical geography post-graduate talents in provincial normal universities focus on the background conditions of local resources and environment, focus on the sustainable utilization of provincial resources and environment, and focus on the evolution of important natural elements (rivers/lakes/seas), soil, water and forest and their externality governance. Compared with the target of physical geography graduates in universities directly under the Ministry of Education, the focus of physical geography graduates in provincial normal universities on the breadth and scale of physical geography elements is less, and they are more inclined to focus on local comprehensive research.

The post-graduate education of Human Geography at Provincial Normal University focuses on the economy, tourism, land use, and transportation of the province and its adjacent regions, with particular emphasis on urban industrial development, land use planning, tourism planning, and population policy. Compared with the research of human geography in universities directly under the Ministry of Education, the research fields of cultural and social geography, administrative regionalization, and geopolitics are lacking. The deep reasons are as follows: firstly, there is a lack of scientific and educational personnel in the corresponding fields; secondly, taking education as the main task leads to difficulties in opening or elective courses in some fields, which leads to the closed structure of the malignant accumulation cycle and fails to promote the overall progress of human geography.

There are significant differences in the orientation of GIS education in provincial normal universities. The discipline of Maps and Geographic Information System in Nanjing Normal University is the most mature with a wide range of research scopes, and its overall strength is inferior to Wuhan University, Institute of Geographic Science, and Natural Resources Research, CAS, and Chinese Academy of Surveying and Mapping. Shanghai Normal University concentrates on urban remote sensing and urban GIS application, while Hunan Normal University focuses on spatial big data acquisition and application, and Capital Normal University focuses on land subsidence data processing, 3D data acquisition and analysis, and the water resources management information system.

5.1.3. The Provincial Characteristics in Provincial Comprehensive Universities

The education and training of post-graduate geography talents in provincial comprehensive universities focuses on provincial characteristics. It indicates that the development level of geography in provincial comprehensive universities is general, and there is a big gap compared with the universities directly under the Ministry of Education and the provincial normal universities. The education and training schemes of geography graduates in provincial comprehensive universities were sorted out, and the characteristics of the education and training of geography graduates among different universities in the secondary discipline of geography were compared (Table 4).

The regionality of post-graduate geographical education in provincial comprehensive universities is very significant. Through the comparison of the educating and training direction of physical geography, it is found that the research characteristics of desertification and soil and water conservation, arid and semiarid, and loess plateau physical geography in Northwest University and Xinjiang University are distinct; Yunnan University's focus on international rivers and the confluence of the three rivers is remarkable in its natural and cultural features; Henan University focuses on resources and environmental issues in the middle reaches of the Yellow River. There is little difference in the orientation of human geography post-graduate education, which generally concentrates on the fields of land use and urban and rural planning, industrial geography and regional development, tourism geography, and tourism planning. The orientation of GIS education is mainly based on the comprehensive application of 3S technology in the study of physical and human geography in specific regions, with general emphasis on GIS spatial analysis, remote sensing data processing, and the development of special GIS platforms, etc. Compared with the research contents of universities directly under the Ministry of Education, it lacks in-depth innovation.

Table 4. Characteristics of geographical post-graduate education in provincial comprehensive universities.

University	Physical Geography	Human Geography	Cartography and GIS
Northwestern university	Land use change, relationship between changes in natural environment and human activities, Natural Geography of Loess Plateau, water resources and watershed water environment, natural disasters and prevention	Urbanization and its Resource and Environmental Effects, Urban and Rural Planning and Management, Regional Development and Planning of Industrial Development and Spatial Structure, Tourism Geography and Tourism Impact	Surface Information Detection Technology, Geospatial Information Management and Processing Technology, GIS Spatial Analysis, remote sensing digital image processing, Digital Terrain Analysis and Modern Surface Process Simulation
Henan university	Environmental planning and management, Sustainable use of regional natural resources, Landscape Ecology and Biogeography	Integrated urban development, the tourism development and the plan, Urbanization and Urban Sustainable Development, Urban and Rural Planning and Design	Regional Simulation and Urban Information System, Resource Environment and Ecological Remote Sensing, Virtual Geographical Environment and Geovisualization, spatial data analysis and sharing services
Yunnan university	Karst Environment, plateau mountain disasters, sustainable use of natural resources, International Hydrological and Water Resources	Territorial Spatial Planning, Natural Resource Management and Land Use Planning, international rivers and regional cooperation, mountain disaster risk management	Geographic Information System for Mountain Resources and Environment, Method and Application of Remote Sensing Technology, Development of Land Resource Management Information System
Ningbo University	Coastal Zone Development and Wetland Protection, Resource Environment and Regional Sustainable Development, Global change and natural disasters	Urban and Rural Development and Regional Planning, urban cultural and creative industries, Seaport Traffic and Urban Habitat Environment	Land resource management 3S application, Intelligent Interpretation and Typical Application of Coastal Zone Remote Sensing

Data Sources: https://yz.chsi.com.cn/ (accessed on 15 September 2020).

5.2. The Spatial Difference of Post-Graduate Geographical Talents Education

The economic development of China is divided into three regions: the eastern region (13 provinces/autonomous regions), the central region (nine provinces/autonomous regions), and the western region (10 provinces/autonomous regions). The number of universities with authorization for a master/doctor degree in geography in the three regions show: (1) there are 35 and 14 universities in the eastern region, 25 and nine in the central region, and 24 and 10 in the western region, respectively. These results indicate that the spatial distribution of post-graduate geographical education institutions in China is unbalanced, and the main talent education institutions are concentrated in the eastern developed provinces. High-level talent educating and training centers in regional geography, such as Wuhan, Xi'an, Lanzhou, and Kunming, have taken shape in the central and western regions, but the overall strength is weak, and the discipline influence is low. The education and training of post-graduate geography talents in eastern provinces has improved, with Beijing, Nanjing, and Guangzhou forming three major educating and training centers for geography doctoral students. However, there are no doctoral centers in geography in colleges and universities in Zhejiang, Hainan, and Guangxi, where the economic development level is better in the eastern region. (2) The vast central and western regions of China have fragile ecological environments, as well as the headwaters of the Yangtze River and the Yellow River and Mount Qomolangma. The talent base for resource and environment utilization and sustainable economic and social development is weak. Therefore, it is urgent for geographical institutions to produce a large number of talents to serve local sustainable capacity construction. At the same time, facing the implementation of the national "One Belt and One Road" initiative and the maritime power strategy, eastern coastal provinces such as Zhejiang, Hainan, and Guangxi need more land–sea coordinated geographical researchers to solve the practical problems of marine ecological civilization, marine territorial governance, and national maritime rights and interest protection [31]. However, Ningxia, Xizang, Shanxi, Sichuan, Zhejiang, Hainan, Guangxi, and other provinces/regions have not been approved by the state to set up geography doctor authorization centers, and a high-level geography personnel education system has not been formed, making them the weakest provinces in the development of higher geography education in China [32,33]. This has formed a significant talents demand and the lack of institution for spatial dislocation characteristics.

5.2.1. The Spatial Imbalance of Post-Graduate Geographical Talents Education

The number of post-graduate geographical education institutions is an important aspect of the development quality of geography in the region. The distribution of post-graduate geographical education institutions in Chinese universities is unbalanced, which significantly clusters in the mega-central cities and have characteristics of regional gradient distribution. Beijing, Nanjing, Lanzhou, Xi'an, Wuhan, Guangzhou, Kunming, and Changchun, as the central cities of higher education in China, also take a leading position in the geographical post-graduate talents, and the authorized number of master/doctoral programs is far more than that of other provinces. Shandong, Hunan, Henan, and 17 other provinces belong to the second tier, which merely has a university authorization for the doctor degree and 2–5 universities with authorization for the master degree. Sichuan, Zhejiang, Guangxi, Hainan, Ningxia, Shanxi, and Tibet belong to the third tier, whom have no university authorization for the doctor degree, and Tibet even has no university authorization for the master degree. These provinces have slower geography development of post-graduate education, and post-graduate education capacity lags behind, seriously affecting the sustainable development of the talents supply and leading to a significant spatial imbalance.

5.2.2. The Significant Spatial Stratification of Post-Graduate Geographical Talents Education

A total of 22 universities directly under the Ministry of Education in China are authorized to educate and train geographical post-graduate talents, 11 of which are authorized to educate doctoral students. Their talents education and training directions are broad, ranging from global scale to national scale or urban scale research, and the research content is relatively comprehensive. Provincial normal universities are the main body of post-graduate geographical education in China, and there are 32 universities with geography authorization. Compared with the universities directly under the Ministry of Education, the research scale and research content of post-graduate geographical education in provincial normal universities focus on the province as a whole, forming a geography discipline system with local characteristics. As a whole, the geography graduates in provincial comprehensive universities are similar to those in provincial normal universities in terms of field and content, but they pay more attention to application. The education level of geography graduates in the three types of colleges and universities directly affiliated with the Ministry of Education, provincial normal universities, and provincial comprehensive universities presents significant hierarchical characteristics. The direction of geography graduates in universities directly under the Ministry of Education focuses on all three-level disciplines of geography at global and national scales, which are the most comprehensive. Provincial normal universities and provincial comprehensive universities aim to educate and train geographical post-graduate talents who serve the ability of local sustainable development, and the direction focuses on the local: the ability of local comprehensive development and the regulation of the core shortcoming elements of local sustainable development.

5.2.3. The Increasing Prominence of Comprehensive Regional Characteristics of Post-Graduate Geographical Talents Education in Provincial Universities

Regional and local comprehension is the difference between other subjects and is one of the essential characteristics of geography. China attaches great importance to the local resources of post-graduate education in geography environment background conditions associated with human activities and the evolution law. Vigorously, developing China can solve the geography of the local economic and social development and resources and environment conservation research talents. The education and training of geographical post-graduate talents in universities directly under the Ministry of Education attaches great importance to the evolution of natural or human factors at the global or national scale and the mechanism basis of their interaction with other factors and tries to explore global sustainable development goals and explain their regional capacity differentiation. For example, Southwest University has established a series of courses in karst science, and East China Normal University has established delta science and global city studies. The education and training of geographical talents in provincial normal universities and provincial comprehensive universities focus on educating and training high-quality talents for the local areas, and the regional comprehensiveness of the training of talents is more significant. For example, the confluence of the Three Rivers in Yunnan University, the desertification and soil and water conservation in Xinjiang University and Ningxia University, and the coastal resources and wetland protection in Liaoning Normal University and Ningbo University all reflect the regional characteristics of the education and training of geographical talents in local universities.

6. Conclusions

The study found that post-graduate geographical talents education has strong interregional differentiation and imbalance. A series of challenges should break through during the transition between post-graduate geographical talents education and the work of serving local resources and environmentally friendly utilization and sustainable development capacity. To optimize the spatial production pattern and characteristics of geographical post-graduate education, it is urgent to take a series of measures to balance the spatial production of geographical post-graduate talents and further improve the quality of geographical post-graduate education. At the same time, after globalization and the knowledge-based economy, the mobility of international talents is increasing. Facing the uneven distribution and development of geographical education resources between regions, how to cultivate post-graduate geographical talents for a more comprehensive development is currently a problem that needs to be solved.

6.1. Coordination with Degree Authorization for Regional Post-Graduate Geographical Talents

To match the production of geographical talents with the governance needs of China's ecological environment and territorial space, authorization for a master and doctor degree for regional geographical post-graduate talents should be balanced. The central and western regions of China lack geographical post-graduate education institution. Meanwhile, these regions are rich in natural resources and fragile in ecological environment, which are of high research value. To realize the linkage development of the Higher Education System of Geography and Economic and Social Construction, Resource and Environmental Protection, and Territorial Spatial Planning, the authorization for a geographical master and doctor degree should be balanced in China.

6.2. Consideration with Multi-Disciplinary Construction to Educate and Train Geographical Talents

In the era of information geography, multi-disciplinary areas should be paid attention and actively adapted to the education mode of geographical post-graduate talents. The geographical post-graduate education should strengthen the ability of inquiry-based learning, project study, field observation, investigation, and analysis. With the vigorous development of the new knowledge-based economy, talent competition and cross-regional flow of talent have become increasingly fierce around the world. The geographical post-graduate education should organically combine talents education and training with scientific research, and strengthen discipline critical thinking and theoretical construction ability education and training. Moreover, the structure of multi-disciplinary graduate courses should be constructed, while the content of courses should be optimized. Reformation of the management system of enrollment and training and graduation of multi-disciplinary graduates to provide a sound atmosphere for the education and train of innovation ability of geographical post-graduate talents are important.

6.3. Cooperation with World-Class Universities or Neighboring Countries to Educate and Train International Geographical Talents

Local universities in China should be based on the regional construction of geography, actively strengthen the global perspective of post-graduate education and the global learning ability of advanced technology, and solve the organic integration of local synthesis and globalization in the talents education and training process. Therefore, it is necessary to educate and train the integrity, diversity, spatial thinking, global, and local vision and general quality of prospective geographers, increase national and world geography-related courses, strengthen the application of multi-scale remote sensing and geographic information technology in daily scientific research, and form the characteristic direction of geography majors in provincial universities.

The development of science and technology has led geography into a new era. In the new era, geography has become interdisciplinary, regional, and comprehensive, which is very consistent with the sustainable development goals. Facing the requirements of the sustainable development goals, it is necessary for countries around the world to strengthen high-level talents in geography education, and pay attention to the regional differences and imbalances of geography education. The government should use a series of means such as capital regulation, resource redistribution, and education strengthening to reduce the differences between regions, adjust the geography professional training system, and optimize its curriculum structure and training mechanism to alleviate the unreasonable flow of high-level talents.

Finally, this research has potential room for improvement, and there is an urgent need for further research. Theoretically, equal accessibility to post-graduate geographical talents education and training should be proposed in the next step, which includes more detailed demographic and spatial data, by which we can identify the spatial differentiation more accurately. Equal accessibility to post-graduate geographical talents education and training can further solve equal distribution, which results from incomes, age structures, education levels, and other complicated conditions, and can lead to social injustice. In future research, questionnaires and social surveys should be carried out urgently, in order to reveal injustice in the accessibility of post-graduate geographical talents education and training. Methodologically, the previous research was limited by demographic and spatial data, and the data of different situations, which would be improved in the future research. Therefore, the next research will incorporate more complicated situation data into the model in order to gain more accurate results, and thereby could more effectively reflect the spatial differentiation.

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Developing a Coding Scheme for Exploring Preservice Science Teachers' Metacognition in a Method Course

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Abstract: Promoting metacognition in preservice science teachers (PSTs) is necessary for effective science teaching. However, metacognition is an abstract attribute that requires in-depth investigations with qualitative methods. This study aimed to express the process utilized to develop a coding scheme of PSTs' metacognition (CSPM). Methods: This study started with a review of the metacognition conceptual framework. Next, the researchers collected data about PSTs' metacognition from a metacognitive self-report (MS) and a metacognition interview protocol (MIP). The participants were 22 third-year PSTs who studied at one public university. All data were analyzed for codes by using content analysis. Results: The CSPM consisted of 177 codes that can be divided into two main components and six subcomponents. The validity of the CSPM was checked by a panel of experts through the item–objective congruence index (IOC) into two different levels: an IOC between codes and components of metacognition, and an IOC between codes and levels of metacognition. The IOCs of the CSPM in the two levels were acceptable. In conclusion, the CPSM was a qualified coding scheme for qualitatively analyzing metacognition in PSTs as well as other types of participants. This study also pointed out an urgent need to develop metacognition in PSTs.

Keywords: metacognition; pre-service science teacher (PST); coding scheme; method course; qualitative research

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1. Introduction

In a global view, the United Nations (UN) [1] announced the "Transforming our world: The 2030 agenda for sustainable development" document, a plan of action for people, the planet, and prosperity. All countries and stakeholders are expected to work collaboratively as partners to implement this agenda. The 2030 agenda for sustainable development consists of 17 sustainable development goals and 169 targets. Goal 4 mentions the aim to "Ensure inclusive and equitable quality education and promote life-long learning opportunities for all" (p. 18). In detail, Goal 4.7 mentions that "By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and culture's contribution to sustainable development" (p. 21). Metacognition is one of the important elements of the sustainable development of human beings. It refers to a person's ability to think and reflect on one's thinking process itself, which monitors and controls his or her cognitive ability [2]. There are multiple examples to support the relationship between metacognition and sustainable development, e.g., ref. [3] proposes a metacognitive instruction model for developing EFL speaking competence or skills. They found that Chinese EFL teachers might want to help their students in the sustainable learning of EFL speaking. In relation to [4], drinking-related metacognitive awareness can be improved by metacognitive guidance that directs students to think critically about healthy drinking. Metacognitive guidance holds a significant pedagogical potential to improve sustainable healthy habits among children.

In a national view, Thailand has announced the vision of the National Education Plan of Thailand [5], which states that "All Thais must be able to receive a high quality of education and life-long learning. They must be able to lead a happy life in line with the principle of self-sufficiency economy and changes in the 21st-century world. Intentional learning strategies for lifelong learning requirements of addressing students' need for higher-order abilities in thinking and learning, intentional learning helps students develop the general metacognitive and self-directed learning skills that facilitate autonomous lifelong learning" [6,7]. In being a lifelong learner, an individual person demands metacognitive thinking. In education, to help learners attain metacognition, a teacher must first attain metacognition himself/herself. Additionally, in the case of future teachers as preservice teachers, a teacher preparation program must prepare metacognition in preservice teachers. Metacognition should be set as a desirable attribute of preservice teachers and developed in preservice teachers in a teacher preparation program. In pursuing this, we expect that all preservice teachers will graduate from universities with the required level of metacognition that is sufficient for them to further develop metacognition in the students that they teach.

Metacognition is not new, as it is historically rooted in educational research from about four decades ago. The definition of metacognition was first delivered by Flavell, a developmental psychologist. He defined metacognition as an individual's ability to monitor, regulate, and orchestrate their cognitive processes to attain a particular objective [8,9]. Later this concept was adjusted [7,8,10–12], such that metacognition generally consisted of two main components: (a) metacognitive knowledge and (b) metacognitive regulation. In addition, metacognition is defined as how individuals monitor and control their cognitive processes [13]. Although the definition of metacognition and its components is not universally defined, educators are commonly aware that metacognition is a desirable and important attribute for individuals who aim to be successful and lifelong learners [14].

In the context of science teaching and learning, effective teachers must attain effective teaching skills and deliver efficient teaching [15,16] to help students learn. Teachers with metacognition will be able to understand student learning and achievement in their tasks. Various studies have affirmed that teachers with metacognition could effectively help their students reach the targeted learning objectives. Metacognition, therefore, is related to the development of students' learning processes [8–10,17–21]. The explanation for this is that learners with metacognition are expected to be able to monitor, control, and regulate their learning until achieving learning goals. When learners understand their thinking and can regulate it effectively, they will be better learners.

Metacognition yields several advantages for teachers and students. The authors of [22] stated that teachers' metacognition is essential for teaching students to develop higher-order thinking. To cultivate metacognition in science learners, teachers are required to develop their metacognition first to ensure that they are able to correctly communicate metacognition as well as enhance their students' metacognition. Thus, it is critical to develop metacognition in preservice science teachers (PSTs), who will soon be science teachers serving the nation. In general, there was a lack of integration of metacognition in science classrooms [23]. In addition, science teachers could not explore and facilitate the development of metacognition in their teaching of science [24].

There are two major approaches to exploring metacognition: quantitative and qualitative approaches. From a literature review, there are 12 kinds of quantitative instruments: (1) a metacognitive awareness inventory for use with in-service teachers [25], (2) a metacognitive reading awareness inventory [26], (3) a taxonomy of metacognitive activities [27], (4) a metacognitive awareness of a reading strategies inventory [28], (5) a state metacognitive inventory [29], (6) reading strategy use [30], (7) a meta comprehension strategy index [31], (8) a metacognitive awareness inventory [32], (9) a junior metacognitive awareness inventory [33], (10) a physics metacognition inventory [34], (11) a learning and study strategies inventory [35], and (12) a metacognition scale [36]. However, there are rarely research instruments specifically designed for exploring PSTs' metacognition. It is necessary for metacognition to be included in a series of university activities, such as seminars and classroom action research. Teacher educators should offer approaches, techniques, and methods that help PSTs reflect on their metacognition [37,38]. However, it will be very difficult for teachers to contribute to students' metacognition if they cannot improve their own metacognition [39]. According to [40], a PST program is required to promote teachers' metacognition ability, which will be required as one of the key competencies to be a professional teacher. Therefore, metacognition is proposed as one essential factor for teacher development.

Metacognition is genuinely an abstract attribute in educational research. To study such abstract attributes, several qualitative methods are proposed, such as self-reports, worksheets, interviews, observations, and think-aloud protocols [41]. There was an upward trend in using qualitative data collection methods in research on metacognition. Several science education researchers currently prefer to use qualitative approaches to explore and report their research results. However, there are some concerns with using qualitative data collection methods in research on metacognition. Self-reports and in-depth interviews may rely heavily on participants' writing and speaking abilities, respectively. Science teachers require such qualitative instruments to investigate their students' metacognition.

Although qualitative instruments are important in studying metacognition when deriving data, the qualitative analysis of metacognition is also very difficult. There was a lack of a coding scheme for analyzing data about metacognition. From the literature review, two studies dealt with the coding of metacognition [42,43]. However, no study proposed a coding scheme and the differentiation of metacognitive levels among the codes. This study, therefore, aimed to develop a coding scheme of PSTs' metacognition (CSPM). This study focuses on three research questions:

1. What are codes and their components in the CSPM?
2. What is the quality of the CSPM?
3. What is the quality of the CSPM in differentiating PSTs' levels of metacognition?

2. Methods

This study is qualitative in nature. There were two qualitative research instruments that were used to collect data about metacognition in PSTs: a metacognitive self-report (MS) and a metacognition interview protocol (MIP). The data collected from the MS and MIP were qualitatively analyzed using content analysis. The context of this study was one public university located in the northeast region of Thailand. The duration of this research was from May 2019 until November 2019. The data collection was conducted in a 16-week method course that took 48 h in total (3 h a week). This method course is a three-credit course in a Bachelor of Education (B.Ed.) degree majoring in general science at the Faculty of Education. The method course description is "Principles and theoretical framework of science education, Teaching models and techniques, and Performing micro-teaching of science were integrated with metacognition". The total credits of the B.Ed. curriculum in general science at the Faculty of Education amounted to 173 credits. Overall, the B.Ed. curriculum in general science is divided into three major sections: general courses, required courses, and elective courses. All PSTs are required to take general courses in common. Required courses include both scientific content and pedagogy. PSTs can freely choose elective courses related to their own interests. The method course that was the context of this study was included as one of the required courses. The methodology is shown as the steps to designing the CSPM in Figure 1.

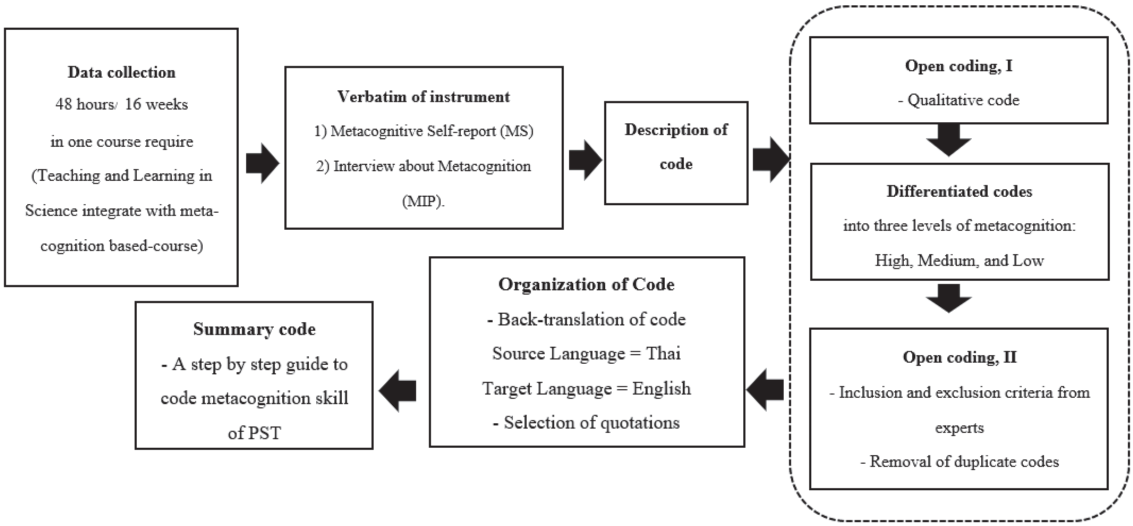

Figure 1. Diagram of the methodology of the CSPM.

2.1. Research Participants

Purpose sampling was used to select participants in the CSPM. The participants were 29 fourth-year PSTs majoring in the general science education program enrolled in the 2019 academic year. There were 16 females and 6 males. The data used for developing CSPM came from 22 PSTs. Seven PSTs were excluded from the data analysis because they did not respond to the MS and attend the MIP. In addition, they participated in the method course lower than 80% of the total hours. This study was submitted to, and the research ethics were reviewed by, the Mahidol University Institutional Review Board (IRB) before the collection of real data.

2.2. Research Process

To answer each research question, the researchers accomplished the following research process.

2.2.1. RQ 1: What Are the Codes and Their Components in the CSPM?

- Review, analyze, and synthesize the theoretical framework of metacognition.
- Apply the theoretical framework of metacognition in coding raw data collected from PSTs in the method course.
- Eliminate the redundant codes and reach the first draft of the CSPM.

2.2.2. RQ 2: What Is the Quality of the CSPM?

The researchers asked five experts to check the correspondence between the codes and components of metacognition. These experts graduated in the fields of science education, educational measurement and evaluation, educational guidance, and psychology education.

- Revise the CSPM according to the experts' comments and reach the second draft of the CSPM.

2.2.3. RQ 3: What Is the Quality of the CSPM in Differentiating PSTs' Levels of Metacognition?

- The researchers developed three groups of codes to differentiate three levels of PSTs' metacognition (high, medium, and low). Then, five experts were asked to check the correspondence between the codes and levels of metacognition.

- Revise the CSPM according to the experts' comments and reach the third draft of the CSPM.
- The researchers conducted back translation by asking two experts in both English and Thai to check the correspondence between the original language (Thai) and the translated language (English).

2.3. Data Collection and Analysis

Two qualitative research instruments, i.e., the MS (Appendix A) and MIP (Appendix B), were used to collect data about PSTs' metacognition. There were four items in the MS (Appendix A) and nine interview questions in the MIP (Appendix B). Raw data about PSTs' metacognition from both instruments were gathered and then coded based on the theoretical framework of metacognition by using content analysis. Content analysis was appropriated in determining the presence of certain words, themes, or concepts within some given qualitative data (i.e., texts). Using content analysis, researchers can quantify and analyze the presence, meanings, and relationships of such certain words, themes, or concepts [44–47]. The final product of content analysis was the CSPM. The validity of the CSPM was evaluated by a panel of five experts in the field of science education, educational measurement and evaluation, educational guidance, and psychology education through the item–objective congruence index (IOC). The IOC of the CSPM was categorized into two different levels: a correspondence of the codes and components of metacognition, and a correspondence of the codes and levels of metacognition. The CSPM was verified by the IOC in two steps: (a) to assure the content validity of the codes and (b) to clarify the quality of the codes.

2.4. Trustworthiness

This study employs methodological triangulation to ensure the external validity of this study. Methodological triangulation involves the use of different methods to collect the same source of data [48]. Methodological triangulation was conducted in this study through the use of different data collection methods to collect the same data, such as the use of the MS (self-report type of data collection) and MIP (interview type of data collection) to collect data about PSTs' metacognition.

3. Results

3.1. RQ 1: What Are the Codes and Their Components in the CSPM?

There were eight steps in developing the CSPM, as shown in Table 1.

Table 1. Steps for developing the CSPM.

Step	Description
Step 1: Determine a theoretical framework of metacognition.	• Review the literature related to metacognition. • Determine the theoretical framework of metacognition.
Step 2: Collect data from PSTs through the MS and MIP.	• Collect data from 22 PSTs by using the MS and MIP throughout the method course.
Step 3: Conduct open coding according to the theoretical framework.	• Conduct open coding with raw data from the MS and MIP. • Conduct axial coding to connect between the main codes into subcategories. • Conduct selective coding to reach a theme of the codes. • Check the meaning of the categories and the accuracy of the codes.
Step 4: Check the IOC of the first version of the CSPM.	• Five experts were asked to check the IOC (Appendix C, Table A1) of the CSPM through the correspondence between the codes and components of metacognition.
Step 5: Revise the CSPM.	• Researchers revised codes according to the experts' suggestions.

Table 1. *Cont.*

Step	Description
Step 6: Differentiate codes in the CSPM into three different levels.	• Researchers differentiated the codes into three levels of metacognition: high, medium, and low.
Step 7: Check the IOC of the second version of the CSPM.	• Five experts were asked to check the IOC (Appendix C, Table A2) of the CSPM through the correspondence between the codes and levels of metacognition.
Step 8: Conduct back translation and reach the final version of the CSPM.	• Two language experts were asked to participate in the back translation process in order to check the clarity and accuracy of the languages used.

From step one: Determine a theoretical framework of metacognition, as in Table 1. Referring to [9], the term "metacognition" referred to an individual's awareness and consideration of his or her own cognitive processes and strategies. Since then, a variety of interpretations have been provided regarding the term "metacognition", which makes this term "fuzzy" [49]. This being the case, metacognition is not universally defined. Based on [8,9,50], metacognition refers to an individual's ability to monitor, regulate, and orchestrate their cognitive processes to attain a particular objective. Metacognition generally consists of two main components: (1) metacognition knowledge (knowledge of cognition) and (2) metacognition regulation (regulation of cognition) [8,10–12].

Referring to [8,51], there are two components of metacognition: (1) Metacognitive knowledge refers to what a person knows about his or her own cognitive processes [8,52–54] or the strategies a person uses to oversee his or her own learning. This component consists of three subcomponents: declarative knowledge, procedural knowledge, and conditional knowledge. In addition, metacognition regulation refers to essential skills/actions that authorize an individual person to control their own learning. This component consists of three subcomponents: planning, monitoring, and evaluating [8–10,32,55].

In summary, Figure 1 represented the theoretical framework of metacognition used in this study for the subsequent coding process. PSTs with metacognition, according to the theoretical framework of metacognition in this study, should possess metacognitive knowledge (MK) and metacognitive regulation (MR). Regarding MK, PSTs should possess declarative knowledge (DK), procedural knowledge (PK), and conditional knowledge (CK). In addition, PSTs should possess MR, which consists of planning, monitoring, and evaluating. The theoretical framework of metacognition, as shown in Figure 2, was then used as a basis to analyze all of the codes derived from the MS and MIP.

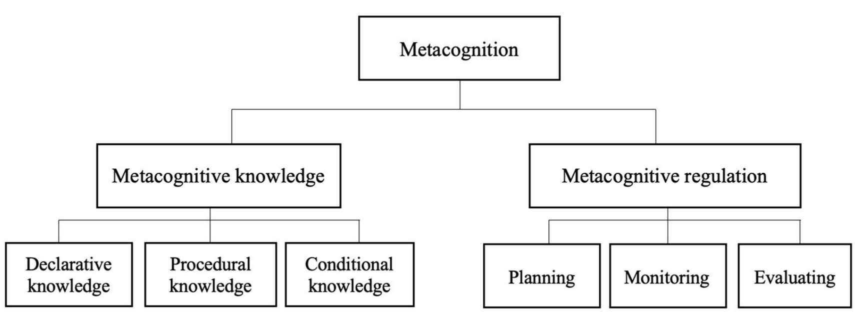

Figure 2. The theoretical framework of metacognition as a basis for analyzing the codes in the CSPM.

The description of each subcomponent of the theoretical framework of metacognition being used as a basis for analyzing the codes in the CSPM in this study are illustrated in Table 2.

Table 2. Descriptions of the subcomponents of the theoretical framework of metacognition.

Subcomponent	Description
Declarative knowledge (MC-DK)	Knowledge about one's own understandings, skills, and wisdoms as a learner, including an awareness of the various factors affecting his/her own learning process.
Procedural knowledge (MC-PK)	Knowledge about various methods or procedures and how to appropriately choose a specific method or procedure for solving a particular problem or accomplishing a particular learning goal.
Conditional knowledge (MC-CK)	Knowledge about the conditions potentially affecting one's learning.
Planning (MR-P)	Regulation of the prediction and preparation for accomplishing a particular learning goal.
Monitoring (MR-M)	Regulation of the monitoring of one's own learning and managing or controlling intellectual processes.
Evaluating (MR-E)	Regulation of collecting data, analyzing, and evaluating one's own learning performance.

3.2. *RQ 2: What Is the Quality of the CSPM?*

The researchers analyzed raw data obtained from 22 PSTs' MSs and MIPs according to the subcomponents of metacognition shown in Table 2. After that, the frequency of each subcomponent of metacognition was counted and calculated for its percentage. The results of the frequencies of each subcomponent of the CSPM are shown in Table 3.

Table 3. The frequencies of the subcomponents of the CSPM.

Subcomponent	Frequency	%
MC-DK	773	51.26
MC-PK	174	11.54
MC-CK	51	3.38
MR-P	302	20.03
MR-M	140	9.28
MR-E	68	4.51
Total	1508	100.00

There were 1508 codes in total derived from 22 PSTs' MSs and MIPs collected throughout 16 weeks of the method course. The three most frequent subcomponents were MC-DK (51.26%), MR-P (20.03%), and MC-PK (11.54%), respectively. After that, these codes were checked and the redundant codes were excluded until the number of codes was derived, as shown in Table 4.

Table 4. Number of codes after reducing the redundant codes in each subcomponent of the CSPM.

Subcomponent	Frequency	%
MC-DK	75	34.40
MC-PK	23	10.55
MC-CK	14	6.42
MR-P	36	16.51
MR-M	40	18.35
MR-E	30	13.76
Total	218	100.00

For Table 4, the first version of the CSPM consisted of 218 codes that could be allocated into six subcomponents of metacognition. The three most frequent subcomponents were MC-DK (34.40%), MR-M (18.35%), and MR-P (16.51%), in that order. The examples of raw data and how to code them according to each subcomponent of the CSPM are shown in Table 5.

The MC-DK 004 code was very popular for PSTs, it being expressed 99 times by them. The examples of the MC-DK 004 code expressed throughout the method course by PSTs are shown below.

From Table 6, it can be seen that codes of the MC-PK (f = 13), MC-DK (f = 10), and MR-E (f = 6) subcomponents were highly excluded from the second version of the CSPM.

Table 5. Examples of each subcomponent of the CSPM.

Subcomponent	Example of Raw Data	Assigned Code
MC-DK	I realized the importance of my prior knowledge that can hinder or support my learning every week.	MC-DK 004
MC-PK	I learned the way to find the answer to the question I'd like to know or did not understand by myself.	MC-PK 019
MC-CK	I have learned that I can find many solutions, not performing one way until not achieving and then stopping.	MC-CK 010
MR-P	I have learned that well-prepared teaching is very important. We must prepare all tools will be used in teaching beforehand.	MR-P 019
MR-M	During learning, I found that providing an opportunity for learners to conclude knowledge by themselves is an important part of their learning.	MR-M 029
MR-E	I obtain a better understanding of metacognition after I learn in this course.	MR-E 001

The MC-DK 004 code was very popular for PSTs, it being expressed 99 times by them. Examples of the MC-DK 004 code expressed throughout the method course by PSTs are shown below.

MC-DK 004: Realization of the importance of prior knowledge that can hinder or support PSTs' learning every week.

> "*After this method course, I think that I am confident in integrating metacognition in my science teaching and learning*."(PST26, week three MS). Note: PST26 stands for PST no. 26.

> "*I learned that some activities in science subject require good prior knowledge. What I have learned and experience before can help me learn the subject easier or more difficult or not*."(PST10, week 12 MS).

> "*I rely on my prior knowledge and experience in helping me find out the answer of assigned problem*." (PST03, week two MS).

3.3. RQ3: What Is the Quality of the CSPM in Differentiating PSTs' Levels of Metacognition?

The 218 codes expressed in Table 5 were sent to five experts for the validation of their IOCs. After that, 41 codes with low IOCs, which were judged by a panel of experts, were excluded from the second version of the CSPM. Then, the number of codes in the second version of the CSPM was 177, as shown in Table 6.

Table 6. The number of codes in the second version of the CSPM.

Subcomponent	No. of Codes in the First Version of the CSPM	No. of Codes in the Second Version of the CSPM	No. of Codes Being Excluded
MC-DK	75	65	10
MC-PK	23	10	13
MC-CK	14	10	4
MR-P	36	33	3
MR-M	40	35	5
MR-E	30	24	6
Total	218	177	41

After that, the researchers differentiated all the codes in each subcomponent into three different levels of metacognition: high, medium, and low. The description of the codes in each subcomponent are shown in Table 7.

Table 7. Description of the high, medium, and low levels of metacognition in each subcomponent of the CSPM.

Subcomponent	Level	Description
MC-DK	High	The PST explicitly realizes, knows, and understands their own level of knowledge, including factors potentially affecting their development of knowledge and understanding.
	Medium	The PST can judge his/her knowledge and understanding without the realization of factors potentially affecting their development of knowledge and understanding.
	Low	The PST knows and understand things he/she has learned, or he/she knows only content they have learned.
MC-PK	High	The PST can identify a specific method or process as being effective in acquiring knowledge and learning. The PST can also effectively adjust a specific method or process to suit his/her own purpose of learning.
	Medium	The PST can identify a specific method or process to acquire knowledge or learning. He/she may try some methods, but they are not effective enough.
	Low	The PST can identify a specific method to acquire his/her own knowledge or learning.
MC-CK	High	The PST knows their own learning ability, the conditions of knowing and learning, and the conditions of the tasks that will effectively and appropriately lead him/her to knowledge and understanding.
	Medium	The PST knows their own learning ability, the conditions of knowing and learning, and the conditions of tasks; however, he/she cannot utilize these in an effective and appropriate way.
	Low	The PST knows the conditions of a task or strategy to accomplish the task, but is yet to implement it.
MR-P	High	The PST can predict a learning process and possible learning outcomes before performing a task. He/she can design a plan and choose an appropriate strategy for learning.
	Medium	The PST can predict or plan a learning process before performing a task; however, he/she cannot explain it in detail.
	Low	The PST can explain his/her plan that will be implemented in the future, but does not provide any detail.

Table 7. *Cont.*

Subcomponent	Level	Description
MR-M	High	The PST can perceive and judge his/her efficiency in performing a specific task. He/she can also explain his/her own method to monitor, check, and control cognitive or learning processes.
	Medium	The PST can perceive his/her efficiency in performing a specific task; however, he/she cannot clearly explain his/her own method to monitor, check, and control cognitive or learning processes.
	Low	The PST can perceive his/her efficiency in performing a specific task without any clarification.
MR-E	High	At the end of a learning process, the PST can evaluate his/her own success in learning, knowledge gained, and learning outcome achieved according to a specific learning objective, as well as provide supporting reasons.
	Medium	At the end of a learning process, the PST can evaluate his/her own success in learning, knowledge gained, and learning outcome achieved according to a specific learning objective, but he/she cannot provide supporting reasons.
	Low	At the end of a learning process, the PST does not evaluate his/her own learning.

Metacognition, as found in Table 6, was classified from experts' IOC results. There were 177 codes in the recorded data after revisions (excluded from the IOC results). However, MC-DK still had the highest number of codes (n = 65). At the same time, we found that MC-PK dropped rapidly, from n = 23 to n = 10.

The three different levels of codes in the CSPM were validated by a panel of five experts. The codes with low IOCs were excluded from the third version of the CSPM. In total, there were eight codes that were excluded, and the final number of codes in the third version of the CSPM was 169. Table 8 shows the number of codes in each level of metacognition of the CSPM. Of 169 codes, 54 (31.96%), 46 (27.21%), and 69 (40.83%) codes were categorized as high, medium, and low level of metacognition, respectively. Interestingly, the low level of metacognition was dominant among the three different levels of metacognition.

Table 8. The number of codes in each level of metacognition of the CSPM.

Subcomponent	No. of Codes in the Second Version	No. of Codes in the Third Version	No. of Excluded Codes	% of Codes in the Third Version	High Level		Medium Level		Low Level	
					Frequency	%	Frequency	%	Frequency	%
MC-DK	65	62	3	36.69	18	10.65	12	7.10	32	18.93
MC-PK	10	8	2	4.73	4	2.37	1	0.59	3	1.78
MC-CK	10	10	0	5.92	5	2.96	2	1.18	3	1.78
MR-P	33	32	1	18.93	11	6.51	9	5.33	12	7.10
MR-M	35	34	1	20.12	13	7.69	8	4.73	13	7.69
MR-E	24	23	1	13.61	3	1.78	14	8.28	6	3.55
Total	177	169	8	100.00	54	31.96	46	27.21	69	40.83

The detail of codes categorized into three different levels of metacognition in the CSPM can be shown, as in Table 9.

Table 9. Codes categorized into three different levels of metacognition in CSPM.

Subcomponent	High Level of Metacognition	Medium Level of Metacognition	Low Level of Metacognition	Frequency
MC-DK	MC-DK 01, 03, 04, 07, 10, 16, 21, 36, 37, 38, 40, 45, 47, 49, 52, 65, 66, and 69	MC-DK 24, 28, 39, 44, 51, 57, 58, 59, 60, 63, 64, and 70	MC-DK 02, 05, 06, 08, 09, 11, 12, 13, 14, 15, 17, 18, 19, 22, 23, 25, 26, 29, 31, 32, 33, 34, 35, 42, 43, 46, 48, 53, 54, 55, 62, and 68	62
MC-PK	MC-PK 06, 07, 17, and 19	MC-PK 23	MC-PK 01, 02, and 03	8
MC-CK	MC-CK 04, 05, 07, 10, and 12	MC-CK 06, 08	MC-CK 01, 02, and 03	10
MR-P	MR-P 05, 06, 13, 15, 21, 23, 24, 25, 30, 33, and 34	MR-P 03, 04, 09, 10, 14, 17, 18, 19, and 20	MR-P 01, 02, 07, 08, 11, 12, 22, 26, 27, 28, 29, and 32	32
MR-M	MR-M 01, 03, 04, 09, 10, 13, 14, 18, 20, 21, 30, 36, and 37	MR-M 02, 08, 11, 16, 17, 25, 33, and 35	MR-M 06, 07, 12, 15, 19, 22, 23, 26, 27, 28, 29, 31, and 32	34
MR-E	MR-E 07, 08, and 24	MR-E 01, 03, 04, 05, 06, 09, 10, 15, 17, 18, 19, 20, 25, and 26	MR-E 02, 12, 14, 23, 27, and 28	23
Total				169

The example of codes derived from PSTs' MSs and MIPs, which could be differentiated into three levels (high, medium, and low) of metacognition in the CSPM, are shown below.

High Level of Metacognition: MC-PK 019
PST learns to find the answer they did not understand by themselves.

"*I learned by myself until I can understand the content of the lesson. I finally can synthesize it to become my own understanding*." (PST07, week one MS).

"*I went back to my home and tried to resolved what I tied to learn. If I am still unclear, I will find another way to solve that such as asking a teacher, a friend, or searching from Internet*." (PST0, MIP).

Medium of Metacognition: MC-PK 023
PST learns from question and answer.

"*I learned through Q&A among a teacher and my friends in classroom*." (PST14, week one MS).

Low of Metacognition: MC-PK 003
PST learns from explanation and example provided by a teacher.

"*I learned to understand things by listening from explanation from a teacher*." (PST05, week 10 MS).

"*I learned from teacher explaining and giving me an example*." (PST17, week nine MS).

"*I learned from PPT slide that teacher presented*." (PST19, MIP).

The 169 codes of the third version of the CSPM were submitted to two language experts to conduct back translation. At the end, three codes were removed from the 169 codes of the third version of the CSPM because they may lead to the misunderstanding or misinterpretation of metacognition. Therefore, the final version of the CSPM consisted of 165 codes. Four codes were excluded in this process: MC-DK23,58, MR-M02, and MR-P23, as shown in Table 10.

Table 10. Final version of the CSPM.

Subcomponent	Frequency	%
MC-DK	60	36.36
MC-PK	8	4.85
MC-CK	10	6.06
MR-P	32	19.39
MR-M	33	20.00
MR-E	22	13.33
Total	165	100.00

4. Discussions and Conclusions

This study presents eight steps for developing a CSPM that may be useful for other educators or science educators through its application in specific educational contexts and purposes. In particular, in the context of science teacher education, these eight steps are effective in analyzing raw data from qualitative methods until reaching the final code list of the CSPM. The eight steps necessary to construct the CSPM majorly highlight the content validity of the codes. Several techniques are used to check the CSPM's validity, as the IOCs are judged by a panel of experts.

The codes derived from the raw data from PSTs' MSs and MIPs in this study come from an inductive process in nature that is regarded as a basic approach for qualitative data analysis. This may be one characteristic that is different from other coding schemes proposed by other studies that may originate from a deductive approach. In any case, the CSPM was constructed qualitatively (in other word, inductively) from this study; it requires further implementation with the deductive approach, especially in contexts of science education. The deductive approach will verify the CSPM and may provide some useful codes or dimensions of PSTs' metacognition. Through this complete process, the CSPM will be more useful in the context of the development of science teachers.

There is a lack of research instruments used to explore research participants' metacognition, especially in the context of PSTs. The two qualitative data collection methods employed in this study are self-reports, through the MS, and interviews, through the MIP. These two methods work very well in exploring PSTs' metacognitive knowledge and metacognitive regulation aligned with [36]. The MS is suitable for collecting data about metacognition from a person with high writing ability and/or writing preference [55]. On the other side, the MIP is also effective for a more in-depth exploration of PSTs' metacognition by directly asking PSTs about the details of what he/she thinks and how he/she acts in a particular learning context [56]. This study confirms the effectiveness of combining both methods into the same study, especially for collecting raw data about metacognition that are then regarded as a reservoir for constructing a good and valid coding scheme.

The development of PSTs' metacognition and ability to teach science by integrating metacognition is the original passion of this study. Noticeably, the CSPM shows that a majority of the PSTs in this study possess a low level of metacognition. This is a major concern for us as teacher educators, and it is necessary that this is fixed as soon as possible. Science teachers with a low level of metacognition may face difficulties in developing their students' metacognition, which may subsequently affect students' learning and impede the development of students into lifelong learners [57]. This is consistent with [58], who mentioned that various researchers utilize metacognition as a key variable in terms of students' development in learning. In addition, the development of metacognitive knowledge and processes can improve students' conceptual understanding of targeted conceptions [58]. Therefore, PSTs' levels of metacognition can be explored by the CSPM, and this information will be taken into account as a valuable input of PST development throughout the university program. In addition, PSTs may develop their metacognition by learning to think of answering MSs and MIPs about teaching and learning in science by integrating metacognition. In this way, the CSPM may be regarded as one effective tool to help to improve the sustainable development of teaching and learning science.

5. Limitations and Future Research

Researchers who are interested in developing a coding scheme for exploring or measuring research participants' metacognition can apply the eight steps utilized to construct the CSPM in this study in their future research. The utilization of the CSPM in exploring, evaluating, and monitoring PSTs throughout their teacher education programs may be one challenging research question for us as teacher educators. The inclusion of a deductive approach to fulfill the complete picture of the CSPM is also suggested for future research.

The readers of this article should be kindly reminded that generalization is not a focus of this study, as the main research approach is qualitative in nature.

However, increasing the number of participants may help increase the diversity of the codes from PSTs. The unique type of research participants may affect the transferability of the findings of this study. The application of the CSPM in other educational contexts is one recommendation of this study.

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Institutional Review Board Statement: This study was conducted according to a protocol approved by the IPSR Institutional Review Board (IPSR-IRB) at Mahidol University, Thailand (COA. No. 2019/04-140).

Informed Consent Statement: All the participants took part voluntarily and signed an informed consent form.

Data Availability Statement: The data presented in this study are not publicly available due to IRB protections. Information on and queries concerning the data used can be obtained from the corresponding author of this study.

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Conflicts of Interest: The authors declare that they have no conflict of interest regarding this study.

Appendix A. Metacognitive Self-Report (MS)

(Metacognitive knowledge)

Q1: What have you learned in the last week and how much did you understand the content?

(Metacognitive regulation)

Q2: What is your goal for learning this week?

Q3: What are the difficult things this week that you learned? Give an example/explain a case in which you faced the problem.

Q4: From this week, what is an important thing that you should remember?

Appendix B. Metacognition Interview Protocol (MIP)

(Perspective or views in this course)

Q1: How was your experience in this course? Could you explain?

(Metacognitive regulation)

Q2: How did you prepare yourself for study before/during a class? (MR-P)

Q3: Are you knowing yourself when you face any difficulties learning in this course? (MR-M)
(Metacognitive knowledge)
Q4: What are the challenging things in this course? (MC-D)
Q5: How can you pass this? (MC-C)
Q6: How did you study in this course? (MC-D)
Q7: Did you change the strategies to learn or not? If changed, why? (MC-C)
(Metacognitive Regulation)
Q8: Do you have any feedback or suggestion for this course? (MR-E)
Q9: Did you understand more as your own wording from this course? (MR-E)

Appendix C

Table A1. IOCs of the CSPM.

Code	IOC	Result
KC-DK	0.6–1.00	Qualified
KC-PK	1.00	Qualified
KC-CK	0.8–1.00	Qualified
RC-P	0.8–1.00	Qualified
RC-M	0.6–1.00	Qualified
RC-E	0.8–1.00	Qualified

Table A2. IOCs of the CSPM differentiate.

Code	IOC	Result	Excluded (Code)
KC-DK	0.4–1.00	Qualified	3
KC-PK	0.4–1.00	Qualified	2
KC-CK	0.8–1.00	Qualified	0
RC-P	0.4–1.00	Qualified	1
RC-M	0.4–1.00	Qualified	1
RC-E	0.4–1.00	Qualified	1

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Knowledge and Expectations Regarding Sustainable Food Systems among Students from Georgian Agricultural Universities and Georgian Food Industry Representatives

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Abstract: This study establishes the role of sustainability in higher education (HE) and the food industry in Georgia by examining Sustainable Food Systems (SFS) background knowledge among students and food industry representatives, their behaviours as consumers, and their level of food citizenship. This study also investigates the most interesting SFS topics in relation to future training, students' expectations in developing competencies, and the SFS elements they deem most important. This cross-sectional study was performed through an online survey comprising a higher education questionnaire administered in five agricultural universities in Georgia which obtained 321 responses. Another questionnaire administered to Georgian food industry (FI) representatives obtained 54 responses. Data were analysed through non-parametric and multivariate statistical analysis. Georgian students and food industry representatives were knowledgeable on Sustainable Food Systems topics, yet some were neither interested nor had received training previous training in SFS. Students' food purchasing and consumption motivations are most influenced by taste and health, demonstrating significant differences between universities. The maintenance of healthy ecosystems was the most important component of SFS, while organic agriculture and agroecology are the most interesting topics. In Georgia, higher education and the food industry both play equally essential roles in the development of Sustainable Food Systems.

Keywords: Georgian higher education; teaching and training; European food systems; food systems transformation; sustainability education

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1. Introduction

The global food system is described as a multifaceted, complex nexus incorporating environmental, economic, social, and technological processes involving food, from its production and utilization to waste disposal [1,2]. To achieve sustainable development at the European level, transitioning towards Sustainable Food Systems is equally imperative for developed and developing countries such as Georgia. In the past, with post-Soviet Georgian governments, the development of the agriculture sector was unprioritized and this was attributed to the absence of a functioning agricultural research–education–extension system in the country [3]. In order to address this gap, since the turn of the millennium, Georgia has been undergoing reforms and transformations through various developments, integrating modernization and the concepts of economic liberalization [4,5].

Traditional education environments focusing on simply increasing environmental knowledge have been found to be inadequate in fostering pro-environmental and sustainable change [6]. Education should not only involve a transfer of knowledge but a space for dialogue to increase the creativity of individuals and groups [5] (p. 1088). In this light, higher education institutions (HEIs) in Georgia play an invaluable role in the formation of future scholars and professionals, actors who will directly structure and influence the future food system. These actors need to possess a keen attention to system elements and the capacity to make decisions in the face of complexity through various forms of thinking and performance [7]. Georgian HEIs should be able to develop these actors' creativity in solving problems through a systems approach (e.g., transdisciplinary research) instead of narrowly defined and isolated disciplines. This would not only prevent graduates from being insufficiently prepared to deal with food system complexity but also in interacting with multidisciplinary environments [7,8]. Georgian HEIs play a pivotal role in instilling a systems approach through the cognitive, socio-economical, and behavioural domains [7] whilst engaging students to be active food citizens in fulfilling the Sustainable Development Goals (SDGs).

Furthermore, food citizenship, a vital component of SFS development, can be conceptualized as an outcome of transformations in the personal, cultural, political, and practical spheres. Food citizenship is defined as the practice of engaging in food-related behaviours acknowledging the need to move beyond food as a commodity and individuals as consumers [7,9,10]. HEIs play a crucial role in developing students' food citizenship by deepening their grasp of SFS topics through immersive and multi-perspective approaches [7,11,12].

To equally cover the political and practical spheres of transformation, where the "outcomes" and "systems and structures" of transformations are respectively situated [13], mapping out sustainability and its components in the Georgian food industry is equally indispensable. These non-state actors play a significant role in food politics, particularly in the context of the creation and implementation of private norms, rules, and standards which are vital in reforming the food system [14].

Georgia's geographical setting allows it to be a country of rich agrobiodiversity and this provides great potential for economic development [5,15]. In the past two decades, the Biological Farming Association Elkana, in partnership with German public institutions, spearheads strategies in the development of organic farming by providing advisory services to farmers, leading to the country's harmonization with EU regulations in the present day [16]. However, Georgia still faces challenges in preserving its natural biodiversity while developing policies to accelerate economic development and population well-being, as reported by previous studies [5,16]. Furthermore, there is very limited literature examining the role of Georgian higher education in the empowerment of future generations to address these challenges and thereby ensure sustainable development.

Given this context, the following working hypotheses serve as the basis for this research paper:

Hypothesis 1 (H1). *Georgian students and food industry representatives may have limited background knowledge of SFS and its topics. The authors propose this hypothesis in the assumption that the level of knowledge of the Georgian population may be lesser in comparison to the western European population, where a sizeable proportion of students enrolled in food and agriculture programs reported not receiving courses on Sustainable Food Systems or courses covering related topics [12]. Another study carried out in a neighbouring Asian country, Pakistan, reported that both students and educators have inadequate knowledge of SFS [17]. Furthermore, the limited number of scientific publications from Eastern European research bodies and universities suggests that Sustainable Food Systems may be less developed in these regions [18].*

Hypothesis 2 (H2). *Students' behaviours as consumers strongly influence their level of food citizenship (motives, values, and habits toward food). Emerging studies establish that consumers and citizens play an essential role in sustainability transition [9,12,19]. Concurrently, factors that influence consumer behaviour, such as social background, family cooking traditions, and cultural and financial background, have been established as influencing students' levels of food citizenship [12].*

Hypothesis 3 (H3). *The element of SFS that is most important for students and food industry representatives is "maintains healthy ecosystems".*

Hypothesis 4 (H4). *The teaching methods preferred and most interesting to students which should be included in contemporary education programs are "seminars and interactive workshops" while "e-learning courses" are considered least interesting.*

The authors postulate H3 and H4 based on the results of a similar study performed in western European universities where "healthy ecosystems" was rated as the most important element of SFS, while "seminars and interactive workshops" and "e-learning courses" are considered the least interesting [12]. Additionally, Georgia has received support from experts and lecturers from German public institutions, such as the University of Kassel and the German Federal Agency for Nature Protection, in training stakeholders on sustainable farming practices (i.e., organic composting) [20]. This suggests that topics of interest and teaching methods in SFS may be shared in both populations.

Hypothesis 5 (H5). *The topics related to SFS and the Georgian agri-food industry that are most relevant and interesting for future training are "organic agriculture" and "agroecology". Spearheaded by Elkana, the Georgian transition to SFS involves strategies that mainly focus on organic agriculture and the protection of the environment over the previous two decades [20]. Additionally, unsustainable agricultural practices which led to the deterioration and depletion of natural resources remain a present challenge [4]. Therefore, these topics are hypothesized as the most interesting for Georgian stakeholders.*

2. Materials and Methods

2.1. Study Design and Methods

A two-phase cross-sectional quantitative study design was implemented to come up with a more holistic picture of SFS in Georgia. The first phase involved a structured survey adapted from the European Union (EU) SUSPLUS project (Innovative Education towards SFS) in which the working group was part of and was modified to serve the Georgian higher education (HE) system. This Higher Education Questionnaire (HEQ) included 24 questions (composed of open-ended questions, multiple-choice questions, and Likert scales) and was organized into three major components. The first part was "present attitudes, values, and behaviours", which inquired about students' purchasing habits (frequency of food purchasing and food preparation), lifestyle, and the factors influencing their food citizenship. The second part involved their "present knowledge and understanding" of the topic of SFS and its elements, which included asking students about their overall learning experience with SFS and which specific SFS topics they had covered in their modules. The third part inquired about students' expectations for future higher educational curricula (which skills were most valuable for them, which topics they found most interesting, and what kind of teaching methods they preferred). The HEQ was administered to all universities in Georgia offering agricultural/horticultural science and food/nutrition science programs at various levels (bachelor's, master's, and Ph.D.) as illustrated in Table 1. Adapted from the methods of Migliorini et al. (2020), the protocol prioritized students in agri-food universities since the sensitisation of this young generation of future active consumers and agri-food professionals to the topic of Sustainable Food Systems is of vital importance [7]. All students who pursued other degree programs and those who were not enrolled in the listed universities were excluded from the analysis.

Table 1. Georgian agricultural universities and their topics of focus.

University Name	Acronym	Focus Areas
Agricultural University of Georgia	"AUG"	"Agriculture, agronomy, agricultural engineering, ecology, food science, viticulture, veterinary sciences"
Akaki Tsereteli State University	"ATSU"	"Medicine, agricultural sciences, natural sciences"
Batumi Shota Rustaveli State University	"BSRSU"	"Agriculture, agricultural engineering, agro-technology, food science, and forestry"
Georgian Technical University	"GTU"	"Business, law, engineering, architecture, agricultural sciences, and biosystems engineering"
Telavi Iakob Gogebashvili State University	"TIGSTU"	"Agrarian sciences, educational sciences, humanities, social sciences, and law"

On the other hand, the second phase was a survey composed of 19 questions administered to food industry representatives in Georgia. This included industry partners, farmers, professionals in associations, and representatives of academia. Similar to the HEQ, the food industry questionnaire (FIQ) was also composed of three components. The first part inquired about "present attitudes, values, and behaviours" on SFS topics and how these individuals find these factors relevant to their line of business or profession. The second part inquired about their "background knowledge and understanding of SFS and related topics" (their professional training in SFS). The third part asked industry representatives about their "future expectations about SFS in an industrial context" (professional development, desirable skills for future professionals, topics for future training). Both questionnaires were translated into Georgian and were administered online using Survey Sparrow with a data collection period from June to August 2021. The survey was available both in English and Georgian, and respondents were able to choose the language while accomplishing the questionnaires. To gather a sufficient spread of students across the five universities, the survey link was shared through social media, emails, and word of mouth, with the assistance of the Agricultural University of Georgia (Prof. Dr. Teo Urushadze) in following up on responses and cascading the online link for the survey until the representative sample size was achieved.

The first phase of the study had a total of 321 responses collected from five Georgian universities, namely, the Agricultural University of Georgia (AUG) N = 117, Akaki Tsereteli State University (ATSU) N = 86, Batumi Shota Rustaveli State University (BSRSU) N = 31, Georgian Technical University (GTU) N = 57, and Telavi Iakob Gogebashvili State University (TIGSTU) N = 29. All the participants were presently enrolled in their respective Georgian universities.

The second phase of the study was initiated after gathering sufficient responses for the first phase (students). Through the assistance of the Agricultural University of Georgia and its network of industry partners and academics, a total of 54 responses were again collected using b snowballing and sending the survey link online via mail and social media platforms. The respondent pool consisted of professionals from various food industries and sectors of the value chain, including academics, growers and producers, retailers, and food industry professionals.

2.2. Statistical Analysis

Using IBM SPSS Statistics 26, both data sets for phase 1 and phase 2 were analysed to be not normally distributed, as commonly observed among questionnaires using the Likert scale. The Kruskal–Wallis H non-parametric test was performed to assess significant differences for each categorical variable. Statistically significant differences ($p \leq 0.05$) were observed between the Georgian universities. Due to the limited size for phase 2, differences between categorical variables were observed to be not significant. To analyse the relationship between responses, one-way ANOVA with Games–Howell post hoc tests was performed. Furthermore, principal component analysis and Pearson correlations were performed to study the relationship between students' responses from different universities.

3. Results and Discussion

3.1. Demographic Data of Respondents: Higher Education and Food Industry Surveys

3.1.1. Demographic Data of Georgian University Students

A representative sample size of 321 respondents distributed at the 5 universities was obtained and illustrated in Table 2. The sample was 46% male, 53% female, and 1% identified as non-binary. The highest proportion of females was observed in the Agricultural University of Georgia (AUG) at 65%, while the lowest was observed in Batumi Shota Rustaveli State University (BSRSU) at 40%. The average respondent age was 22 years old, ranging from 18 to 52 years. Most of the students studied agricultural and horticultural sciences (70.7%), while 29.3% studied food and nutrition sciences. Studies in bachelor's, master's, and Ph.D. degrees were 80%, 15%, and 5%, respectively. Among the participants, 18% were first-year students, 32% were second-year students, 23% were in their third year, and 27% were in their fourth year or more.

Table 2. Demographic data of Georgian students.

	Bachelor's	**Master's**	**Ph.D. or Higher**	**Total**
Number of students	256	49	16	321
Gender ratio (male: female)	1.032	0.361	0.6	0.865
Mean age in years	20.64	24.51	33.25	21.86

3.1.2. Demographic Data of Georgian Food Industry Survey

Of the 54 respondents who participated in the Food Industry Survey, 63% identified as female while 37% identified as male. As shown in Table 3, in terms of educational background, the highest proportion (43%) of respondents attained a master's degree, followed by those with a bachelor's degree (31%), and those having a Ph.D. or a higher qualification (26%). Most of the respondents were either employed in primary production (27.8%), academia or research (20.4%), or retail or distribution (16.7%). In terms of the food business category, most respondents were engaged in fruits and vegetables (29.6%), alcoholic beverages (16.7%), and dairy or cheese (11.1%).

Table 3. Demographic data of Georgian food industry representatives.

	Bachelor's	**Master's**	**Ph.D. or Higher**	**Total**
Number of respondents	17	23	14	54
Gender ratio (male: female)	0.417	0.769	0.56	0.865
Mean age in years	33.29	39	49.79	40

3.1.3. Students' Background Knowledge of Sustainable Food Systems and Its Topics

Results for the student's background knowledge of Sustainable Food Systems showed that 58% of the students were interested in the topic of SFS, while 46% reported (AUG 60%, TIGSU 48%, GTU 39%) that they had never taken a course in their program which covered SFS and its topics. As illustrated in Table 4, ATSU and BSRSU students reported that most of the topics were covered in their programs in comparison to AUG, GTU, and TIGSU students. In contrast to a highly specialized university in the agricultural sciences such as AUG, ATSU, which is located in the west region of Georgia, ranked the highest in most of the topics, such as "Traditional/regional food", "Community-supported agriculture", "Food box schemes", "Food sovereignty", "Vegetarianism", "Veganism", and "Food loss and waste", with significant differences among other universities. AUG and BSRSU cover the topic "Food safety" more fully than other universities. BSRSU covers "Food security" and "Sustainable Development Goals" the most in comparison to other universities.

Table 4. Sustainable Food Systems topics are covered in different study programmes among five agricultural universities in Georgia.

				AUG	ATSU	BSRSU	GTU	TIGSU	
Variable	**Total Mean**	**N**	**SD**	**117**	**87**	**31**	**57**	**29**	***p*-Value**
Traditional food/regional food (PDO or PGI)	1.62	321	0.69	1.53a	1.94abc	1.68	1.39b	1.41c	***
Community- supported agriculture (CSA)	1.61	321	0.69	1.46a	1.94abc	1.68	1.46b	1.45c	***
Food box schemes	1.45	321	0.64	1.43	1.66ab	1.45	1.3a	1.17b	**
Food sovereignty	1.54	321	0.66	1.47	1.72	1.65	1.40	1.41	
Food security	2.12	321	0.74	2.08	2.24	2.29	2.07	1.90	
Food safety	2.25	321	0.74	2.31	2.18	2.42	2.19	2.17	
Sustainable Development Goals (SDGs)	1.72	321	0.71	1.58ab	1.92a	2b	1.65	1.55	**
Vegetarianism	1.32	321	0.56	1.23a	1.49ab	1.42	1.26	1.21	**
Veganism	1.30	321	0.56	1.2a	1.52ab	1.29	1.25	1.17b	***
Food loss and waste	1.84	321	0.69	1.67a	1.99a	1.97	1.89	1.79	

Notes: Respondents chose between 1 = Not at all covered, 2 = Yes, there were a few lectures (1–4) on this topic within other courses, 3 = Yes, it was a whole course (at least 15 h). Kruskal–Wallis tests: ** marks $p < 0.001$; *** marks $p < 0.0001$; letters indicate significant differences between universities (post hoc Games–Howell tests). The letters a, b, c signify statistical differences between universities.

3.2. Food Industry Representatives' Background Knowledge of Sustainable Food Systems and Its Topics

The largest proportion—46.3% of respondents—indicated that they were interested, while 42.6% reported that they were a little bit interested in Sustainable Food Systems. When asked if they had attended training covering topics on Sustainable Food Systems, 50% reported that they had already received training, while 50% had not received training at all. The lack of interest among the food industry representatives may be explained by the lack of knowledge and experience of topics related to SFS. Furthermore, those who had already attended training on SFS reported that this training was not provided by their employer or the company they were working for. Even with a very limited population for the survey, these findings reveal that, presently, in the Georgian food industry, there is very little awareness of SFS and therefore emphasize the role of higher education institutions in forming future professionals and catalysing this transformation.

3.3. Students' Behaviour as Consumers and Their Levels of Food Citizenship

Referring to H2 (How does students' behaviour as consumers affect their food citizenship?), the results for "values and motives for food purchasing and eating" and "food purchasing and cooking frequency" are identified as determinants of students' food citizenship. These findings are illustrated on Table 5.

Values and Motives of Students for Purchasing and Eating

The results presented in Table 5 demonstrated significant differences amongst students' values influencing food purchasing and consumption decisions based on which university they came from. Among the various motives and values, "health" and "taste" were considered most important by the students, while "special diet" and "tropical production" were the least important. ATSU students stand out from the four other universities since its students considered "labels", "seeking tastes from childhood", "environmental", and "social" impacts most important, demonstrating significant differences from AUG, GTU, and TIGSU. Furthermore, students from ATSU considered "tropical production" significantly more important than the four other universities. That ATSU students had the highest means for several of the values and motives may be attributed to the university's location. The campus being in a more rural and western setting in comparison to Tbilisi, students may have better access to local produce and healthier food choices at more affordable prices. On the other hand, GTU students considered "social impact", "animal welfare", "local and tropical production", "labels", and "seeking tastes from childhood" as not important, scoring lower than the other four universities, while considering "price" of moderately high importance. AUG students also considered environmental impact least among the five universities. This finding is contrary to AUG's strong focus on organic agriculture and its numerous collaborations with Western European universities. Moreover, the high proportion of international students mostly concentrated in Tbilisi may have affected the observed scores. One notably common motivation for all students which was considered of moderately high importance was "price".

Table 5. Students' motives and values on food purchasing and eating.

				AUG	ATSU	BSRSU	GTU	TIGSU	
Variable	**Total Mean**	**N**	**SD**	**117**	**87**	**31**	**57**	**29**	***p*-Value**
Environmental impact	2.57	321	0.54	2.42a	2.74a	2.58	2.60	2.66	**
Health	2.85	321	0.36	2.75a	2.93ab	2.90	2.86	2.97ab	**
Price	2.42	321	0.54	2.47a	2.5a	2.19	2.37	2.31	
Social impact	2.08	321	0.69	2.03a	2.41abc	2.10	1.81b	1.86c	***
Taste	2.68	321	0.53	2.83ab	2.84cd	2.61	2.28ac	2.48bd	***
Animal welfare	2.44	321	0.60	2.31a	2.74ab	2.45	2.18bc	2.55c	***
Labels	2.19	321	0.75	2.15a	2.58abc	2.16	1.77ab	1.97c	***
Special diet	1.77	321	0.79	1.66a	2.09ab	1.84	1.51b	1.69	***
Local production	2.28	321	0.71	2.3a	2.56abc	2.32	1.91ab	2.0c	***
Tropical production	1.93	321	0.69	1.88ab	2.31abcde	1.84c	1.6d	1.76e	***
Seeking tastes from childhood	2.03	321	0.73	1.96a	2.36abc	1.84b	1.82c	1.93	***

Notes: Respondents chose between 1 = not important, 2 = moderately important, 3 = very important. Kruskal–Wallis tests: ** marks $p < 0.001$; *** marks $p < 0.0001$; letters indicate significant differences between universities (post hoc Games–Howell tests). The letters a, b, c, d, e signify statistical differences between universities.

Examining the relationships among the responses (Figure 1) provided by the students, those who considered labels in their purchasing decisions also considered special diets and animal welfare and strongly considered environmental impact and local and tropical production (in Georgia). These correlations suggest that students who pay attention to labels may be vegans/vegetarians or follow religious practices (fasting and modification of diets) during special periods in the year. Those who cared about animal welfare considered environmental and social impacts on their purchasing decisions. Students who considered "seeking tastes from childhood" in their purchasing decisions considered tropical production. Price, on the other hand, had a weak positive correlation with environmental impact, social impact, and animal welfare while having the strongest correlation with taste among the motives given. This suggests that even though students were wary of price, they still considered the mentioned factors in their purchasing decisions. Tropical production was positively correlated with taste, animal welfare, and special diet. Interestingly, no correlation was observed between health and taste nor between health and price. No negative correlations were observed among the values and motives. There were no significant differences observed between students based on sex or field of study.

Referring to the results of the principal components analysis illustrated in Figure 2, students who were motivated by taste tended to care less about health. Moreover, the food purchasing decisions of students were not strongly influenced by price. In comparison to the results of a similar study performed at 10 universities in the European Union [7], Georgian students also considered health as an important aspect while being less "price-sensitive". This may suggest that Georgian students who can access tertiary education in universities in highly urbanized regions come from families of middle to upper-middle class economic backgrounds, while underprivileged students, especially those from rural areas, have limited access to these higher educational institutions [21]. Furthermore, the same reference elucidates that state spending on higher education is greater than primary and secondary education, further widening social and economic gaps since fewer disadvantaged students can pursue higher education.

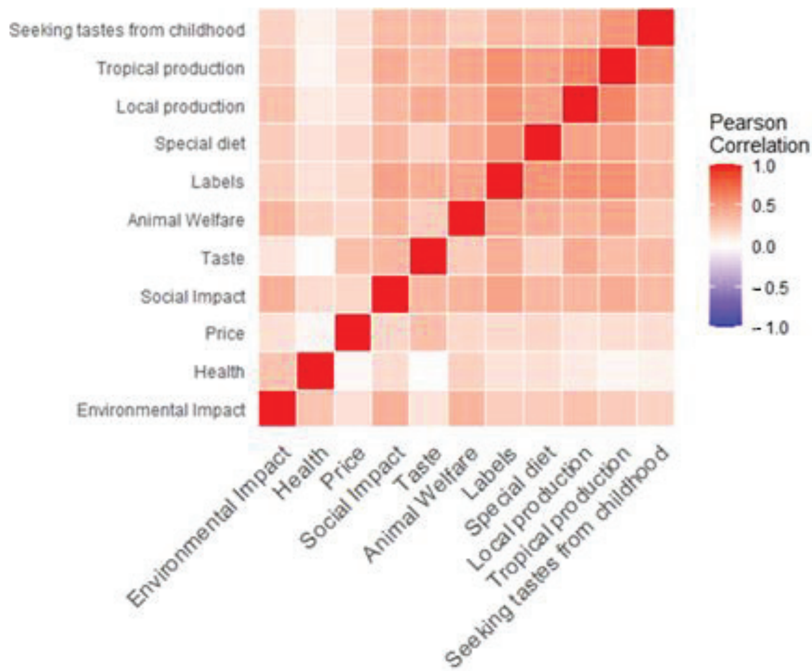
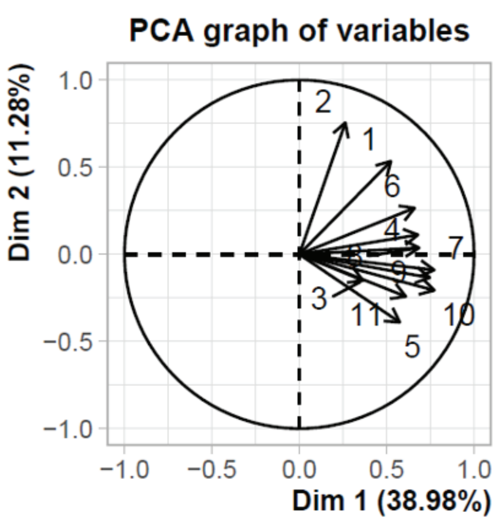


Figure 1. Correlation between different values and motives of students for food shopping and eating.



1	Environmental impact
2	Health
3	Price
4	Social impact
5	Taste
6	Animal welfare
7	Labels
8	Special diet
9	Local production
10	Tropical production
11	Seeking tastes from childhood

Figure 2. Results of principal component analysis of the values and motives of students for food purchasing and eating. Note: The length and direction of arrows denote the magnitude of single questions concerning the first two principal components.

Georgian students are also strongly influenced by labels (Figure 2), confirming the findings of Todua that, generally, Georgian consumers have positive attitudes towards food labelling and are particular about the clarity of the information presented to them such that their purchasing decisions are thereby influenced [22]. In contrast with Western European students [7], Georgian students consider health and taste strongly in their purchasing decisions, yet no correlation was observed between these two values. This implies that the importance of health is a weak predictor of the importance of taste among students. This observation can be explained by the transition to unhealthy diets among students due to the limited availability of food options [21] and the increasing presence of fast-food establishments in Georgian urban areas where schools or universities are situated [22]. Finally, Georgian students considering "seeking tastes from childhood" as an important factor in their purchasing decisions may be explained by the socio-political developments in post-Soviet Georgia during the 1990s. During this period, Muehlfried described eating and participating in banquets as popular, this being encouraged by the numbers of restaurants opening in urban areas, especially in Tbilisi, even under the difficult economic situation [23]. These events were the occasion for families to socialize, go out of their households, and take pleasure from abundant amounts of food. For university students who are away from their families in the course of their studies, these experiences during their childhood may therefore elicit a sense of longing as they miss the tastes from such events.

3.4. Students' Food Purchasing and Cooking

Almost a quarter (23%) of the Georgian students who participated in the survey reported that they were in charge of purchasing food for the households they were living in. On the other hand, the majority of the students (48%) participated in food purchasing activities for their household but shared the responsibility with someone else. The frequencies of cooking and food purchasing are illustrated in Figures 3 and 4. A majority of the students participated in both purchasing and cooking food twice or three times a week. As shown in Figures 5 and 6, ATSU and AUG students purchase and cook food the most frequently (between once a week and twice or thrice a week). These scores were observed to be significantly higher in comparison to TIGSU students, who, on average, purchase and cook food between twice or thrice a month and once a month. In general, the majority of the students purchase and cook food either every day or twice/thrice a week. A similar pattern can be observed in the Western European students, especially at the Technical University of Madrid [7], since a majority of Georgian students live with their families. With these established findings, it can be inferred that Georgian students' food purchasing and cooking habits are influenced by socio-cultural backgrounds, financial situation, and traditions, which therefore play an indispensable role in developing their food citizenship. Undoubtedly, universities play a crucial role in developing students' levels of food citizenship by deepening their grasp of SFS topics through immersive and multi-perspective approaches which directly involve them in such complex and dynamic topics [7,11,12].

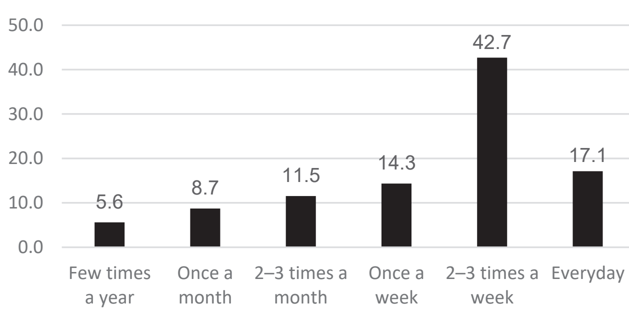


Figure 3. Number of students purchasing food for their household.

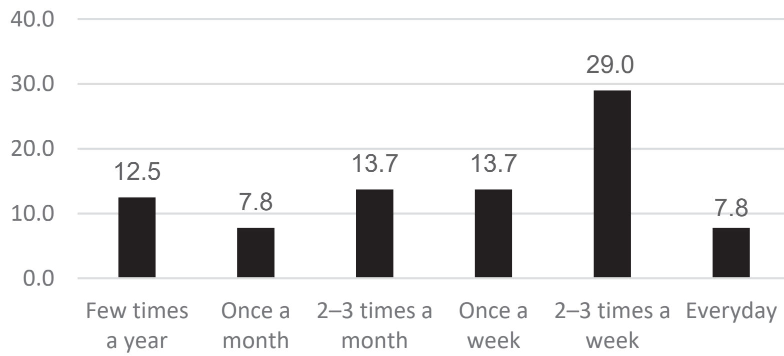


Figure 4. Number of students cooking food for their household.

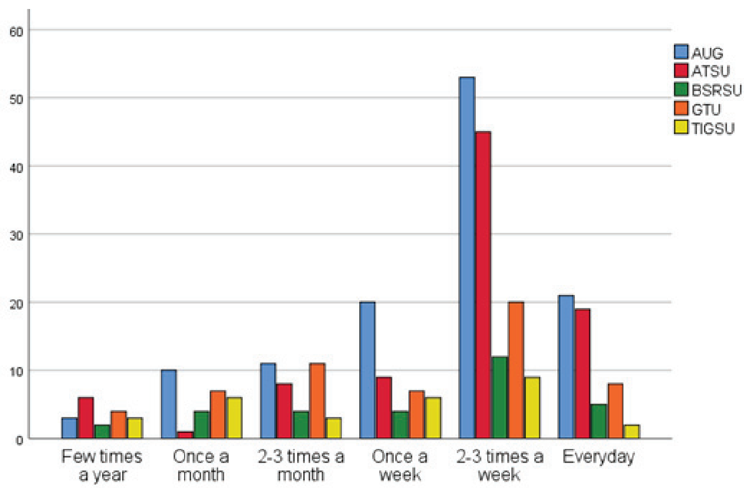


Figure 5. Number of times Georgian students purchase food in the household they live per university.

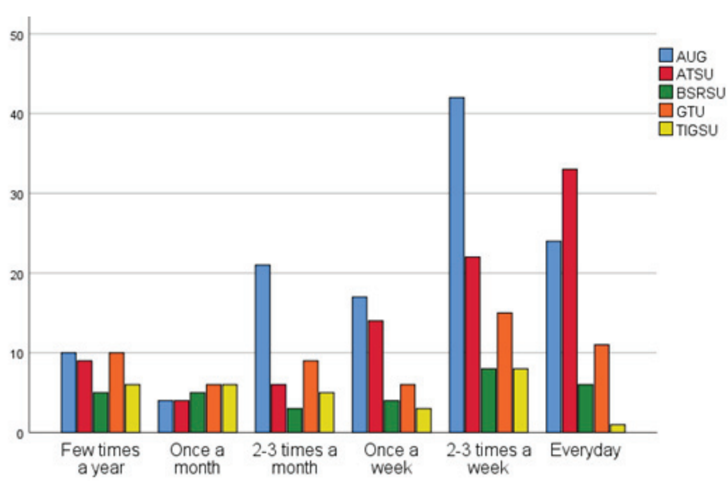


Figure 6. Number of times Georgian students cook in the household in which they live per university.

3.5. Students' Preferences on Sustainable Food Systems Topics and Elements

All Georgian students rated all the listed elements as important, with "maintains healthy ecosystems" and "protects biodiversity" ranking the two most important, as illustrated in Table 6. Significant differences were observed between the five universities with respect to all elements except "protects biodiversity". AUG and ATSU ranked the SFS elements highest compared to the other universities, exhibiting significant differences from GTU and TIGSU. This may be justified by the fact that SFS topics are not comprehensively covered or that no courses were offered in GTU (39%) and TIGSU (48%), revealing the students' lack of background knowledge of the mentioned topics. Moreover, GTU and TIGSU students were reported to purchase and cook food the least among the five universities, showing significant differences from AUG and ATSU students. This again underlines the need for higher education institutions to provide a strong foundation and deeper understanding of SFS concepts, thus enabling students to acquire more sustainable behaviours as consumers and strengthen their level of food citizenship.

Table 6. Students' opinions on the different elements of a sustainable food system.

				Bachelor's	Master's	Ph.D. or Higher	
Variable	**Total Mean**	**N**	**SD**	**17**	**14**	**54**	***p*-Value**
Makes nutritious food available, accessible, and affordable to all	2.46	54	0.539	2.53	2.3	2.64	
Maintains healthy ecosystems	2.56	54	0.572	2.59	2.39	2.79	
Respects the needs of future generations	2.54	54	0.573	2.65	2.35	2.71	
Has minimal negative impact on the environment	2.35	54	0.677	2.47	2.04a	2.71a	**
Encourages local production and distribution infrastructures	2.2	54	0.683	2.29	1.91a	2.57a	*
Is humane and just, protecting farmers and other workers, consumers, and communities	2.13	54	0.754	2.18	1.87	2.5	*
Respects animal welfare	2.22	54	0.718	2.18	2.04	2.57	
Is economically sound (provides fair income to producers, distributors, and sellers)	2.02	54	0.765	2	1.74a	2.5a	*
Protects biodiversity	2.41	54	0.687	2.47	2.22	2.64	

Notes: Respondents chose between 1 = not important, 2 = moderately important, 3 = very important. Kruskal–Wallis tests: * marks $p < 0.01$; ** marks $p < 0.001$; letters indicate significant differences between universities (post hoc Games–Howell tests).

3.6. Georgian Food Industry Representatives' Preferences on Sustainable Food Systems Topics and Elements

All the respondents indicated that all elements of SFS are important. The most important SFS elements were "maintaining healthy ecosystems" and "respecting the needs of future generations", while the least important was "is economically sound (provides fair income to producers, distributors, and sellers)". Due to the small sample size of the second phase, only a few significant differences were observed between the respondents' educational attainments. No significant differences were observed between food business categories and food value chain sectors. As illustrated in Table 7, Ph.D. holders rated all of the elements higher, in terms of importance, in comparison to bachelor's and master's degree holders. This may be due to those professionals possessing PhDs being not only more engaged in socio-environmental issues but also more immersed in interdisciplinary sustainability perspectives [24]. Moreover, these elements are considered less important by bachelor's and master's degree holders, which may be attributed to their lack of knowledge or previous training in SFS. These findings reveal that, in Georgia, education on Sustainable Food Systems is still confined to highly specialized instruction and is far from mainstream pedagogy. This finding again provides a solid basis for the importance of incorporating SFS modules in universities, starting with bachelor's degrees.

Table 7. Food industry representatives' opinions on the different elements of a sustainable food system.

				AUG	ATSU	BSRSU	GTU	TIGSU	
Variable	**Total Mean**	**N**	**SD**	**117**	**87**	**31**	**57**	**29**	***p*-Value**
Makes nutritious food available, accessible, and affordable to all	2.54	321	0.620	2.71ab	2.7cd	2.42	2.25ac	2.03bd	***
Maintains healthy ecosystems	2.69	321	0.510	2.8ab	2.83cd	2.55	2.51ac	2.34bd	***
Respects the needs of future generations	2.60	321	0.610	2.72ab	2.78cd	2.52	2.28ac	2.28bd	***
Has minimal negative impact on the environment	2.55	321	0.630	2.73ab	2.63c	2.52	2.28ac	2.17b	***
Encourages local production and distribution infrastructures	2.52	321	0.670	2.73abc	2.68de	2.26a	2.18bd	2.14ce	***
Is humane and just, protecting farmers and other workers, consumers, and communities	2.50	321	0.710	2.74ab	2.68cd	2.32	2.05ac	2bd	***
Respects animal welfare	2.49	321.00	0.610	2.53	2.68a	2.29	2.3a	2.31	***
Protects biodiversity	2.65	321.00	0.510	2.67	2.74	2.61	2.58	2.52	

Notes: Respondents chose between 1 = not important, 2 = moderately important, 3 = very important. Kruskal–Wallis tests: *** marks $p < 0.0001$; letters indicate significant differences between universities (post hoc Games–Howell tests).

3.7. Students' Preferred Future Learning Topics on Sustainable Food Systems

As reported in Table 8, all the topics mentioned were interesting to the students, with organic agriculture and agroecology ranking the highest. This may be explained by the consistent growth of the organic agriculture industry which has outpaced the whole Georgian food industry in terms of output in recent years [3]. Additionally, the Georgian dairy industry has been relentless in its efforts to meet EU food regulations [5], which justifies the strong interest among university students. Significant differences were observed among the universities except for the topics of organic agriculture, organic food, and agroecology. AUG and ATSU students were most interested in the mentioned topics, while GTU and TIGSU students ranked the least interested on average. This observation may, again, be justified by the lack of knowledge and first-hand experiences of SFS topics amongst GTU and TIGSU students.

Table 8. Topics of interest for future teaching courses, as reported by Georgian students.

				AUG	ATSU	BSRSU	GTU	TIGSU	
Variable	**Total Mean**	**N**	**SD**	**117**	**87**	**31**	**57**	**29**	***p*-Value**
Organic food	2.56	321	0.690	2.66	2.50	2.55	2.49	2.45	
Fair trade	2.34	321	0.690	2.48abc	2.7adef	2.23d	1.79be	1.9cf	***
Slow food	2.15	321	0.640	2.27a	2.24	1.97	2a	1.93	*
Agroecology	2.60	321	0.660	2.64	2.63	2.68	2.60	2.28	
Organic agriculture	2.68	321	0.740	2.69	2.60	2.74	2.75	2.66	
Protected Denomination of Origin (PDO) and Protected Geographical Indication (PGI)	2.25	321	0.740	2.42a	2.48bc	2.16	1.75ab	1.93c	***
Local food	2.51	321	0.710	2.68ab	2.69cd	2.48	2.09ac	2.1bd	***
Community-supported agriculture (CSA)	2.28	321	0.560	2.42a	2.57bc	2.23	1.75ab	1.93c	***
Food box schemes	2.14	321	0.560	2.37ab	2.27c	2.10	1.61ac	1.86b	***
Sustainable Development Goals (SDGs)	2.42	321	0.690	2.53a	2.61b	2.29	2.14ab	2.14	***

Notes: Respondents chose between 1 = not interesting, 2 = moderately interesting, 3 = very interesting. Kruskal–Wallis tests: * marks $p < 0.01$; *** marks $p < 0.0001$; letters indicate significant differences between universities (post hoc Games–Howell tests).

3.8. Food Industry Representatives Preferred Topics for Future Training

The topics most interesting for future training amongst food industry representatives were organic agriculture and agroecology (data not shown). The least interesting topics were food box schemes and sustainable diets. This finding, again, reveals that the lack of interest in sustainable diets may be attributed to a lack of knowledge or previous training concerning the subject. Sustainable diets are a result and driver of food systems and therefore provide a perspective on the transition towards sustainability [25]. Sensibilization to sustainable diets is crucial for the Georgian food system transition and therefore should be comprehensively covered in food–agricultural programs and as part of continued professional development. In conjunction with the students' preferred topics, organic agriculture and agroecology are considered the primary focus of both the industry and higher education institutions. Confirming the assumptions of Al Sidawi et al. (2020), these common interests and foci between higher education institutions and the private sector provide a promising opportunity in supporting the Georgian value chain by strengthening their relationships. This commonality presents future career opportunities for students and improved support both from the private and public sectors for research and instruction, thereby leading to economic development.

3.9. Students' Expectations for Future Teaching Programmes for Skills, Topics, and Methods

A majority of the students (85%) believed that Sustainable Food Systems topics would be useful for their future careers. All learning skills were indicated as highly interesting by students, while significant differences were exhibited between universities (Table 9). The skills ranked highly interesting were creative problem-solving skills, the ability to adapt/act in new situations, the ability to innovate and create, and the ability to make judgements and justify decisions. On the other hand, even with a high average, the least interesting skill for the students was the ability to search for relevant information on the internet.

Table 9. Different learning skills of interest to Georgian students.

				AUG	ATSU	BSRSU	GTU	TIGSU	
SKILLS	**Total Mean**	**N**	**SD**	**117**	**87**	**31**	**57**	**29**	***p*-Value**
Analytical problem-solving skills	2.44	321	0.720	2.66ab	2.65cd	2.32	1.98ac	1.97bd	***
Creative problem-solving skills	2.52	321	0.700	2.69ab	2.84def	2.26d	2.04ae	2.07bf	***
Ability to work in a lab	2.48	321	0.750	2.69ab	2.69cd	2.29	2ac	2.07bd	***
Ability to search for relevant information on the internet	2.42	321	0.670	2.58ab	2.59cd	2.23	2.18ac	1.9bd	***
Communication skills	2.51	321	0.670	2.64ab	2.74cd	2.39	2.23ac	1.97bd	***
Team-working skills	2.49	321	0.690	2.56abc	2.8adef	2.29d	2.19be	2.1cf	***
Ability to adapt/act in new situations	2.52	321	0.720	2.76abc	2.76def	2.23ad	2.04be	2.07cf	***
Ability to innovate and create	2.52	321	0.720	2.76abc	2.77def	2.29ad	2.04be	1.97cf	***
Possessing basic knowledge	2.49	321	0.690	2.68ab	2.66cd	2.29	2.18ac	2.03bd	***
Ability to compare and analyse different opinions	2.46	321	0.740	2.7abc	2.69def	2.16ad	2.02be	1.93cf	***
Ability to make judgements and justify decisions	2.52	321	0.720	2.75abc	2.77def	2.29ad	2.04be	2cf	***

Notes: Respondents chose between 1 = not interesting, 2 = moderately interesting, 3 = very interesting. Kruskal–Wallis tests: *** marks $p < 0.0001$; letters indicate significant differences between universities (post hoc Games–Howell tests).

ATSU students were most interested in creative problem-solving skills and teamwork skills, more so than the other universities. AUG students, on the other hand, were most interested in the ability to innovate and create and the ability to adapt or act in new situations, showing significant differences from BSRSU, GTU, and TIGSU students. For TIGSU students, the ability to search for relevant information on the internet was the least interesting. These results suggest that students may find skills or competencies less interesting if they have already taken up training in these competencies in their past coursework. Meanwhile, those abilities they find most interesting may be unfamiliar to them or have not existed in their past coursework such that they find them important to acquire. Higher education institutions must be able to ensure the development of the skills that not only empower students but also equip them to deal with complex issues and handling uncertainties as future professionals and principal actors in the food system [7,10,26].

Amongst the different teaching methods, Georgian students show the highest interest in "international courses", "seminars/interactive workshops", and "lectures with discussions", while being least interested in "e-learning courses" (Table 10). Significant differences were observed among the five Georgian universities. AUG and ATSU students were notably more interested in considering several teaching methods. AUG students preferred seminars and interactive workshops the most, while ATSU and BSRSU students preferred lectures with discussions most. On the other hand, GTU and TIGSU students preferred "international courses" the most. This observation may be explained by the fact that Georgia is a popular destination for international students. During the past several years, Georgia has increasingly gained more international students, which, in turn, has helped Georgian universities invest in infrastructure, technology, and the development of new educational programmes [27]. This presents a potential opportunity for Georgian universities to equip students with knowledge of SFS and increase their level of food citizenship to a wider extent, not only among Georgian students but among international students, too.

Table 10. Interests and preferences of Georgian students regarding different teaching methods.

				AUG	ATSU	BSRSU	GTU	TIGSU	*p*-Value
	Total Mean	**N**	**SD**	**114**	**87**	**31**	**57**	**29**	
Regular lectures	2.19	321	0.700	2.15abc	2.52ade	2.29f	1.79bdf	2e	***
Lectures with discussion	2.50	321	0.680	2.62ab	2.74cd	2.48d	2.14ac	2.07bd	***
Seminars/interactive workshops	2.50	321	0.670	2.7ab	2.64cd	2.35	2.16ac	2.1bd	***
Group work	2.41	321	0.730	2.47ab	2.73acd	2.35	1.95bc	2.17d	***
International courses (multi-cultural, international environment)	2.54	321	0.610	2.69a	2.69b	2.32	2.21ab	2.38	***
E-learning courses	2.08	321	0.680	1.96a	2.24a	2.10	2.00	2.28	
Cooperation with schools (e.g., giving lectures by students to school pupils)	2.28	321	0.790	2.4a	2.53bc	2.35d	1.77abd	2c	***

Notes: Respondents chose between 1 = not interesting, 2 = moderately interesting, 3 = very interesting. Kruskal–Wallis tests: *** marks $p < 0.0001$; letters indicate significant differences between universities (post hoc Games–Howell tests)

Like Western European students, Georgian students found "e-learning courses" to be the least interesting, which may be attributed to students' misconception that e-learning courses often involve a highly passive learning method whilst they may be highly collaborative and thus highly appreciated by students [7,28]. Correlation analyses show that students who prefer lectures with discussions as a teaching method are also interested in seminars/interactive workshops (r = 0.704), group work (r = 0.633), multi-cultural/international environments (r = 0.627), cooperation with schools (r = 0.584), and regular lectures (r = 0.440). No negative correlations were observed between the teaching methods.

These results show that Georgian students prefer traditional teaching methods such as lectures while having simultaneous discussions and collaborative activities with other students from other schools or in international environments. These discussions enable students to attain "a critically informed understanding of the topic, self-awareness and capacity for self-critique, appreciation of diversity, and informed action" [20,29,30]. These exchanges serve as channels for students to combine theoretical concepts and practical examples while developing perspectives in interacting with international students. Moreover, this method of learning complements the skills sought by Georgian students, such as creative problem-solving skills, the ability to adapt/act in new situations, and the ability to innovate and create. Through eliciting creativity and collaboration among students, transdisciplinary and transactional learning may further develop these skill sets [7,20] and develop their collaborative skills at the same time. In order to ensure the implementation of effective food systems programmes in Georgia, these learning methods should therefore serve as a basis for improvement of existing contemporary modules.

4. Study Limitations

Although the researchers intended to reach a representative part of all agriculture and food science students studying at Georgian universities, the two phases of the study were conducted during the COVID-19 pandemic, which may have limited the population sizes of the survey. This may be attributed to the lack of access to the internet, the unavailability of personal computers, or the lack of motivation to participate in any school-related activities among students during the confinement. Another limitation of the study is that the survey did not account for the nationality of the respondents, especially given that Georgian universities cater to a large population of international students. Moreover, the researchers were not able to access registrar data from the Georgian universities (to determine whether students lived with their families in the same city as their university). These factors may have influenced students' food preferences and purchasing behaviour. Finally, even though the selected universities all offer food and agriculture science degree programs, they vary largely in their foci and cover different specializations. This may have affected students' background knowledge, learning preferences, and behaviours. Ideally, the Higher Education Survey was to be shared and disseminated by professors/academic partners to their students on-site, yet this was not feasible since university instruction in Georgia during the data-gathering period was carried out by remote learning in accordance with pandemic restrictions. The food industry survey, on the other hand, was intended to be administered through in-depth qualitative expert interviews, yet due to travelling restrictions outside the EU and since the research program finished at the end of 2021, the researchers opted to administer the survey online through a structured questionnaire, therefore obtaining a limited population size.

5. Conclusions

In Georgia, as a developing country currently with a transitional economy, higher education and the food industry both play equally important roles in the development of Sustainable Food Systems. Notably, Georgian universities play a key role in the formation of specific competencies among the next generation of professionals in the country's transition to sustainability. The private sector, on the other hand, reinforces this transition through investment in smallholders and by providing an infrastructure for sustainable innovations and therefore reforming industry norms. Students' roles as future actors within the food system are not only established by their professional activities but also by their behaviours and attitudes as consumers. The results of providing a picture of sustainability from five agricultural universities in Georgia and of the Georgian food industry may provide pathways for the improvement of HE curricula with Sustainable Food Systems at their core.

H1—Georgian students' and food industry representatives' background knowledge of SFS and their topics. Most of the students have already received training or courses covering Sustainable Food Systems and its topics. These courses mainly cover the topics concerning "Food security" and "Food safety". The Georgian food industry representatives on the other hand are also generally knowledgeable about the subject but to a lesser extent. In terms of instruction and professional training, not all universities in Georgia which offer food and agriculture degree programs cover the identified topics. Likewise, not all food industry professionals have received training in Sustainable Food Systems. This suggests that both academic and professional training in Georgia need to develop pedagogical strategies to incorporate sustainability at the core of their instruction and business.

H2—Student's behaviours and food citizenship are positively influenced by their background knowledge of Sustainable Food Systems. A clear relationship between students' purchasing motives related to SFS was also established.

H3—The maintenance of healthy ecosystems was considered most important by students and professionals alike. Students who received more training in SFS considered more the needs of future generations, that the food system should be humane and just and had more respect for animal welfare. This may, therefore, serve as a basis for HEIs to better form their students as future enablers of SFS while serving as a corporate social responsibility framework for the private sector.

H4—Students' preferences with respect to teaching methods and expectations in developing skills and competencies based on SFS. The results of this study demonstrate that the majority of Georgian students believe that Sustainable Food Systems topics would be useful for their future careers. The most-sought skills are problem-solving, the ability to adapt/act in new situations, the ability to innovate and create, and the ability to make judgements and justify decisions. Moreover, students' most preferred methods of teaching are international courses, seminars/interactive workshops, and lectures with discussions. Thus, these competencies and methods along with the topics of interest (organic agriculture and agroecology) should serve as a basis for the development of future curricula in Georgian higher education.

H5—The most interesting topics in SFS for students and professionals alike are organic agriculture and agroecology. Students who considered organic agriculture as an interesting topic considered environmental impacts, animal welfare, health, and local production in their purchasing decisions. Moreover, the interest of both students and professionals in organic agriculture and agroecology is reflective of the country's present focus and continuous efforts in developing standards to conform with EU regulations. In total, these points of interest may serve as guidelines for instruction in Georgian HEIs and as templates for sustainability strategies or initiatives for the Georgian food industry.

6. Implications for Future Research

The findings of the study represent groundbreaking research, providing an overview of Sustainable Food Systems in Georgian higher education and the food industry. The results show a comparative overview of SFS education among five agricultural universities and thereby reveal pathways in remodelling education programmes towards SFS. These insights may also serve as an empirical basis for interventional studies that aim to improve food citizenship among students and food professionals alike. Since the study only focused on food purchasing and preparation performed by students, future work may focus on examining sustainable food consumption behaviours in more detail while considering whether students live with their families or not. Finally, future studies focusing on Georgian higher education and the food industry may consider the use of a mixed-method approach (i.e., explanatory design) to further explain the mechanisms behind the resulting variables and to address new questions arising from the quantitative phase.

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Evaluation of Student-Perceived Service Quality in Higher Education for Sustainable Development: A Fuzzy TODIM-ERA Method

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Abstract: Evaluating and prioritizing the service quality of higher education is an essential issue for the successful implementation of Education for Sustainable Development (ESD). This study investigates an evaluation framework to assess the performances of higher education institutes (HEIs) within the context of ESD based on student-perceived service quality. First, a conceptual model of the evaluation indicator system is explored by embedding sustainability-related indicators into the fuzzy SERVQUAL scale. Then, the evaluation of student-perceived service quality can be thought of as a problem of multicriteria decision-making (MCDM) that involves uncertainty and bounded rationality. Thus, an evaluation technique called hybrid fuzzy TODIM-ERA is proposed to address such evaluation problems by synthesizing the theoretical strengths of the intuitionistic fuzzy set theory, the evidential reasoning algorithm (ERA), and the TODIM (an acronym in Portuguese for interactive and multicriteria decision-making). Finally, a case study of five Chinese HEIs in maritime transportation is used to demonstrate the effectiveness and robustness of the proposed framework. Results provide the ranking order of all the alternative HEIs and the improvement strategies of each HEI for student-perceived service quality dimensions.

Keywords: MCDM; service quality evaluation; sustainability; higher education; intuitionistic fuzzy theory; evidence theory; TODIM

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1. Introduction

The concept of sustainable development has been discussed intensively in academia since the 1970s [1]. Recently, global environmental issues, such as climate change, environmental pollution, and natural resource scarcity, have changed how we live, think, and act [2]. To ensure a better world, the United Nations approved the 2030 Agenda for Sustainable Development in 2015, which refines the new global sustainable framework that outlines how the international community can work together to achieve 17 Sustainable Development Goals (SDGs) [3,4]. According to the United Nations Educational, Scientific and Cultural Organization (UNESCO), Education for Sustainable Development (ESD), which is the essence of SDG 4, plays a critical role in the achievement of all SDGs in the 2030 Agenda for Sustainable Development [5,6]. Specifically, SDG target 4.7 seeks to "ensure that all learners acquire the knowledge and skills required to promote sustainable development" [7]. This goal embodies the vision and ambitions of ESD for 2030, which emphasizes the provision of inclusive and equitable quality education and lifelong learning opportunities for all [8–10].

In academia, ESD is widely understood to integrate sustainability into education programs' teaching, research, and operations, presenting new challenges in education development [11,12]. In recent decades, ESD has also attracted increasing attention from strategic decision makers in many countries [13]. As an important international power, China has always given priority to development. In 2016, the Chinese government issued China's National Plan on Implementation of the 2030 Agenda for Sustainable Development, which integrates the 2030 Agenda's SDGs into domestic mid- and long-term development strategies [10,14]. Later, China's Education Modernization 2035 was published in 2019 to improve education quality, promote equitable education, and optimize the educational system [15,16]. Higher education institutions (HEIs) foster and promote sustainability competencies [17,18]. Despite the considerable academic progress in ESD [19–21], more research is necessary to address the challenges posed by sustainability implementation in higher education, particularly in terms of student-perceived service quality. Sustainability can only be achieved if students are satisfied with the education service provided by their host institutions [9].

Because students can be considered the primary customers of education, the student-perceived service quality of higher education refers to the students' overall impression of the educational functionality of HEIs and their delivery systems [22]. To better satisfy students in an increasingly competitive environment, HEIs must actively monitor the quality of the services they provide and commit to the continuous improvement of service levels [23]. To this end, there is a strong need for a valid and reliable evaluation of student-perceived service quality in higher education for sustainable development. In general, there are two critical issues in evaluating service quality: identifying reasonable quality indicators and using appropriate evaluation methods [24].

Considering the first issue, academics have become increasingly interested in the identification of educational quality indicators based on a variety of classical models or measurements, such as total quality management [25], the 5Qs model [26,27], the ISO 9001 standards [28], the service quality (SERVQUAL) scale [29], and the performance-based measure of service quality (SERVPERF) scale [30]. As one of the most widely used and mature conceptual models, the SERVQUAL scale has been modified in the evaluation of higher education service quality [23,31–34]. The SERVQUAL scale focuses on five dimensions, including tangibility, reliability, responsiveness, assurance, and empathy. Due to the urgent needs of ESD, sustainability-related indicators are incorporated into the five dimensions of the SERVQUAL scale in this study to measure student-perceived service quality in higher education more accurately.

Considering the second issue, evaluating student-perceived service quality within the context of sustainable development can belong to the scope of multicriteria decision-making (MCDM) [10]. In recent years, a variety of classic MCDM techniques, such as the analytic hierarchy process (AHP) [34,35] and the technique of order preference by similarity to ideal solution (TOPSIS) [33], have been used to evaluate educational performance, curriculum quality, and student satisfaction [23,32]. Due to the diversity of student characteristics and the complexities of decision-making scenarios, the student-perceived service quality can be plagued with vagueness and uncertainty [32]. Additionally, subjective evaluation behavior is more akin to bounded rationality [22,36,37]. According to the literature [34–39], fuzzy set theory can reasonably describe the subjective uncertainty related to educational quality evaluation [34]; ERA (evidential reasoning algorithm) can minimize the loss of uncertainty in the fusion process of evaluation information [38,39]; and TODIM (an acronym in Portuguese for interactive and multicriteria decision-making) can express the psychological behavior of decision makers in MCDM problems [36,37]. Therefore, this study develops the MCDM method based on fuzzy set theory, TODIM, and ERA for student-perceived service quality evaluation with uncertain information and bounded rationality of decision makers.

Inspired by the challenges of the above two issues, the primary objective of this study is to answer two research questions:

RQ1: How can a comprehensive evaluation indicator system be established by linking the goals of ESD to student-perceived service quality in higher education?

RQ2: How can an appropriate MCDM method be developed by fully considering the uncertainty of evaluation information and the bounded rationality of student perceptions?

In addition, integrating sustainability into transportation education is a pivotal subtopic to achieving the Sustainable Development Goals, which has gained growing attention from academia [21,40,41]. Maritime transportation is widely recognized as one of the significant pillars anchored to economic growth, social stability, and environmental issues. According to the UNCTAD reports, about 80% of the world's trade volume is transported by sea [42]. Moreover, maritime transportation enables the delivery of oversized cargo volumes with low costs and less environmental pollution [43]. In recent years, the prevalence of global sustainable development has put forward new requirements for the education of maritime transportation. In 2019, the State Council of China issued the Outline of Building China's Strength in Transportation [44]. Therefore, cultivating high-quality maritime talents with sustainability is one of the crucial components of maritime transportation education and the foundation of the maritime industry.

Based on these considerations, this study proposes an evaluation framework of student-perceived service quality in higher education for sustainable development, including a conceptual model of an evaluation indicator system and an evaluation technique called hybrid fuzzy TODIM-ERA. First, a conceptual model is designed by embedding sustainability-related indicators into the fuzzy SERVQUAL scale. Specifically, there are five dimensions and 22 indicators, of which seven indicators are related to sustainability. Then, a hybrid technique to evaluate student-perceived service quality is devised by integrated intuitionistic fuzzy set theory, ERA, and TODIM. This technique has solid theoretical advantages when managing uncertain information and bounded rationality during student-perceived service quality evaluation. Then, the evaluation of student-perceived service quality for five HEIs related to maritime transportation is conducted to demonstrate the effectiveness and performance of the proposed framework.

The remainder of this paper is organized as follows. Section 2 briefly reviews recent literature on student-perceived service quality in higher education for sustainable development. Section 3 outlines the proposed evaluation method, including a conceptual model and a hybrid fuzzy TODIM-ERA method. In Section 4, the implementation of the proposed method is detailed in five Chinese HEIs. The results and discussion are analyzed in Section 5, and conclusions are summarized in Section 6.

2. Literature Review

In this study, relevant literature can be roughly divided into three themes: higher education for sustainable development, service quality in higher education, and related MCDM methods.

2.1. Higher Education for Sustainable Development

As early as the 1980s, sustainable development attracted the attention of academia. The widely accepted definition of sustainable development was proposed based on the Brundtland Report: "the one that satisfies the needs of the present generation without compromising the capacity to satisfy those of the future generations" [4]. In terms of education for sustainable development (ESD), the Talloires Declaration in 1990 pioneered the critical role of higher education in promoting global sustainable development [10]. In 1992, Agenda 21 elaborated by the United Nations (UN) declared that education provides an essential path for advancing individual capability to deal with sustainability problems [15,18]. Then, the UNESCO Decade of ESD (2005–2014) encouraged a shift in public consciousness, values, and knowledge to promote equitable education and lifelong learning [18]. In 2015, the 2030 Agenda described the urgency to embed the goals of ESD into all levels of education [45].

Currently, higher education institutions (HEIs) are trying to incorporate the concept of ESD into their systems and subsystems, operations, and curricula [1]. Higher education plays a significant role in sustainable development. HEIs have a mission to serve societies to achieve a sustainable life. Conversely, the achievement of the SDGs is also conducive to promoting education quality and increasing student satisfaction. Many scholars have devoted themselves to investigating themes related to higher education for sustainable development in recent years. First, some scholars focus on successfully implementing ESD and addressing sustainability issues in HEIs, such as the evolution, challenges, and strategies of higher education in the ESD framework [3]; the interdisciplinary teaching-learning sequence [2]; and the experiences of sustainability-related courses [21,46]. These ESD practices can effectively promote and enhance the sustainability competencies of teachers and students in higher education. Then, some studies have attempted to identify sustainability competencies in higher education based on the rough-dominance set approach [15] and the questionnaire survey [47]. In addition, the sustainability evaluation of higher education has also attracted the attention of academia. For example, Elmassah et al. introduced a framework for HEIs' sustainable development assessment in three countries, i.e., Germany, Japan, and Egypt [48]. Weng et al. proposed an evaluation model for the improvement of teachers in the context of sustainable development [10]. Staniskis et al. applied the QUESTE-SI evaluation system to analyze educational sustainability at the Kaunas University of Technology [12]. Yuan et al. studied the awareness of sustainability among students based on a questionnaire survey with 53 elements in seven groups [13]. Regarding sustainable transportation education, Lukman et al. elaborated on integrating sustainable development within logistics-oriented programs at European universities [21]. Putz et al. applied field trips to enhance students' knowledge of sustainable transport based on a longitudinal panel study [40]. Wu et al. provided the current state of the major transportation-related departments and programs in North America and Europe based on exploratory empirical content [41].

2.2. Service Quality in Higher Education

The definition of service quality is derived from marketing [23,26] and can be described as a measure of customer satisfaction and perceived service level concerning the factors that characterize service and customer expectations [26,34,49]. The provision of high-quality service is one of the crucial factors affecting the satisfaction level of students [9]. For example, Chen et al. used data mining techniques to analyze the current status of teaching quality in high vocational education through student satisfaction surveys [50]. In addition, high-quality education is also essential for the advancement of maritime transportation. In this view, Koh et al. identified six quality dimensions and 29 measurement items for maritime programs from students' perspectives based on exploratory factor analysis [42]. Liu et al. surveyed maritime undergraduate students' perceptions of associated programs to better understand education and career paths [43]. Bao et al. identified four principal factors affecting the quality of maritime education and training in China by employing an exploratory factor analysis technique [51].

Perceived service quality evaluation is the core component of service quality management. Higher education exhibits the four peculiar characteristics of service, including being intangible, inseparable, heterogeneous, and perishable [23,34]. Therefore, it is common to generalize and apply classic service quality models and methods to higher education, such as total quality management [25], the American Customer Satisfaction Index [31], the ISO 9001 standards [28], the SERVQUAL scale [29], and the SERVPERF scale [30]. As the most prevalent service quality measurement, the SERVQUAL scale was developed based on the discrepancy or gap between perceptions and expectations of service [29]. This scale has been shown to be effective and applicable to evaluate service quality in a wide range of domains, including higher education. For example, Nojavan et al. developed a hybrid evaluation approach based on fuzzy SERVQUAL questionnaires to study the service quality performance of education units [32]. Cheng et al. modified the SERVQUAL instrument by considering the characteristics of hospitality, tourism, and leisure undergraduate programs [23]. Choudhury investigated a modified SERVQUAL instrument with four dimensions, including competence, tangibility, responsiveness, and convenience, to capture customers' perceptions of service quality [33]. Lupo proposed a reliable model based on an extension of the SERVQUAL method for measurements of education services related to the management engineering program [34].

2.3. Related MCDM Methods

Multiple-criteria decision-making (MCDM) is the methodology of prioritizing all available alternatives by comprehensively considering multiple criteria [38,52]. Recently, some researchers have explored various MCDM methods in higher education, such as the DEMATEL (a decision-making trial and evaluation laboratory) method, the DEMATEL-based analytical network process (DANP) [10], importance-performance analysis (IPA), quality function deployment (QFD) [23], and TOPSIS [33]. In order to improve the quality and level of transportation engineering education, Luo et al. studied a teaching system based on CDIO education philosophy and talent training evaluation by using the combination of AHP and expert survey method [53].

Because indicators of service quality evaluation tend to be qualitative or formulated in linguistic terms, uncertainties inevitably exist in the evaluation process. Recently, some scholars have introduced the fuzzy set theory to express epistemic and subjective uncertainty in educational evaluation. For example, Menon et al. developed a conceptual assessment model using the fuzzy logic method to analyze environmental sustainability initiatives in higher education [54]. Nojavan et al. devised a hybrid approach based on fuzzy SERVQUAL questionnaires [32]. Puente et al. proposed a methodology using FDEMATEL and FDAHP for quality assessment in European HEIs [55]. Lupo proposed a combined procedure using fuzzy set theory and AHP for measurements of education services [34]. However, fuzzy set can only describe the preference of "either one or the other" [56]. Intuitionistic fuzzy sets (IFSs) are characterized by membership and non-membership functions [57], can provide more auxiliary decision information, and are useful when representing uncertainty [38,39,52,58]. In terms of evaluating information aggregation, evidence theory is one of the best solutions to fuse uncertain information and is well-known for making the maximum use of all available information [38,39,52].

In addition, previous methods have primarily been developed on the hypothesis that decision makers act completely rationally [10,23,32–34,55]. However, in the real case, the decision behavior with bounded rationality is more in line with the practical characteristics of perceived service quality evaluation. As a popular method of behavioral decision-making, TODIM (an acronym in Portuguese for interactive and multicriteria decision-making) [59] has been successfully applied in various domains [58]. For example, Liu et al. proposed a multiple criteria group decision-making method based on evidence theory and TODIM under double hierarchy hesitant fuzzy linguistic term sets for the application of postgraduate course evaluation [37]. Zuo et al. developed a linear programming technique for multidimensional analysis of a preference model based on prospect theory and the TOPSIS method [22]. Chen et al. designed a hybrid method to analyze sustainable development indicators in the construction minerals industry by combining fuzzy set theory, the Delphi method, and the TODIM [60].

3. Methodology

To evaluate student-perceived service quality in higher education for sustainable development, this study proposes an integrated methodology consisting of two parts. First, a conceptual model with a hierarchical structure can be constructed by incorporating fuzzy SERVQUAL and sustainability-related indicators. According to this model, students' perceptions of higher education can be surveyed and collected. Next, a hybrid fuzzy TODIM-ERA method is developed for the information uncertainty and individual bounded rationality in the real evaluating process. The overall framework of this methodology is shown in Figure 1.

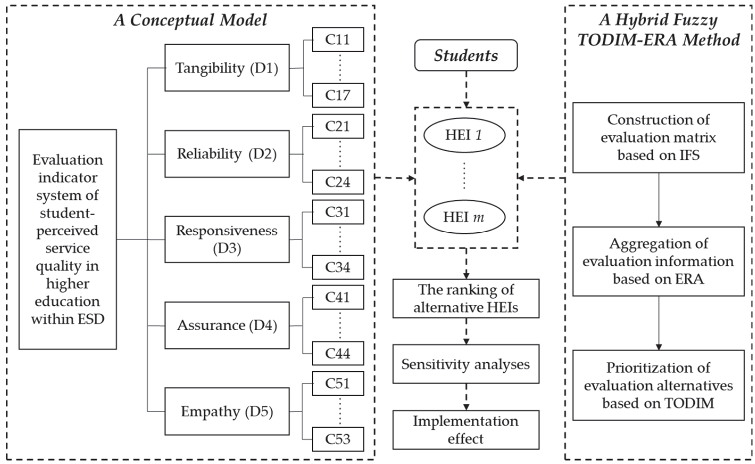

Figure 1. The overall framework of the proposed methodology.

3.1. A Conceptual Model Based on Fuzzy SERVQUAL and Sustainable Development

Establishing a conceptual model with multiple criteria is undoubtedly the foundation for reasonable evaluation. To assess students' perceptions about the service quality of HEIs in this study, the fuzzy SERVQUAL considering uncertainty is an appropriate instrument [32,34]. The method involves five dimensions [1,29]:

(1) Tangibility is concerned with physical facilities, personnel appearance, etc.
(2) Reliability is related to the capacity to deliver the promised service consistently and precisely.
(3) Responsiveness is linked to employee behaviors and attitudes, motivation to work, and willingness to assist customers.
(4) Assurance is related to employees' security, credibility, faith, and confidence.
(5) Empathy refers to specific attention to and communication with consumers.

In higher education, students are typically regarded as the customers of the service, while staff (academic and other) are the primary providers of the service. The level of service quality is affected by physical campus conditions and virtual education policies. In addition, the goals of ESD make the service of higher education more complex. Thus, indicators related to sustainability must be introduced into each of the five dimensions. Therefore, it is necessary to identify the evaluation indicators in the five dimensions of the fuzzy SERVQUAL scale based on the characteristics of higher education practices and the requirements of sustainable development.

Via a thorough literature review on ESD and service quality evaluation, 22 indicators in the five dimensions are shown to constitute the hierarchy of the proposed conceptual model, as shown in Table 1 and Figure 1. Motivated by the literature [1,6,13], seven sustainability-related indicators are introduced into the conceptual model. For example, indicators C16 and C17 are included in the tangibility dimension to describe the sustainability of education infrastructures and student activities. The indicator C24 in the reliability dimension reflects the development of sustainability competencies in higher education curricula. The indicator C34 focuses on the sustainability awareness of students to improve the responsiveness component. The indicators C43 and C44 in the assurance dimension reveal the sustainable development of staff and policies in higher education. In the empathy dimension, the indicator C53 is concerned with particular students to enhance student-centered sustainability.

Table 1. Evaluation indicators of student-perceived service quality in higher education for sustainable development.

Code	Indicator	Description	References
C11	Cleanliness of campus and staff	The campus is kept clean, and staff (academic, other) are neat and professional looking.	[23,31,32,49,61]
C12	Campus Internet and Wi-Fi access	Easy access to campus Internet and Wi-Fi.	[23,31]
C13	Attractive view of physical facilities	Physical facilities (buildings, classrooms, labs) are visually attractive and convenient.	[9,31–33,61]
C14	Adequate equipment and resources	Necessary modern equipment (technologies, materials) is widely used for teaching, and sufficient information resources (books, journals, Internet, etc.) are available to meet the needs of the courses.	[9,23,32,49,61]
C15	Recreational and support facilities	Plenty of recreational and support facilities (medical facilities, canteens, transportation services, etc.) are good enough to serve students' needs.	[9,23,33]
C16	*Environment-friendly infrastructures*	*Environmentally friendly infrastructures and products are widely used for energy conservation and pollution and waste reduction.*	[1,13]
C17	*Sustainability oriented practices*	*Students are encouraged to participate in sustainability initiatives and to consider internships and jobs in enterprises with the pledge of social and environmental responsibility.*	[6,13]
C21	Accuracy of records	Education records remain accurate, coherent, and accessible.	[26,32,61]
C22	Well-kept schedules	There are fixed class schedules and punctual service hours, which are maximally adjusted to students.	[23,31,49]
C23	High-quality teaching	The course's subject matter is adequate to meet the needs of the labor market, and the teaching methods are modern.	[9,26,31,32,49]
C24	*Sustainable curricula*	*Through interdisciplinary teaching and active learning methods, courses on sustainability issues are offered to develop students' critical, holistic, and systems thinking.*	[1,6,13]
C31	Timely and efficient service	Staff (academic, other) are prompt and efficient in issuing services notices (courses, administrative activities, etc.) and resolving students' problems.	[1,23,31–33,49,61]
C32	Availability of staff for assistance	Staff (academic, other) are readily available and capable of providing guidance and support.	[9,23,31–33,49]
C33	Friendly and supportive attitude	Staff (academic, other) have a courteous, friendly, and supportive attitude towards students and protect the best interests of students.	[9,33,61]
C34	*Environmental sensitivity*	*Seminars and workshops on sustainability issues are organized to develop the environmental sensitivity of students.*	[1]
C41	Sincere commitments	Some sincere commitments are fully provided to make students feel safe with campus, faculty, and support services.	[23,31,49,61]
C42	Staff competence	Staff (academic, other) are knowledgeable and familiar with rules, regulations, and procedures.	[23,31,32,61]
C43	*Staff development and rewards*	*Staff (academic, other) have some professional development opportunities to contribute to sustainability, which will be used as a criterion for staff promotion or new employment.*	[13]
C44	*Rules and regulations*	*Rules and regulations are sound and consistent with sustainability requirements.*	[6,31]
C51	Individualized consideration	Rules and regulations are centered on the best interests of the students, the facilities and equipment are arranged for the convenience of the students, and the staff (academic, other) are attentive to the students' individual needs.	[9,23,31,32]
C52	Fair and unbiased treatment	Staff services and learning assessments are fair and unbiased to students.	[23,49]
C53	*Access for disabled students*	*There are adequate services for disabled students.*	[1,13]

According to the conceptual model in Table 1, the questionnaire with fuzzy-linguistic evaluation scales can be developed to survey and collect the student perceptions of service quality. The students are asked to assess their judgements using the linguistic terms for each indicator in five dimensions. Then, the initial evaluation can be determined based on the probability distribution of student-perceived service quality. Next, the overall evaluation results of the alternative HEIs and dimensions can be calculated based on an appropriate MCDM method, a hybrid fuzzy TODIM-ERA in the study.

3.2. A Hybrid Fuzzy TODIM-ERA Method

Evaluating student-perceived service quality in higher education for sustainable development can be considered an MCDM problem. To manage the complex decision problem with uncertainty and bounded rationality, a hybrid MCDM method is developed by combining intuitionistic fuzzy set (IFS) theory, the TODIM method, and the ERA (evidential reasoning algorithm). First, the evaluation matrix for the alternative HEIs on 22 indicators can be generated using a seven-level linguistic preference scale, in which uncertainty of linguistic preference can be represented based on IFS theory. Next, the uncertain evaluation information can be aggregated based on the ERA method to obtain the linguistic preferences for the alternative HEIs, which are further transformed into the format of IFSs. Finally, the ranking and prioritization of all alternative HEIs can be determined using the TODIM method based on the assumption of bounded rationality. The procedure of the proposed hybrid fuzzy TODIM-ERA method is shown in Figure 2. Then, the proposed MCDM procedure is detailed below.

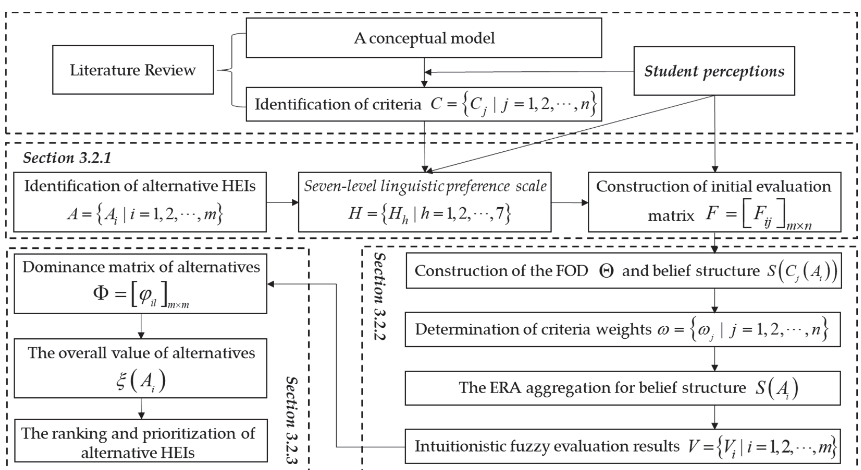

Figure 2. The procedure of the proposed hybrid fuzzy TODIM-ERA method.

3.2.1. Construction of Evaluation Matrix Based on IFS

For the MCDM problem in the study, we assume that there are m alternatives denoted by $A=\{A_i|i=1,2,\cdots,m\}$, and n criteria denoted by $C=\{C_j|j=1,2,\cdots,n\}$. Then the weight vector of criteria can be denoted by $\omega=\{\omega_j|j=1,2,\cdots,n\}$, satisfying $0\le\omega_j\le 1$ and $\sum_{j=1}^{n}\omega_j=1$. Based on the proposed conceptual model, students can express the perceptions on each indicator C_j for the alternative HEIs A_i using a seven-level linguistic preference scale, as represented by $H=\{H_h|h=1,2,\cdots,7\}$. In this study, the linguistic term H_h can be very low (*VL*), lower (*LR*), low (*L*), medium (*M*), high (*H*), higher (*HR*), and very high (*VH*), as shown in Table 2. Thus, we can obtain the initial evaluation matrix $F=[F_{ij}]_{m\times n}$, where F_{ij} is the linguistic preference for alternative A_i concerning indicator C_j. The element $F_{ij}\in F$ consists of the linguistic terms and their probabilities, which can be denoted by $F_{ij}=\left\{\left\langle H_h,\beta_{h,ij}\right\rangle\middle|H_h\in H\right\}$, $i=1,2,\cdots,m$, and $j=1,2,\cdots,n$. For example, $F_{11} = \{\langle L, 0.2\rangle, \langle M, 0.2\rangle, \langle H, 0.6\rangle\}$ indicates that the linguistic terms L, M, and H for alternative A_1 on indicator C_1 have preference probability distributions of 20%, 20%, and 60%, respectively.

Table 2. Equivalent intuitionistic fuzzy numbers for linguistic terms.

Linguistic Terms	Intuitionistic Fuzzy Numbers
Very Low (*VL*)	(0.00, 1.00)
Lower (*LR*)	(0.05, 0.95)
Low (*L*)	(0.25, 0.70)
Medium (*M*)	(0.40, 0.50)
High (*H*)	(0.70, 0.25)
Higher (*HR*)	(0.95, 0.05)
Very High (*VH*)	(1.00, 0.00)

Because linguistic preferences frequently lack confidence degrees, there is inevitably subjective uncertainty when evaluating student-perceived service quality. As mentioned earlier, the most widely-used fuzzy set theory involves only a membership function. In contrast, the intuitionistic fuzzy set characterized by three states of support, opposition, and neutrality can better describe uncertain information. This study lists the relations between IFS and the seven-level linguistic preference scale, as shown in Table 2 [39]. The concept of IFS was initially promulgated by Atanassov [57]. In this study, the definitions of IFS are shown as follows.

Definition 1 [57]. *Let X be a finite universal set, $a = \{\langle x, \mu_a(x), v_a(x)\rangle | x \in X\}$, which is defined as an IFS, where $\mu_a(x), v_a(x) \in [0,1]$ and $0 \le \mu_a(x) + v_a(x) \le 1$ for all $x \in X$. $\mu_a(x)$ is the membership degree of the element x to a, $v_a(x)$ is the corresponding non-membership, and $\pi_a(x) = 1 - \mu_a(x) - v_a(x)$ is the hesitancy degree. Thus, $a = (\mu_a, v_a)$ is called the intuitionistic fuzzy number (IFN).*

Definition 2 [57]. *Let $a_1 = (\mu_1, v_1)$ and $a_2 = (\mu_2, v_2)$ be two IFNs, and then their algebraic operations can be defined as:*

(1) $a_1 \oplus a_2 = (\mu_1 + \mu_2 - \mu_1\mu_2, v_1 v_2)$;
(2) $a_1 \otimes a_2 = (\mu_1\mu_2, v_1 + v_2 - v_1 v_2)$;
(3) $\gamma a_1 = \left(1 - (1-\mu_1)^\gamma, {v_1}^\gamma\right), \gamma > 0$;
(4) ${a_2}^\gamma = \left({\mu_2}^\gamma, 1 - (1 - v_2)^\gamma\right), \gamma > 0$.

Definition 3 [38]. *Assuming that there are n IFNs $a_j = \left(\mu_j, v_j\right)$, $j = 1, 2, \cdots, n$, then the intuitionistic fuzzy weighted averaging (IFWA) operator is defined as:*

$$IFWA_\omega(a_1, a_2, \cdots, a_n) = \omega_1 a_1 \oplus \omega_2 a_2 \oplus \cdots \oplus \omega_n a_n,$$

where ω_j is the weight of a_j, $j = 1, 2, \cdots, n$.

Definition 4 [38]. *For an IFN $a = (\mu_a, v_a)$, its $\boldsymbol{\mathcal{H}}$ score function is defined as $\boldsymbol{S}(a) = \mu_a - v_a$, and its accuracy function is defined as $\boldsymbol{\mathcal{H}}(a) = \mu_a + v_a$. Let $a_1 = (\mu_1, v_1)$ and $a_2 = (\mu_2, v_2)$ be two IFNs. Then:*

(1) $a_1 > a_2$, *if* $\boldsymbol{S}(a_1) > \boldsymbol{S}(a_2)$ *or* $\boldsymbol{S}(a_1) = \boldsymbol{S}(a_2) \wedge \boldsymbol{\mathcal{H}}(a_1) > \boldsymbol{\mathcal{H}}(a_2)$;
(2) $a_1 < a_2$, *if* $\boldsymbol{S}(a_1) < \boldsymbol{S}(a_2)$ *or* $\boldsymbol{S}(a_1) = \boldsymbol{S}(a_2) \wedge \boldsymbol{\mathcal{H}}(a_1) < \boldsymbol{\mathcal{H}}(a_2)$;
(3) $a_1 = a_2$, *if* $\boldsymbol{S}(a_1) = \boldsymbol{S}(a_2) \wedge \boldsymbol{\mathcal{H}}(a_1) = \boldsymbol{\mathcal{H}}(a_2)$.

Definition 5 [62]. *For two IFNs $a_1 = (\mu_1, v_1)$ and $a_2 = (\mu_2, v_2)$, the Euclidean distance is defined as:*

$$DiSt(a_1, a_2) = \sqrt{\frac{1}{2}\left[(\mu_1 - \mu_2)^2 + (v_1 - v_2)^2 + (\pi_1 - \pi_2)^2\right]}.$$

3.2.2. Aggregation of Evaluation Information Based on ERA

Evidence theory was proposed by Dempster [63] and improved by Shafer [64] and is also known as the D-S evidence theory. As a generalization of Bayes probability theory, it is an efficient tool for uncertainty reasoning. Then, Yang and Xu extended the D-S evidence theory to advocate an evidential reasoning algorithm (ERA) for MCDM [65] and has been applied widely in various fields, such as performance evaluation [38] and design decisions [39]. The related concepts are described as follows.

Definition 6 [65]. *Let $\Theta = \{\theta_1, \cdots, \theta_N\}$ be the frame of discernment (FOD), and then its power set is defined as:*

$$2^{\Theta} = \{\varnothing, \{\theta_1\}, \cdots, \{\theta_1, \theta_2\}, \cdots \{\theta_1, \cdots, \theta_{N-1}\}, \Theta\},$$

where $\varnothing$ is an empty set.

Definition 7 [65]. *For the FOD Θ, a basic probability assignment (BPA) $m(\cdot)$, also called a mass function, is a mapping $m : 2^{\Theta} \to [0,1]$ that satisfies:*

$$\sum\nolimits_{A \subseteq \Theta} m(A) = 1,\ m(\varnothing) = 0.$$

Definition 8 [63]. *For two independent BPAs m_1 and m_2 on the FOD Θ, the Dempster combination rule for any element $A \subseteq \Theta$ is defined as follows:*

$$m_{\oplus}(A) = m_1(B) \oplus m_2(C) = \begin{cases} \frac{\sum_{B,C \subseteq \Theta, B \cap C = A} m_1(B) m_2(C)}{1-K} & A \neq \varnothing \\ 0 & A = \varnothing \end{cases},$$

where the normalization coefficient $K = \sum_{B,C \subseteq \Theta, B \cap C = \varnothing} m_1(B) m_2(C)$, indicating the degree of conflict between two BPAs.

Definition 9 [66]. *Let m be a BPA on the FOD Θ, and the belief entropy is defined as:*

$$E_d(m) = -\sum\nolimits_{A \subseteq \Theta} m(A) \log_2 \frac{m(A)}{2^{|A|} - 1},$$

where $|A|$ is the cardinality of the subset $A \subseteq \Theta$.

In this study, we aggregate the uncertain evaluation information of all criteria to calculate the evaluation results of alternatives. Thus, the ERA can fuse the evaluation matrix F and weight vector ω for the alternative A_i on the criteria C_j. The aggregation steps are detailed as follows.

First, the frame of discernment (FOD) can be constructed based on a seven-level linguistic preference scale [39], $\Theta = H = \{VL, LR, L, M, H, HR, VH\}$. Then, the linguistic preference in the evaluation matrix can be considered to be the body of evidence (BOE) on the FOD Θ. Then the element $F_{ij} \in F$ of alternative A_i on criteria C_j can be expressed as a belief structure shown as follows.

$$S(C_j(A_i)) = \left\{ \left\langle H_h, \beta_{h,ij} \right\rangle \middle| H_h \in \Theta \right\},\ i = 1, 2, \cdots, m,\ j = 1, 2, \cdots, n, \tag{1}$$

where $\beta_{h,ij}$ in the evidence theory denotes the belief degree of proposition H_h on criteria C_j for alternative A_i, satisfying $0 \leq \beta_{h,ij} \leq 1$, and $\sum_{h=1}^{7} \beta_{h,ij} \leq 1$. Then, we let $\beta_{H,ij} = 1 - \sum_{h=1}^{7} \beta_{h,ij}$ be the belief degree unassigned to any propositions.

Second, a weighting method based on belief entropy is proposed to obtain more objective weights rather than being directly provided by decision makers. Therefore, $\omega = \{\omega_j | j = 1, 2, \cdots, n\}$ can be determined by measuring the information volume of BOEs based on belief entropy. The weight will be larger when the value of belief entropy is greater, indicating that the BOE contains more information volume [66]. In this study, the belief entropy $E_d\left(S\left(C_j(A_i)\right)\right)$ can be calculated for BOE $S\left(C_j(A_i)\right)$ on the FOD Θ based on Definition 9. Then, the information volume for alternative A_i on criteria C_j can be defined as:

$$IV_{ij} = e^{E_d(S(C_j(A_i)))},\ i = 1, 2, \cdots, m,\ j = 1, 2, \cdots, n. \tag{2}$$

Therefore, the criteria weights can be measured as

$$\omega_j = \frac{\sum_{i=1}^{m} IV_{ij}}{\sum_{j=1}^{n}\sum_{i=1}^{m} IV_{ij}}. \tag{3}$$

Third, the ERA is leveraged to combine the evaluation information of the criteria for each alternative according to the Dempster combination rule (see Definition 8). Let $m_{h,ij}$ be a basic probability mass assigned to the proposition H_h on the jth BOE. Then, the remaining probability mass, which is denoted as $m_{H,ij}$, can represent the unassigned mass to any propositions in the FOD Θ on the jth BOE. They can be calculated as follows:

$$m_{h,ij} = \omega_j \beta_{h,ij},\ h = 1, 2, \cdots, 7,\ i = 1, 2, \cdots, m,\ j = 1, 2, \cdots, n, \tag{4}$$

$$m_{H,ij} = 1 - \omega_j \sum\nolimits_{h=1}^{7} \beta_{h,ij},\ i = 1, 2, \cdots, m,\ j = 1, 2, \cdots, n. \tag{5}$$

We can obtain that $\overline{m}_{H,ij} = 1 - \omega_j$ and $\widetilde{m}_{H,ij} = \omega_j \beta_{H,ij}$. Let $m_{h,iJ_{(j+1)}}$ be the probability mass to proposition H_h on the first j bodies of evidence (BOEs), defined as follows:

$$m_{h,iJ_{(j+1)}} = K_{J_{(j+1)}}\left[m_{h,iJ_{(j)}} m_{h,i(j+1)} + m_{H,iJ_{(j)}} m_{h,i(j+1)} + m_{h,iJ_{(j)}} m_{H,i(j+1)}\right]. \tag{6}$$

Then, the remaining probability mass $m_{H,iJ_{(j+1)}}$ represents the unassigned mass to neither proposition on the first j BOEs, which can be calculated as follows:

$$m_{H,iJ_{(j+1)}} = \widetilde{m}_{H,iJ_{(j+1)}} + \overline{m}_{H,iJ_{(j+1)}}, \tag{7}$$

$$\widetilde{m}_{H,iJ_{(j+1)}} = K_{J_{(j+1)}}\left[\widetilde{m}_{H,iJ_{(j)}} \widetilde{m}_{H,i(j+1)} + \overline{m}_{H,iJ_{(j)}} \widetilde{m}_{H,i(j+1)} + \widetilde{m}_{H,iJ_{(j)}} \overline{m}_{H,i(j+1)}\right], \tag{8}$$

$$\overline{m}_{H,iJ_{(j+1)}} = K_{J_{(j+1)}} \overline{m}_{H,iJ_{(j)}} \overline{m}_{H,i(j+1)}, \tag{9}$$

where $K_{J_{(j+1)}} = \left[1 - \sum_{h=1}^{7}\sum_{h=1,k\neq h}^{7} m_{h,iJ_{(j)}} m_{k,i(j+1)}\right]^{-1}$ is the normalization coefficient.

Finally, the evaluation results of each alternative can be calculated by aggregating the belief degrees on all criteria C_j, $j = 1, 2, \cdots, n$, shown in the following:

$$S(A_i) = \left\{\langle H_h, \beta_{h,i}\rangle \middle| H_h \in \Theta\right\},\ i = 1, 2, \cdots, m, \tag{10}$$

where $\beta_{h,i}$ is the combined belief degree of proposition H_h for alternative A_i that can be defined as follows:

$$C_j \beta_{h,i} = m_{h,iJ_{(n)}} / \left(1 - \overline{m}_{H,iJ_{(n)}}\right),\ h = 1, 2, \cdots, 7,\ i = 1, 2, \cdots, m. \tag{11}$$

According to Table 2, the proposition H_h can be transformed into the corresponding IFNs, denoted by $IFN(H_h) = (\mu_h, v_h)$. For example, $IFN(H_1) = IFN(VL) = (0, 1)$ represents that the IFN related to the proposition H_1 (i.e., the linguistic terms VL) is $(0, 1)$. Then, the evaluation results $S(A_i)$ of the alternative A_i can be expressed in the format of IFN, denoted by $V_i = \left(\mu_i^v, v_i^v\right)$. The belief degree $\beta_{h,i}$ of the proposition H_h can be considered to be the weight of the corresponding $IFN(H_h)$. Based on the IFWA operator, the intuitionistic fuzzy evaluation results V_i of the alternatives A_i can be calculated as:

$$IFWA_{S(A_i)}(H_1, H_2, \cdots, H_7) = \left(1 - \prod_{h=1}^{7}\left(1 - \mu_h^{IFN(H_h)}\right)^{\beta_{h,i}}, \prod_{h=1}^{7}\left(v_h^{IFN(H_h)}\right)^{\beta_{h,i}}\right). \tag{12}$$

Thus, we can obtain the intuitionistic fuzzy evaluation vector of the alternatives, denoted by $V = \{V_i | i = 1, 2, \cdots, m\}$, where $V_i = (\mu_i^v, v_i^v) = IFWA_{S(A_i)}(H_1, H_2, \cdots, H_7)$.

3.2.3. Prioritization of Evaluation Alternatives Based on TODIM

TODIM is derived from prospect theory and can effectively manage the bounded rationality behaviors of decision makers in MCDM problems [37,58,67]. Its basic principle is to determine the dominance degrees between alternatives and obtain the overall evaluation values by combining the dominance matrix of the alternatives. Thus, the alternatives can be sorted and ranked based on their overall values [62]. In this study, intuitionistic fuzzy set theory is introduced into the classic TODIM method to address the vague perceptions of decision makers. The details are described as follows.

First, the dominance degree of the alternative over the other alternatives is based on the intuitionistic fuzzy evaluation vector of alternatives, as shown below. In this study, the dominance matrix of alternatives denoted by $\Phi = [\varphi_{il}]_{m\times m}$ can be calculated as,

$$\varphi_{il} = \begin{cases} \sqrt{DiSt(V_i, V_l)} & V_i \geq V_l \\ -\frac{1}{\theta}\sqrt{DiSt(V_i, V_l)} & V_i < V_l \end{cases}, \; V_i, V_l \in V, \tag{13}$$

where the element φ_{il} is the dominance degree of alternative A_i relative to alternative A_l. $V_i \geq V_l$ and $V_i < V_l$ can be determined using Definition 4 in the IFS theory. The former implies a gain or no loss, while the latter describes a loss. $DiSt(V_i, V_l)$ indicates the gain or loss values of alternative A_i over alternative A_l, which can be calculated based on the Euclidean distance between IFNs (see Definition 5). The parameter θ is the attitude of loss aversion, as shown in Figure 3.

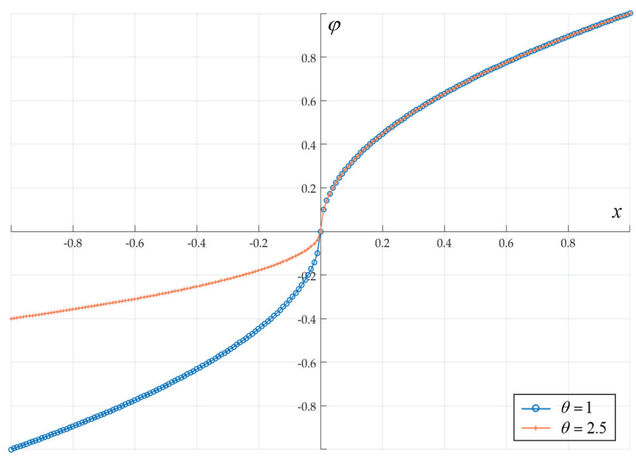

Figure 3. Dominance value function curves.

When $\theta = 1$, the curve in the loss quadrant is steeper. Conversely, the losses are attenuated when $\theta = 2.5$, the curve is to the x-axis. Thus, the decision makers become increasingly sensitive to changes in the losses as parameter θ declines. Also, decision makers are typically more sensitive to changes in losses than to changes in gains [62,68]. In the practical evaluation of educational service quality, HEIs' administrators will pay more attention to students' negative perceptions than positive perceptions, which is consistent with the concept of the loss attenuator in TODIM.

Second, the overall value concerning the alternative A_i can be calculated by

$$\xi(A_i) = \frac{\sum_{l=1}^{m} \varphi(A_i, A_l) - \min_i(\sum_{l=1}^{m} \varphi(A_i, A_l))}{\max_i(\sum_{l=1}^{m} \varphi(A_i, A_l)) - \min_i(\sum_{l=1}^{m} \varphi(A_i, A_l))}, \; i = 1, 2, \cdots, m. \tag{14}$$

Finally, the ranking and prioritization of alternatives can be obtained according to the overall dominance $\xi(A_i)$, $i = 1, 2, \cdots, m$. The larger the value of $\xi(A_i)$ is, the better the sorting of alternative A_i.

4. Case Study

In this section, the proposed method is applied to solve a practical evaluation problem of student-perceived service quality in five Chinese HEIs within the context of sustainable development. Relevant background and problem description are first introduced. Then, the evaluation process based on the proposed hybrid fuzzy TODIM-ERA method is demonstrated to prioritize the performance of five HEIs in terms of student-perceived service quality for sustainability.

4.1. Case Background and Description

In China, the concept of evaluating service quality in higher education is deeply embedded in education policies. In 2019, the State Council of China published China's Education Modernization 2035, highlighting the urgent need to enhance the quality of talent cultivation and innovative skills in higher education [16]. Later the same year, the Outline of Building China's Strength in Transportation was released, stating that one of the primary strategies is to cultivate high-quality talent in the field of maritime transportation [44]. In line with the 2030 Agenda, China has been striving to explore the integration of sustainable development and higher education. Therefore, evaluation of student-perceived service quality within the context of sustainable development is the essential task for HEIs to measure the realization and performance of high-quality talent cultivation in the field of maritime transportation. Comprehensive evaluation enables Chinese HEIs to continuously improve their educational facilities and policies to increase their service quality and contribute to the achievement of the SDGs. In this study, five Chinese HEIs in the field of maritime transportation provide the basis for the case study. These HEIs are renamed in this study to A1, A2, A3, A4, and A5 to maintain anonymity. Therefore, students from the five HEIs can provide individual perceptions on service quality within sustainable development.

4.2. Evaluation Process Based on the Proposed Method

Due to the subjective uncertainty characteristics of student-perceived service quality, it is challenging to make a unified and accurate evaluation for the five HEIs. Thus, the seven-level linguistic preference scale can be used to construct the initial evaluation matrix of 22 indicators in five dimensions for the five HEIs, as shown in Table 3.

We can comprehensively evaluate each alternative HEI by aggregating the initial evaluation information based on the ERA. Thus, the belief structure of ERA is first formed for each alternative on each indicator. Considering space limitations, we take the evaluation information of HEI A1 on indicator C11 as an example. According to Equation (1), its belief structure can be denoted by $S(\text{C11}(\text{A1})) = \{\langle H, 0.5\rangle, \langle HR, 0.5\rangle\}$, indicating that the belief degree of High (*H*) for HEI A1 with respect to indicator C11 is 0.5, and the corresponding belief degree of Higher (*HR*) is 0.5.

In this study, belief entropy can be used to measure the information volumes and further determine the weight vector of the indicators for each dimension. For example, the information volume of seven indicators in the tangibility dimension (i.e., D1) for five alternatives can be calculated using Equation (2) and can thus be denoted by:

$$IV(\text{D1}) = \begin{bmatrix} 2.718 & 3.653 & 4.581 & 3.180 & 4.811 & 1.598 & 3.900 \\ 4.581 & 4.417 & 3.939 & 3.180 & 3.653 & 3.180 & 4.811 \\ 4.811 & 3.939 & 3.900 & 36530 & 4.811 & 3.900 & 4.417 \\ 4.417 & 4.581 & 3.900 & 4.417 & 4.417 & 4.417 & 3.653 \\ 4.581 & 4.417 & 4.417 & 4.417 & 4.811 & 3.653 & 4.581 \end{bmatrix}.$$

Table 3. The initial evaluation information of indicators for five HEIs.

Indicators	Higher Education Institutions (HEIs)				
	A1	A2	A3	A4	A5
C11	<H, 0.5>, <HR, 0.5>	<M, 0.4>, <H, 0.4>, <VH, 0.2>	<M, 0.4>, <H, 0.3>, <HR, 0.3>	<L, 0.2>, <M, 0.5>, <H, 0.3>	<LR, 0.2>, <L, 0.4>, <M, 0.4>
C12	<H, 0.6>, <HR, 0.3>, <VH, 0.1>	<H, 0.2>, <HR, 0.5>, <VH, 0.3>	<M, 0.2>, <H, 0.6>, <VH, 0.2>	<LR, 0.2>, <M, 0.4>, <H, 0.4>	<L, 0.2>, <M, 0.5>, <HR, 0.3>
C13	<M, 0.4>, <H, 0.4>, <HR, 0.2>	<M, 0.2>, <HR, 0.6>, <VH, 0.2>	<L, 0.5>, <H, 0.4>, <HR, 0.1>	<M, 0.4>, <HR, 0.5>, <VH, 0.1>	<L, 0.2>, <H, 0.5>, <HR, 0.3>
C14	<H, 0.2>, <HR, 0.7>, <VH, 0.1>	<H, 0.1>, <HR, 0.7>, <VH, 0.2>	<M, 0.3>, <HR, 0.6>, <VH, 0.1>	<LR, 0.2>, <M, 0.5>, <HR, 0.3>	<M, 0.2>, <H, 0.5>, <VH, 0.3>
C15	<LR, 0.3>, <M, 0.4>, <HR, 0.3>	<L, 0.3>, <H, 0.6>, <HR, 0.1>	<LR, 0.3>, <M, 0.4>, <H, 0.3>,	<L, 0.2>, <H, 0.5>, <HR, 0.3>	<LR, 0.3>, <M, 0.3>, <HR, 0.4>
C16	<HR, 0.9>, <VH, 0.1>	<H, 0.1>, <HR, 0.7>, <VH, 0.2>	<M, 0.4>, <HR, 0.5>, <VH, 0.1>	<M, 0.2>, <H, 0.3>, <HR, 0.5>	<M, 0.3>, <HR, 0.6>, <VH, 0.1>
C17	<L, 0.4>, <H, 0.5>, <HR, 0.1>	<L, 0.3>, <H, 0.4>, <VH, 0.3>	<LR, 0.2>, <M, 0.5>, <H, 0.3>	<L, 0.3>, <H, 0.6>, <HR, 0.1>	<L, 0.4>, <H, 0.4>, <HR, 0.2>
C21	<M, 0.2>, <H, 0.4>, <VH, 0.4>	<L, 0.2>, <H, 0.6>, <HR, 0.2>	<L, 0.2>, <M, 0.4>, <HR, 0.4>	<L, 0.3>, <H, 0.5>, <VH, 0.2>	<L, 0.2>, <M, 0.6>, <HR, 0.2>
C22	<L, 0.1>, <M, 0.5>, <HR, 0.4>	<M, 0.1>, <H, 0.6>, <VH, 0.3>	<L, 0.2>, <M, 0.3>, <HR, 0.5>	<L, 0.1>, <M, 0.4>, <HR, 0.5>	<L, 0.2>, <M, 0.3>, <H, 0.5>
C23	<M, 0.2>, <HR, 0.6>, <VH, 0.2>	<L, 0.4>, <H, 0.5>, <HR, 0.1>	<LR, 0.3>, <M, 0.5>, <HR, 0.2>	<L, 0.2>, <M, 0.4>, <H, 0.4>	<LR, 0.4>, <M, 0.5>, <H, 0.1>
C24	<L, 0.3>, <H, 0.4>, <VH, 0.3>	<L, 0.2>, <H, 0.7>, <HR, 0.1>	<LR, 0.2>, <M, 0.7>, <H, 0.1>	<LR, 0.2>, <M, 0.4>, <H, 0.4>	<L, 0.5>, <M, 0.4>, <HR, 0.1>
C31	<H, 0.1>, <HR, 0.5>, <VH, 0.4>	<M, 0.3>, <HR, 0.6>, <VH, 0.1>	<M, 0.5>, <HR, 0.4>, <VH, 0.1>	<L, 0.3>, <H, 0.5>, <HR, 0.2>	<LR, 0.3>, <M, 0.3>, <H, 0.4>
C32	<M, 0.1>, <H, 0.7>, <VH, 0.2>	<M, 0.5>, <H, 0.5>	<L, 0.2>, <M, 0.3>, <H, 0.5>	<L, 0.3>, <H, 0.6>, <HR, 0.1>	<L, 0.1>, <M, 0.7>, <HR, 0.2>
C33	<LR, 0.1>, <L, 0.3>, <H, 0.6>	<L, 0.2>, <M, 0.5>, <HR, 0.3>	<L, 0.3>, <H, 0.6>, <HR, 0.1>	<M, 0.1>, <H, 0.5>, <HR, 0.4>	<LR, 0.2>, <L, 0.6>, <H, 0.2>
C34	<M, 0.3>, <H, 0.5>, <HR, 0.2>	<L, 0.3>, <H, 0.5>, <HR, 0.2>	<L, 0.2>, <M, 0.6>, <HR, 0.2>	<M, 0.3>, <H, 0.5>, <VH, 0.2>	<L, 0.4>, <H, 0.5>, <HR, 0.1>
C41	<L, 0.2>, <M, 0.2>, <HR, 0.6>	<M, 0.3>, <HR, 0.4>, <VH, 0.3>	<LR, 0.2>, <L, 0.2>, <H, 0.6>	<M, 0.2>, <H, 0.5>, <VH, 0.3>	<L, 0.5>, <M, 0.3>, <H, 0.2>
C42	<M, 0.1>, <H, 0.2>, <HR, 0.7>	<L, 0.2>, <H, 0.5>, <HR, 0.3>	<LR, 0.2>, <L, 0.4>, <H, 0.4>	<M, 0.4>, <HR, 0.5>, <VH, 0.1>	<LR, 0.4>, <M, 0.4>, <HR, 0.2>
C43	<M, 0.3>, <H, 0.5>, <HR, 0.2>	<L, 0.3>, <H, 0.5>, <HR, 0.2>	<LR, 0.1>, <L, 0.4>, <M, 0.5>	<L, 0.3>, <H, 0.5>, <HR, 0.2>	<LR, 0.3>, <L, 0.5>, <M, 0.2>
C44	<LR, 0.3>, <M, 0.6>, <H, 0.1>	<L, 0.3>, <M, 0.4>, <HR, 0.3>	<LR, 0.2>, <M, 0.6>, <HR, 0.2>	<M, 0.3>, <H, 0.6>, <HR, 0.1>	<LR, 0.2>, <L, 0.4>, <M, 0.4>
C51	<L, 0.2>, <M, 0.6>, <H, 0.2>	<L, 0.3>, <M, 0.4>, <H, 0.3>	<LR, 0.4>, <M, 0.4>, <HR, 0.2>	<L, 0.2>, <M, 0.4>, <H, 0.4>	<L, 0.3>, <M, 0.5>, <H, 0.2>
C52	<LR, 0.2>, <M, 0.5>, <H, 0.3>	<L, 0.1>, <M, 0.3>, <H, 0.6>	<L, 0.2>, <M, 0.6>, <HR, 0.2>	<M, 0.3>, <H, 0.5>, <HR, 0.2>	<LR, 0.3>, <M, 0.5>, <H, 0.2>
C53	<L, 0.2>, <H, 0.6>, <HR, 0.2>	<M, 0.1>, <H, 0.5>, <HR, 0.4>	<M, 0.2>, <H, 0.6>, <VH, 0.2>	<M, 0.1>, <H, 0.5>, <VH, 0.4>	<M, 0.3>, <H, 0.4>, <HR, 0.3>

Based on $IV(\mathrm{D1})$ and Equation (3), the weight vector of the seven indicators in the tangibility dimension can be determined to be:

$\omega(\mathrm{D1}) = \{0.148, 0.148, 0.146, 0.132, 0.158, 0.118, 0.150\}$, for indicators C11 to C17.

Similarly, we can determine the indicator weights for other dimensions. Also, the weights of the five dimensions can also be calculated based on the belief entropy and their belief structure after aggregating the corresponding indicators, shown as follows:

$\omega(\mathrm{D2}) = \{0.255, 0.264, 0.247, 0.234\}$, for indicators C21 to C24 in dimension D2;

$\omega(\mathrm{D3}) = \{0.264, 0.218, 0.249, 0.269\}$, for indicators C31 to C34 in dimension D3;

$\omega(\mathrm{D4}) = \{0.255, 0.245, 0.256, 0.244\}$, for indicators C41 to C44 in dimension D4;

$\omega(\mathrm{D5}) = \{0.351, 0.327, 0.322\}$, for indicators C51 to C53 in dimension D5;

$\omega = \{0.191, 0.191, 0.199, 0.254, 0.165\}$, for dimensions D1 to D5.

Based on the core algorithm of ERA in Equations (4)–(11), the evaluation values and weights of the related indicators can be aggregated to generate the combined belief structures of each dimension for the five HEIs, as shown in Table 4. In the same way, the final belief structure of each alternative on the FOD Θ can be calculated based on the combined evaluation values in Table 4 and the dimension weights ω, as follows:

$$S(\mathrm{A1}) = \{\langle H_4, 0.022\rangle, \langle H_5, 0.271\rangle, \langle H_6, 0.707\rangle\} = \{\langle M, 0.022\rangle, \langle H, 0.271\rangle, \langle HR, 0.707\rangle\};$$
$$S(\mathrm{A2}) = \{\langle H_4, 0.002\rangle, \langle H_5, 0.709\rangle, \langle H_6, 0.289\rangle\} = \{\langle M, 0.002\rangle, \langle H, 0.709\rangle, \langle HR, 0.289\rangle\};$$
$$S(\mathrm{A3}) = \{\langle H_4, 0.998\rangle, \langle H_5, 0.002\rangle\} = \{\langle M, 0.998\rangle, \langle H, 0.002\rangle\};$$
$$S(\mathrm{A4}) = \{\langle H_4, 0.001\rangle, \langle H_5, 0.999\rangle\} = \{\langle M, 0.001\rangle, \langle H, 0.999\rangle\};$$
$$S(\mathrm{A5}) = \{\langle H_3, 0.018\rangle, \langle H_4, 0.980\rangle, \langle H_5, 0.002\rangle\} = \{\langle L, 0.018\rangle, \langle M, 0.980\rangle, \langle H, 0.002\rangle\}.$$

Table 4. The combined evaluation information of dimensions for five HEIs.

Dimensions	Higher Education Institutions (HEIs)	
	A1	**A2**
D1	*<H, 0.16>, <HR, 0.84>*	*<L, 0.008>, <M, 0.265>, <H, 0.133>, <HR, 0.375>, <VH, 0.219>*
D2	*<H, 0.129>, <HR, 0.856>, <VH, 0.015>*	*<L, 0.012>, <H, 0.987>, <HR, 0.001>*
D3	*<M, 0.653>, <H, 0.322>, <HR, 0.025>*	*<LR, 0.004>, <L, 0.002>, <M, 0.876>, <HR, 0.118>*
D4	*<M, 0.316>, <H, 0.597>, <HR, 0.087>*	*<L, 0.028>, <M, 0.41>, <H, 0.546>, <HR, 0.016>*
D5	*<L, 0.043>, <M, 0.373>, <H, 0.095>, <HR, 0.489>*	*<LR, 0.002>, <L, 0.053>, <M, 0.933>, <H, 0.011>, <HR, 0.001>*

Dimensions	Higher Education Institutions (HEIs)	
	A3	**A4**
D1	*<L, 0.001>, <M, 0.002>, <H, 0.962>, <HR, 0.025>, <VH, 0.01>*	*<LR, 0.002>, <M, 0.27>, <H, 0.055>, <HR, 0.673>*
D2	*<L, 0.014>, <M, 0.476>, <H, 0.175>, <HR, 0.335>*	*<L, 0.107>, <M, 0.064>, <H, 0.27>, <HR, 0.557>, <VH, 0.002>*
D3	*<L, 0.038>, <M, 0.717>, <H, 0.195>, <HR, 0.05>*	*<LR, 0.064>, <L, 0.274>, <M, 0.39>, <H, 0.272>*
D4	*<L, 0.006>, <M, 0.002>, <H, 0.98>, <HR, 0.012>*	*<L, 0.001>, <M, 0.081>, <H, 0.864>, <HR, 0.051>, <VH, 0.003>*
D5	*<LR, 0.017>, <L, 0.372>, <M, 0.177>, <H, 0.432>, <HR, 0.002>*	*<LR, 0.086>, <L, 0.537>, <M, 0.377>*

Dimensions	Higher Education Institutions (HEIs)
	A5
D1	*<LR, 0.003>, <L, 0.023>, <M, 0.511>, <H, 0.46>, <HR, 0.003>*
D2	*<L, 0.021>, <M, 0.161>, <H, 0.801>, <HR, 0.017>*
D3	*<LR, 0.036>, <L, 0.004>, <M, 0.832>, <H, 0.093>, <HR, 0.032>, <VH, 0.003>*
D4	*<L, 0.003>, <M, 0.161>, <H, 0.817>, <HR, 0.002>, <VH, 0.017>*
D5	*<LR, 0.009>, <L, 0.011>, <M, 0.794>, <H, 0.177>, <HR, 0.009>*

Due to the uncertainty of linguistic preferences during the practical evaluation, the linguistic terms should be converted into the corresponding IFNs based on Table 2. Then, the intuitionistic fuzzy evaluation results of the five HEIs can be obtained using the IFWA operator in Equation (12):

$V_1 = (0.914, 0.081)$, for HEI A1; $V_2 = (0.821, 0.157)$, for HEI A2; $V_3 = (0.401, 0.499)$, for HEI A3; $V_4 = (0.700, 0.250)$, for HEI A4; $V_5 = (0.398, 0.503)$, for HEI A5.

Finally, due to the bounded rationality of subjective assessment, five HEIs can be prioritized based on the TODIM method. Let $\theta = 2.5$, and thus, the dominance matrix between five HEIs can be determined based on Equation (13):

$$\Phi = \begin{bmatrix} 0 & 0.293 & 0.688 & 0.442 & 0.690 \\ -0.117 & 0 & 0.622 & 0.331 & 0.624 \\ -0.275 & -0.249 & 0 & -0.211 & 0.055 \\ -0.177 & -0.133 & 0.527 & 0 & 0.529 \\ -0.276 & -0.250 & -0.022 & -0.212 & 0 \end{bmatrix}.$$

According to Equation (14), the overall dominance of each HEI can be described by:

$$\xi(\text{A1}) = 1;\ \xi(\text{A2}) = 0.773;\ \xi(\text{A3}) = 0.028;\ \xi(\text{A4}) = 0.524;\ \text{and}\ \xi(\text{A5}) = 0.$$

Therefore, we can determine that $\xi(\text{A1}) > \xi(\text{A2}) > \xi(\text{A4}) > \xi(\text{A3}) > \xi(\text{A5})$. The ranking of the five Chinese HEIs can be determined as A1 $\succ$ A2 $\succ$ A4 $\succ$ A3 $\succ$ A5, where the symbol '$\succ$' means 'superior to'.

5. Results and Discussion

To evaluate student-perceived service quality in five Chinese HEIs within the context of sustainable development, the obtained result (i.e., A1 $\succ$ A2 $\succ$ A4 $\succ$ A3 $\succ$ A5) reveals that A1 achieves the best performance by comprehensively considering all five dimensions. Using the hybrid fuzzy TODIM-ERA method, the overall dominance degrees of all the HEIs for each of the five dimensions can be calculated to obtain the corresponding prioritization results and analyze the pros and cons of each HEI.

As shown in Figure 4, HEI A1 is the best rated in dimensions D2, D3, and D4, and ranks second and third in dimensions D1 and D5, respectively. Thus, it is not surprising that A1 is the optimal HEI for all-around performance. However, the overall dominance degree of A1 on the empathy dimension (D5) is only 0.255, which is markedly lower than those of the top two HEIs (A4 and A2). These results suggest that HEI A1 must develop student-centered educational policies and pay attention to educational equity in teaching and administrative implementation. HEI A2 performs best in dimension D1 and ranks second in the other four dimensions. Specifically, all the degrees of overall dominance for D2, D3, and D5 are near 0.5. Thus, the service quality of A2 must be improved in terms of the reliability, responsiveness, and empathy dimensions. In general, HEI A3 ranks lower in all five dimensions. In particular, the overall dominance degree of A3 on D1 is 0, indicating that A3 has the lowest evaluation in the tangibility dimension. In practice, HEI A3 has just moved to a new campus on the city's outskirts. Therefore, HEI A3 should continue to construct and upgrade its campus, facilities, and equipment to meet the needs of students in learning and living. HEI A4 achieves the first performance level in dimension D5, highlighting the success of its personalized talent training model. However, there is still room for A4 to improve in dimensions D1 to D4, in which A4 only ranks third and fourth, respectively. Therefore, HEI A4 must fully consider the relevant indicators in the dimensions of tangibility, reliability, responsiveness, and assurance in future educational practice. Regarding HEI A5, its best performance is in dimension D1, in which the overall dominance degree is 0.532. However, the degrees of A5 for the other dimensions D2 to D5 are the worst among the five HEIs. Therefore, there is an urgent need for HEI A5 to pay attention to students' insights and formulate comprehensive and long-term strategies to improve its service quality with sustainability.

As discussed by Lau et al. [43], maritime transportation education is considered to stem from practical orientation. Professional education needs to bridge scientific knowledge and practical requirements. For maritime transportation students, it should be essential to acquire the fundamental theories and pick up practical skills to fulfil the expectations of the labor market and sustainable development [21]. The school-enterprise cooperative training model has been emerging and popular in China in recent years. Therefore, the HEIs are encouraged to establish collaboration relations with industrial enterprises, such as port operators and shipping companies [51]. To align with the educational trends in maritime transportation, the HEIs must enhance the teaching facilities and environments in the tangibility dimension [42]. In terms of the reliability dimension, the multi-disciplinary curriculums and programs need to focus on the involvement of industry professionals to prepare students for the workforce [51]. Maritime transportation courses need to incorporate innovative pedagogical approaches in the responsiveness dimension, such as guest lectures, game-based learning, and problem-solving education [21,40], to encourage a shift in thinking and attitudes toward environmentally friendly behavior. In the assurance dimension, the HEIs should ensure that teachers and other staff possess sufficient relevant expertise in maritime transportation to guide their students in their career planning [42]. Additionally, student-centered educational philosophy should be emphasized in the empathy dimension to strengthen the students' satisfaction, engagement, and performance [33].

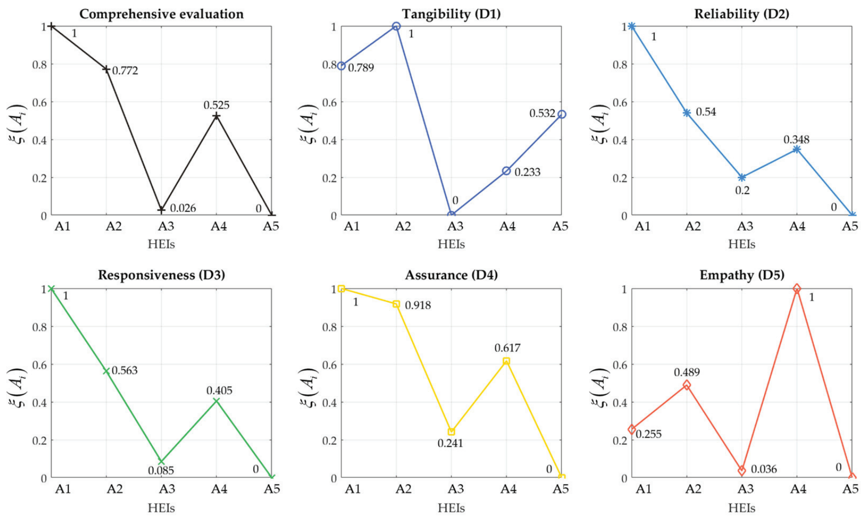

Figure 4. The ranking of alternative HEIs for each dimension.

To investigate the influence of the parameter θ, sensitivity analyses are conducted in this section. Assuming that the parameter θ ranges from 0.25 to 10, then the overall dominance of each HEI can be determined based on different θ, as shown in Figure 5. The parameter θ represents the attitude to loss aversion: a better alternative can provide more gain when θ is larger and can provide less loss when θ is smaller [37]. As shown in Figure 5, the variation of the parameter θ has only a marginal effect on the overall dominance degrees of the alternative HEIs, particularly for the best and worst alternatives. These results imply that the results of this study can be used reliably and effectively to guide the HEIs to evaluate their service quality. Regarding the other HEIs (A2–A4), their overall dominance degrees decrease smoothly as θ increases. A2′s better performance also gives it a lower rate of change (approximately 8%), while A3's worse performance gives it a markedly higher rate of change (approximately 16%), which indicates that loss aversion has different influences on various HEIs.

The evaluation results can prioritize all alternative HEIs and potentially affect higher education policymakers. From a practical perspective, the evaluation of HEIs in this study can clarify the implementation effect of educational policies and thus ensure the continuous improvement of higher education service quality within sustainability. First, the evaluation results can describe the strengths and weaknesses of each HEI from various aspects. Thus, empirical evidence can be provided to policymakers to make reasonable decisions concerning campus construction, teaching reform, administrative management, etc. Second, each HEI's performance level for different dimensions can assist managers in determining which aspects of the HEI require the most attention and how to allocate the limited resources most appropriately. Third, the evaluation method based on uncertainty and bounded rationality can help decision makers manage the complex environment while considering five dimensions and 22 indicators. Also, the proposed evaluation process has been shown to be reliable and robust. Finally, the ranking of the alternative HEIs should encourage HEIs to set their own benchmarks by considering their competitors' performances. Thus, HEIs can more effectively develop strategic planning and achieve their development goals based on the evaluation results produced by this study's proposed method.

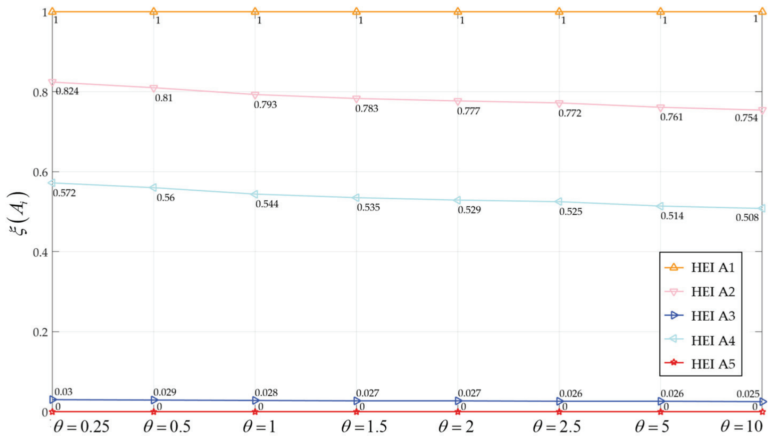

Figure 5. The overall dominance degrees of alternative HEIs with different θ.

6. Conclusions

In this study, a novel evaluation framework of higher education service quality for sustainable development is established and employed in five Chinese higher education institutes (HEIs). Using the fuzzy SERVQUAL scale and ESD goals, a conceptual model is designed by systematizing 22 indicators in five dimensions: tangibles, reliability, responsiveness, assurance, and empathy. Then, to address such a multicriteria decision-making (MCDM) problem catering to uncertainty and bounded rationality, a hybrid fuzzy TODIM-ERA method is proposed to obtain the comprehensive evaluation results of all alternative HEIs. Based on empirical research and sensitivity analysis, the proposed evaluation framework is shown to be effective and robust. In this study, the innovative contributions can be primarily summarized into the following three key points:

(1) Compared with the classic SERVQUAL scale, the conceptual model of the evaluation indicator system has added seven indicators related to sustainable development, namely "Environmentally friendly infrastructures (C16)", "Sustainability oriented practices (C17)", "Sustainable curricula (C24)", "Environmental sensitivity (C34)", "Staff development and rewards (C43)", "Rules and regulations (C44)", and "Access to disabled students (C53)". Therefore, this study provides a theoretical basis for HEIs to improve service quality and formulate sustainable development goals.

(2) To address uncertainty in evaluating higher education service quality, intuitionistic fuzzy theory and the ERA are used to represent and aggregate the uncertain information, respectively. This method can provide a more reasonable and accurate representation and fusion of uncertain information in contrast to the fuzzy set and its aggregation operators in the existing literature.

(3) The ranking order of all the alternative HEIs is determined based on the TODIM method and the intuitionistic fuzzy Euclidean distance. This method can consider the various attitudes of loss aversion by adjusting the value of the parameter θ and then has the advantage of overcoming the drawbacks of assuming complete rationality.

In future research, the perceptions of more stakeholders, such as administrators, teachers, and the government, must be considered when assessing the quality of higher education for sustainable development, which will markedly increase the complexity and difficulty of the evaluation process.

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Article

Exploring Sustainable E-Learning Platforms for Improved Universities' Faculty Engagement in the New World of Work

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Abstract: The familiar places where faculty and students engage, collaborate, debate, interact and exchange viewpoints appear to have been improved by introducing digital technology. This study investigates the influence of e-learning opportunities on faculty engagement in Nigerian universities. Five hundred faculty members were surveyed across eight private universities in Nigeria using purposive and convenient sampling techniques. Only 431 copies of the questionnaire, representing 86.2% response rate, were analysed with Smart PLS 3.0. The results show that virtual learning platforms, digital databases, online short courses and webinar learning platforms significantly influenced teaching, research, administrative and community engagements. The study concludes that the faculty of various universities should leverage e-learning platforms to be more engaged. The study recommends the machinery needed by the faculty members of Nigerian universities during the COVID-19 lockdown that challenged the conventional practice. The study empirically contributes to strengthening the current teaching, research, partnership and collaboration trends for improved faculty engagement in the new-normal world of work.

Keywords: e-learning; digital databases; sustainability; administration; teaching and research engagements

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1. Introduction

The outbreak of COVID-19 in December 2019, which the World Health Organization (WHO) described as a global pandemic, has forced many governments and other organisations to put in place several measures to curtail the spread of the virus [1,2]. Some of the measures put in place to stop the spread of the virus include social distancing and discouragement of social and religious gatherings, among others, necessitating the closure of many organisations before the vaccination exercise. The education sector is not left out of this as schools, including universities, were shut down, forcing students and faculty to stay safe at home [3,4]. However, many universities around the world had been working remotely using different e-learning platforms before the outbreak of the COVID-19 pandemic. The case in Nigeria is different. Only national open universities in Nigeria used e-learning platforms for their full operations before the COVID-19 pandemic. Some of the critical job responsibilities of universities' faculty include but are not limited to teaching engagement, research engagement, administrative engagement and collaborative/partnership engagement. Universities in the developed world have been using technology to engage with their core job responsibilities. However, the lockdown compelled many universities' lecturers in Nigeria to work remotely, and the attention was shifted to remote learning during the lockdown. Most universities' lecturers in Nigeria now explore e-learning platforms for teaching, research, community service and other administrative roles.

Existing studies have acknowledged the influence of e-learning on students' performance. In [5], the authors examined how digital literacy enhanced students' performance, while [6] also emphasised the role of digital media in student academic engagement. Studies have also shown how the e-learning environment influences students' learning culture [7]. Moreover, in [8], the authors investigated how the e-learning engagement framework promotes the reading culture among students at all levels. In [9], the authors also studied the relationships between e-learning, reading culture and education, while [10] assessed the impact of digital technology and how it influenced university education. In a related development, some scholars have also studied the job engagement of academic staff in the university system. In [11], the authors examined the effect of job engagement strategies in Nigerian universities. In [12], the authors analysed how employee engagement helps fortify the service–profit chains. Other researchers studied the relationship between employee engagement and job satisfaction [13–19]. Some scholars looked at job engagement in multigenerational workplaces [20,21], while [22–24] investigated the relationship between engagement, learning culture, work performance and organisational survival. In [25], the authors examined the implications of faculty stress for the performance of public universities' lecturers, while [26] worked on "The Performative University: 'Targets', 'Terror', and 'Taking Back Freedom'" by the faculty members. As a sequel to the above, most existing studies look at the relationship between e-learning and students' performance in universities. Besides, the existing studies also emphasise engagement strategies and faculty performance. None of these studies examine the influence of e-learning platforms on teaching, research, administrative responsibilities and partnership/collaboration engagements of faculty in Nigerian universities; this implies that there is a research gap.

Since 2015, the United Nations has introduced 17 Sustainable Development Goals (SDGs) for the purpose of environmental and social sustainability; attention has been given to clean and affordable energy, economic growth, sustainable cities, climate change and public–private partnerships, i.e., SDGs 7, 8, 11, 13 and 17, in that order. However, quality education (Goal-4) is one of the SDGs that have received little attention in the literature when teaching, research and innovation have significant roles in achieving the Sustainable Development Goals (SDGs). Both faculty and students will have the knowledge and skills needed to promote long-term development because scholarly e-resources are excellent academic tools that can be used to facilitate teaching, research and innovation. No doubt e-learning has helped in enhancing social and environmental sustainability. This is noticeable in the reduction of harmful emissions from transportation and travel. Students can connect to virtual classes from anywhere in the country without having to travel to a campus. Therefore, transportation-related pollution and the use of fossil fuels will be drastically reduced. As a result, the negative impact of pollution on the environment could be reduced.

Furthermore, universities would use less energy for power, electricity, heating and cooling systems, benefiting the environment. In virtual classes, facilitators/faculty and students use e-materials, which may help to reduce paper waste and tree consumption. All of these will enhance the environmental sustainability drives of universities.

To this end, the current study examines the influence of e-learning platform opportunities (virtual learning platforms, digital databases, online short courses and webinar learning platforms) on faculty engagement with core job responsibilities (administrative engagement, collaborative partnership, teaching and research engagements) in Nigerian private universities. Thus, this study will provide insight into how e-learning platforms can influence faculty engagements in Nigerian universities. Consequent to the foregoing, this study seeks to investigate the influence of e-learning opportunities on faculty engagement in Nigerian private universities. The significance of the study stems from the specific objectives of this study, which include examining the effect of virtual learning platforms on faculty engagements, investigating the influences of access to digital databases on faculty engagements, analysing the impact of online short courses on faculty engagement and examining the effect of the webinar learning platform on faculty engagement.

The study is structured into five sections: introduction; insight from existing literature on the subject matter, materials and methods; discussion of the findings; and conclusion, recommendations, limitations and suggestions for further studies.

2. Materials and Methods

2.1. Research Design

The study designed a cross-sectional survey approach to collect data on e-learning platforms and faculty engagement in selected private universities in Nigeria. The choice of the selected private universities was based on their adoption of technology facilities for e-learning activities. In addition, it must be noted that many universities in Nigeria are not licensed by the National Universities Commission (a government agency saddled with the responsibility of regulating Nigerian universities) to operate on the e-learning platform. However, the private universities selected were given accreditation to run distance learning in some specific cases in addition to the internal blended learning arrangement (i.e., e-learning and traditional learning). E-learning opportunities were measured with carefully selected constructs from the literature, including virtual learning platforms, online short courses, digital databases and webinar learning platforms. Faculty engagement was also measured with four constructs: administrative engagement, collaborative partnership engagement, teaching and research engagement.

The study population comprised all private universities in Southwest Nigeria, which accounted for 34 private universities out of 79 approved private universities in Nigeria. Meanwhile, out of the 34 private universities in Southwest Nigeria, only 8, representing 24.5%, were purposively selected. The choice of the selected private universities was based on appreciable technology adoption, scientific innovations and quality service delivery. The selected universities have about 3300 faculty members across all levels, excluding graduate assistants. The sample size was determined using a table chart [27] depicted in Table A2, which accounted for 499 and approximated to 500 at a margin error of 0.05. The Proportional Affixation Criterion (PAC) was used to determine the copies of the questionnaire administered to each university. This indicates that the university sample in each stratum is proportional to the relative weight of the study population, as depicted in Tables 1 and A1.

Table 1. Breakdown of selected universities.

Name of the Universities	The Population of the Categorised Faculty	Sample Size	The Return Rate of the Administered Questionnaire
University A	371	57	51
University B	484	74	65
University C	344	53	49
University D	369	57	46
University E	502	76	62
University F	332	51	45
University G	383	59	47
University H	473	73	66
TOTAL	**3258**	**500**	**431**

2.2. Sample Size and Sampling Technique

Purposive, stratified and convenient techniques were used in this study. Purposive sampling was used because only faculty members of the selected private universities, excluding graduate assistants, participated in the survey. Similarly, stratified sampling was also adopted because the population comprises different strata of faculty members across departments, colleges and different cadres. Therefore, all faculty members in each stratum were given an equal chance of being selected based on their availability and readiness to participate in the study. The respondents' data were collected by adapting the structured questionnaire to a 5-point Likert scale format. Copies of the questionnaire were administered with the help of two research assistants. It is equally important to note that the following categories of faculty members were excluded: graduate assistants, visiting lecturers and adjunct lectures from other universities. The graduate assistants are yet to be involved in teaching, and because of that, they were excluded from the study. Visiting and adjunct lecturers visit the universities occasionally, and they might not fully understand how e-learning works in the selected universities.

2.3. Reliability and Validity

A pilot study was carried out to determine the validity and reliability of the research instrument. In [28], the authors recommended a sample size of at least 10% of the study population for the pilot study. Since the sample population of this study is 500, 10% accounted for 50. Therefore, 50 copies of the questionnaire were administered to a public university in Ogun State.

Table 2 shows that the data were normally distributed and the scale reliabilities (factor loadings, compose reliability, average variance extracted (AVE) estimate and Cronbach's alpha) were higher than the recommended thresholds by [28,29], indicating internal consistency. The composite reliability for all the variables is above the 0.60 benchmarks. The composite reliability values and Cronbach's alpha coefficients are well above the 0.70 thresholds, implying internal consistency [29]. The study compared AVE with the squared correlation for each of the constructs to determine the discriminant validity. The AVE of the latent variable is greater than the squared correlations between the latent variable and the other model constructs. In addition, the heterotrait–monotrait (HTMT) ratio of correlations method was used to validate the discriminant validity. This is to ensure that the latent constructs used for measuring the causal relationships under study are truly distinct from each other. It was discovered that the average heterotrait–heteromethod correlation is relative to the average monotrait–heteromethod correlation. All the values are less than the critical value of HTMT0.85, as recommended by [29]. Based on the foregoing, discriminant validity was established.

Statistical Package for Social Sciences (SPSS) software version 26 was used to code the data. In contrast, Smart Partial Least Square (Smart PLS 3.0) was used to analyse the influence of e-learning opportunities on faculty engagement in selected universities. The algorithm and bootstrapping models are displayed by Smart PLS. The algorithm model is a structure of regressions expressed in weight vectors that aid the determination of the path coefficient, r-square values and significant values. In a related development, bootstrapping facilitates the determination of significant coefficient and *t*-value testing. It must be noted that the default bootstrapping in Smart PLS is 500 subsamples, which help to boost significant results. To enhance the significant results, the bootstrapping value was increased to 5000, as suggested by [30].

Common Method Bias: The variance inflation factor (VIF) was used to check for common method bias. As noted by [31], all factor-level VIFs from a complete collinearity test must be equal to or less than 3.3. The findings revealed that all the VIF values for each item and the variables' measurement are less than 3.3. This indicates that the study was free of common method bias (see Table 2).

Compliance with Ethical Standards: Research ethical issues were considered where all respondents were offered the option to stay anonymous. In the same way, the respondents were also assured that all the information provided would be treated with topmost confidentiality. Meanwhile, oral consent was obtained from the respondents because this type of study does not require participants' formal consent; instead, implied consent is acceptable and considered sufficient. At the same time, all the respondents were invulnerable adults who agreed to fill the copies of the questionnaire administered to them without any form of coercion or compulsion.

Table 2. Properties of the final measurement model.

	Loading	VIF	Compose Reliability	AVE	Cronbach's Alpha
Variables & Constructs	**≥0.5**	**<3.3**	**≥0.8**	**≥0.5**	**>0.7**
Virtual Learning Platform (VLP)			0.873	0.794	0.766
VLP1	0.907	1.135			
VLP2	0.760	1.578			
VLP3	0.785	1.616			
VLP4	0.724	2.524			
Digital Data Bases (DDB)			0.814	0.721	0.728
DDB1	0.702	2.493			
DDB2	0.848	1.719			
DDB3	0.636	3.104			
DDB4	0.699	2.489			
Online Short Courses (OSC)			0.806	0.702	0.761
OSC1	0.623	3.118			
OSC2	0.678	3.060			
OSC3	0.731	2.534			
OSC4	0.775	2.601			
Webinar Learning Platform			0.816	0.725	0.761
WLP1	0.673	3.113			
WLP2	0.772	2.596			
WLP3	0.745	2.555			
WLP4	0.711	2.506			
Administrative Engagement (AAE)			0.710	0.671	0.710
AAE1	0.679	3.241			
AAE2	0.683	3.236			
AE33	0.651	3.224			
Collaborative Partnership Engagement (CPE)			0.800	0.757	0.891
CPE1	0.730	1.533			
CPE2	0.837	1.701			
CPE3	0.698	2.987			
Teaching Engagement (TE)			0.804	0.760	0.763
TE1	0.761	1.579			
TE2	0.751	1.564			
TE3	0.768	1.590			
Research Engagement (RE)			0.710	0.671	0.887
RE1	0.688	2.473			
RE2	0.600	2.360			
RE3	0.721	1.520			

Table 3 depicts the model fit. The outcome showed that all the model fit indices are within the acceptable level. SRMR is an indicator of standardised residual average between the observed matrix and the hypothesised covariance matrices. The SRMR measures the model fit estimation. The SRMR is reliable when its value is less than 0.08, as Hu and Bentler (1998) recommended. It also shows that the SRMR for this study model was 0.067, which revealed a good fit for this study. The NFI estimate for this study is 0.911, which is above the benchmark of 0.90 with the chi-square value of 101.72.

Table 3. Model fit.

	Estimated
SRMR	0.066
Cmin/df	2.281
d_G	0.2576
Chi-Square	201.64
NFI	0.921

3. Results

E-learning opportunities were measured with four constructs, virtual learning platforms, digital databases, online short courses and webinar learning platforms, while faculty engagement was measured with research, teaching, administrative responsibilities and collaborative/partnership engagements. The outcome of the analysis is depicted in Figure 1.

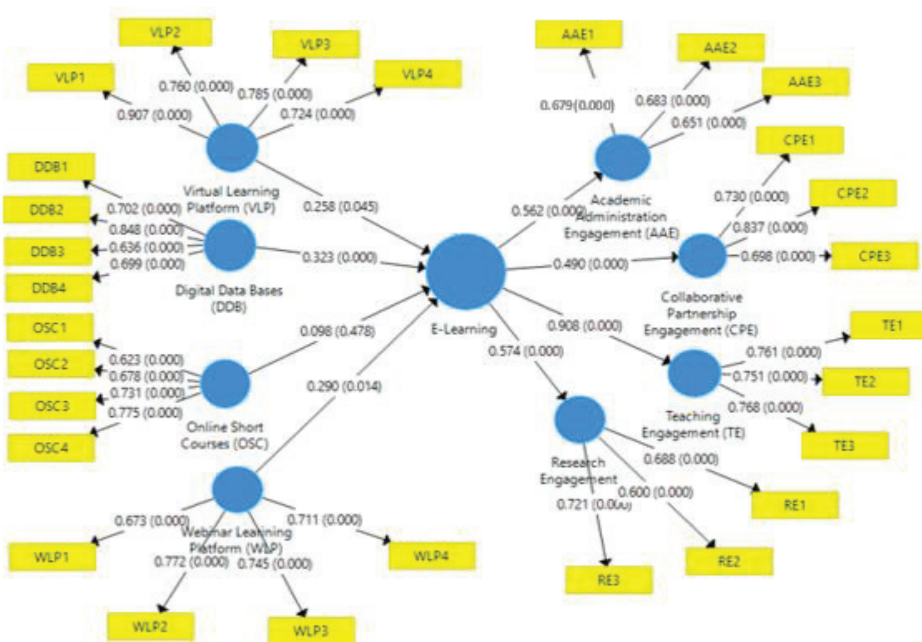

Figure 1. PLS bootstrapping model with β and *p*-values of e-learning opportunities and faculty engagement.

Figure 1 depicts the PLS bootstrapping model of e-learning opportunities that can be leveraged for enhanced job engagement. The path depicts the relationship between the independent variable (e-learning opportunities) and the dependent variable (faculty engagement). The researchers resampled the bootstrapping setting to 5000, as recommended by [31,32] confirmatory reasons. Bootstrapping helps calculate path coefficients, outer loading, outer weights, indirect effect and total effect, as shown in Figure 1. All the *t*-values in Table 3 are greater than 1.96, while the *p*-values in Figure 1 are significant at 0.05. This suggests that e-learning opportunities have a significant influence on faculty teaching, research, partnership and administrative engagements.

To test the significant effect of formulated hypotheses, the β-value, which indicates the expected variance in faculty engagement for a unit variation in the e-learning opportunities, was used. This implies that the greater the β-value, the more substantial the effect on e-learning opportunities. The significant impact of e-learning on faculty engagement was also verified through the T-statistical test. The inner model results (path coefficient, standard deviation, T-statistics and *p*-values) are presented in Table 4.

Table 4. Inner model results.

Variables	Path Coefficient	R Square	Standard Deviation	T-Statistics	*p*-Values
E-learning → Administrative Engagement	0.562	0.316	0.075	7.510	0.000
E-learning → Collaborative/Partnership Engagement	0.490	0.204	0.097	5.029	0.000
E-learning → Teaching Engagement	0.908	0.824	0.017	52.588	0.000
E-learning → Research Engagement	0.574	0.329	0.061	9.345	0.000

Further to the empirical findings presented in Table 3, it was found that the path coefficient of the measures of e-learning dimensions has a significant effect on the administrative engagement of the academic staff of universities at 0.05. The findings revealed that e-learning opportunities have a significant influence on the administrative engagement of the academic staff of universities ($\beta = 0.562$, T-statistic = 7.510 > 1.96, *p*-value = 0.000 < 0.05). The path coefficient of 562 suggests a considerable degree of relationship between e-learning opportunities and the administrative engagement of the academic staff of universities, which is significant at 0.000. The r-squared value of 316 suggests that a 31.6% variance in the administrative engagement of academic staff can be explained by e-learning opportunities.

The findings also revealed that e-learning dimensions significantly influence collaboration/partnership engagement endeavours of the academic staff of universities at 0.05. The findings showed that e-learning opportunities have a significant influence on collaboration/partnership engagement endeavours of the academic staff of universities ($\beta = 0.490$, $R^2 = 0.204$, T-statistic = 5.029 > 1.96, *p*-value = 0.000 < 0.05). The path coefficient of 0.490 implies a reasonable degree of relationship of e-learning opportunities and collaboration/partnership engagement endeavours of the academic staff of universities, which is significant at 0.000. The r-squared value of 0.204 suggests that the 20.4% variance in collaboration/partnership engagement endeavours of the academic staff of universities can be explained by e-learning opportunities.

The results also revealed that e-learning dimensions significantly influence teaching engagement of the academic staff of universities at 0.05. The findings indicated that e-learning opportunities have a significant influence on the teaching engagement of the academic staff of universities ($\beta = 0.908$, $R^2 = 0.820$, T-statistic = 52.588 > 1.96, *p*-value = 0.000 < 0.05). The path coefficient of 0.908 implies a huge degree of relationship between e-learning opportunities and teaching engagement of the academic staff of universities, which is significant at 0.000. The r-squared value of 0.824 suggests that the 82.4% variance in the teaching engagement of the academic staff of universities can be explained by e-learning opportunities.

Lastly, the study also discovered that e-learning dimensions significantly influence the research engagement of universities' academic staff, at 0.05. The findings indicated that e-learning opportunities have a significant influence on the research engagement of the academic staff of universities ($\beta = 0.574$, $R^2 = 0.329$, T-statistic = 9.345 > 1.96, *p*-value = 0.000 <0.05). The path coefficient of 0.574 implies a moderate degree of relationship of e-learning opportunities and the research engagement of the academic staff of universities, which is significant at 0.000. The r-squared value of 0.329 suggests that a 32.9% variance in the research engagement of the academic staff of universities can be explained by e-learning opportunities.

4. Discussions

It was discovered from the findings that e-learning opportunities have a significant influence on the way academic staff discharge their administrative engagement. This suggests that e-learning opportunities, such as virtual learning platforms, digital databases, online short courses and webinar learning platforms, have a significant influence on the administrative engagement of academic staff. Administrative engagement in this context refers to the running of the non-teaching activities required of academic staff. These administrative activities include advising, committee membership, deanship, HoDship and directorship. For example, universities in Nigeria have been using the Zoom platform for meetings, conferences and online teaching. This finding corroborates the findings of [33], who posited that technology influences discussion quality, particularly when it becomes practically impossible to have a face-to-face meeting. The findings of the study also align with the similar submission of [34]. They noted that technology facilitates meeting patterns of administrative engagement. This was also validated by [35,36]. They posited that e-learning opportunities influence the quality of interaction with people. This implies that the quality of information via e-learning platforms enhances the quality of information dissemination to faculty members and students at the university communities.

In a related development, the R^2 for collaborative partnership engagement is 0.240, with a path coefficient of 0.490 and a p-value of 0.000. This indicates that collaborative partnership engagement explains 24.0% of the variance in e-learning opportunities. The findings also suggest that e-learning platforms, to some extent, increase the quality of collaboration and partnership. One of the core responsibilities of faculty members of any university is to collaborate and partner with others for more quality research in providing solutions to socio-economic issues. The finding also suggests that up-to-date e-learning platforms can be leveraged for quality collaborations and partnerships with industries. This finding supports the submission of [37–40]. They believed that e-learning enhances collaborative partnerships. In [41–43], the authors made similar findings.

Similarly, the study also revealed that e-learning opportunities significantly influence the teaching engagement of faculty members. This implies that the information accessed on various e-learning platforms can be leveraged to enrich the lecture content given to the students. Since teaching is one of the core responsibilities of the faculty of universities, e-learning platforms such as virtual learning, digital databases and webinars can be leveraged for improved pedagogical practices and teaching engagement [44–48]. Meanwhile, e-learning platforms can also be used to disseminate and share helpful information that will broaden the students' horizons on a subject matter. This finding validates similar empirical findings of [49–52]. They found that e-learning platforms facilitate comprehensive teaching strategies that reshape the future of teaching practices in institutions of higher learning. The finding also validates the similar submission of [53–56], who noted that e-learning platforms help to rethink university teaching engagement.

Meanwhile, the study also discovered that e-learning opportunities have a significant effect on the research engagement of faculty members. The implication is that research productivity and the research published in high-index journals remain sine-qua-non for faculty promotion and universities ranking. The influence of e-learning platforms on research engagement cannot be overemphasised. Digital databases, webinar training and virtual conferences are useful platforms to access information that will improve the research engagement of faculty members. This finding validates the findings of [57–62], who noted that the research effectiveness of the faculty of universities is a function of institutional support. Institutional support in this context is the access to various subscribed digital databases and the virtual conference supports, among others.

5. Limitations and Suggestions for Further Studies

Only 8 out of 34 private universities in Southwest Nigeria participated in the survey. This implies that the study achieved the set objective but is limited in scope considering the number of other private and public universities in Nigeria. To this end, future studies may broaden the scope of the study to include private universities in the other five geopolitical zones in Nigeria. The focus of this study is quantitative. However, future studies can also use a mixed method. The qualitative aspect will provide more information that may shed deeper insight into the influence of e-learning on faculty engagement.

6. Conclusions

E-learning opportunities at a time like this, when COVID-19 threatens the conventional practice of universities in Nigerian universities, is indeed a relief that has prevented a total shutdown of universities. Therefore, it will be a good step for management to invest in technology that will drive teaching, research and collaborative partnership and other core areas of the university system. Efforts must be intensified by the management of universities to provide adequate training that will help the faculty maximise the e-learning opportunities to enrich their job engagements. E-learning has dramatically helped in improving environmental performance. This is evident in the reduction of emissions from transportation/travelling, which are detrimental to the environment. Since students can connect to virtual classes anywhere without necessarily travelling to the campus within and outside the country, the pollution generated by the vehicles and aircraft and fossil fuel used will be reduced. This could lessen the detrimental effect of pollution on the environment. In addition, universities would use less energy for power, electricity, heating and cooling systems, which is better for the environment. In virtual classes, facilitators/faculty and students use e-materials; this could also help reduce paper waste and tree consumption, which is better for the environment. However, e-learning has its challenges. Some of the challenges are attributed to unstable Internet facilities, particularly in developing countries, such as Nigeria; thus, accessing e-classes, smooth downloading of study materials and virtual interaction between the facilitators and students are usually disrupted. Therefore, the role of university management, particularly in ensuring a sustainable e-learning environment, increasingly engaging with stakeholders in the educational sector for a sustainable e-learning curriculum and the development of high-tech platforms that allow students and faculty/facilitators to stay abreast of the best e-learning practices, is strongly recommended. Finally, the insight from this study will serve as a platform for researchers and HR educators to explore the applicability of sustainable e-learning platforms for improved faculty engagement in the new normal across higher-education institutions' culture in both the developing and the developed world.

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Appendix A

Table A1. List of the Selected Universities.

University A	Afe Babalola University	Southwest, Nigeria
University B	Babcock University	Southwest, Nigeria
University C	Bells University	Southwest, Nigeria
University D	Crescent University	Southwest, Nigeria
University E	Covenant University	Southwest, Nigeria
University F	Bowen University	Southwest, Nigeria
University G	Joseph Ayo Babalola University.	Southwest, Nigeria
University H	Redeemer's University	Southwest, Nigeria

Table A2. Sample Size Determination Table.

	Sample Size					
Population Size	**Continuous Data (Margin of Error = 0.03)**			**Categorical Data (Margin of Error = 0.05)**		
100	46	55	68	74	80	87
200	59	75	102	116	132	154
300	65	85	123	143	169	207
400	69	92	137	162	196	250
500	72	96	147	176	218	236
600	73	100	155	187	235	316
700	75	102	161	196	249	341
800	76	104	166	203	260	363
900	76	105	170	209	270	382
1000	77	106	173	213	278	399
1500	79	110	183	230	306	461
2000	83	112	189	239	323	**499**
4000	83	119	198	254	351	570
6000	83	119	209	259	362	598
8000	83	119	209	262	367	613
10,000	83	119	209	264	370	623

Source: Bartlett, J.E., Kotrlik, J.W., Higgins, C.C. (2001).

Table A3. Questionnaire.

	StronglyAgree	**Agree**	**Undecided**	**Disagree**	**Strongly Disagree**
Virtual Learning					
Virtual conferences attended had impacted positively on my research endeavours.					
My university environment is conducive to virtual learning.					

Table A3. *Cont.*

	StronglyAgree	Agree	Undecided	Disagree	Strongly Disagree
I am satisfied with my experience with virtual learning platforms.					
My university provides online training for all Faculty to cope with the new-normal era.					
Digital Data Bases					
My university subscribed to many scientific databases for the use of all faculty and students.					
I have access to enough scientific databases for my quality research and teaching endeavours.					
I use digital file management tools confidently.					
I have the competency to prepare study materials.					
Online Short Courses					
My university encourages me to do short courses online.					
The online courses I did have impacted positively on my teaching career.					
I have at least two online certifications in my field.					
Online short courses have equipped me with the skills to thrive in my field.					
Webinar Learning Platform					
I have attended a series of webinars organised by my university in the last two years.					
The webinar allows for better interaction between the students and the faculty.					
Webinar training has broadened my skills in my field of interest.					
The webinar allows me to grow my networks.					
Administrative Engagement					
I am bursting with energy in my academic-administrative-related responsibilities.					
I am inspired to do my academic advising well.					
I feel happy working in different committees.					
Collaborative/Partnership Engagement					
I have collaborated with my colleagues in the last two years.					
I have published articles from the collaborated work in the last two years.					
I have facilitated industry partnerships with my university in the last two years.					

Table A3. *Cont.*

	StronglyAgree	Agree	Undecided	Disagree	Strongly Disagree
Teaching Engagement					
I enjoy teaching because of the availability of virtual teaching facilities provided by my university.					
My virtual teaching engagement with my students have been quite engaging and interactive.					
The virtual teaching platforms are effective for quality teaching delivery.					
Research Engagement					
I have published articles in high-indexed journals in this new-normal period.					
I have attended virtual conferences with a paper presentation in this new-normal era.					
My research profile has greatly increased in the last two years.					

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Article

Approach Developed According to Sustainable Development Goals and Challenges for Future Professionals in Social Intervention

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Abstract: In 2015, the United Nations and various countries committed to achieving the Sustainable Development Goals. The 17 goals revolve around 3 main axes: eradicating poverty, protecting the planet, and ensuring peace and prosperity for all people by 2030. These goals are integrated so that interventions in one area inevitably affect the others. Undoubtedly, this application involves developing competencies related to Prejudice, conflict resolution, and empowerment. Our research aims to analyse the knowledge and competency of university students undergoing specific training to facilitate the application of UNESCO's objectives in their work performance, while incorporating human rights as a basis for all future actions. A total of 241 students from the University of Salamanca participated. The average age of the sample was 21.13 years; 76.8% were female, and 23.2% were male (22.41 ± 7.17 years old). The data collection protocol included questions related to knowledge of the Sustainable Development Goals and involving SDGs in their personal life and future profession, which were assessed using the empowerment Scale, the Conflictalk Scale, and the Subtle and Overt Bias Scale. Significant differences were found between SDGs knowledge and involvement with academic courses. There was a direct relationship between this knowledge and involvement with the control, esteem, and activism dimensions of the Empowerment Scale, cooperative from the Conflictalk Scale, and positive emotions had inverse relationships with threat–rejection, and traditional values from the prejudice scale. Our study found that students who are more engaged with the SDGs resolve conflicts cooperatively, foster community activism, and experience positive emotions, whereas students with aggressive conflict resolution are more Prejudiced.

Keywords: environmental education; sustainability; sustainable development goals; Prejudices; empowerment

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1. Introduction

In 2015, the United Nations, together with different countries, committed to achieving the Sustainable Development Goals (SDGs). In Spain, this commitment is reflected in the 2030 agenda or action plan to fulfil these commitments, considering different measures and the implementation timeframe (ONU 2015a, 2015b). The 17 goals revolve around 3 main axes: eradicating poverty, protecting the planet, and guaranteeing peace and prosperity for all people. These axes are integrated so that interventions in one area inevitably affect the others. In Table 1, the 17 SDGs are grouped into 5 thematic blocks of major importance for people and the planet.

Table 1. Classification of SDGs according to thematic blocks.

Thematic Blocks	Goals
People	End poverty
	Zero hunger
	Health and well-being
	Quality education
	Gender equality
Prosperity	Affordable and clean energy
	Decent work and economic growth
	Water, industry, innovation, and infrastructure
	Reducing inequalities
	Sustainable cities and communities
Planet	Clean water and sanitation
	Responsible production and consumption
	Climate action
	Underwater life
	Life of terrestrial ecosystems
Peace	Peace, justice, and strong institutions
Partnerships	Partnerships to achieve these goals

Note: prepared by the author based on the United Nations' SDGs.

Undoubtedly, achieving these goals means eradicating poverty and achieving sustainable development based on a sustainable, inclusive, and equitable economy. Promoting opportunities for all people, especially those with additional difficulties, helps in eliminating inequalities and promotes integrated and sustainable management of natural resources and ecosystems. This desired reality is part of a positive vision for the world and the capacity to meet SDG challenges.

We acknowledge that the commitment and interest of states manifest through signing agreements and their governance; however, it is impossible to achieve these objectives without the active participation of society. In their environment, each person, through their daily actions and together with others, encourage progress towards social and sustainable development. Regardless of their field of work, everyone is responsible for achieving the social commitment to jointly achieve this action plan, favouring people, the planet, and prosperity.

As argued above, it is not only social intervention professionals who are entrusted with this task; however, the role they play in their professional career is very relevant to human rights education, the fulfilment of SDGs, and achieving social change. We will call this task, as a whole, the culturalization of SDGs.

After analysing different interpretative frameworks from psychology fitting these claims, we recognise positive psychology as a facilitator in constructing a more satisfactory and positive reality from a scientific point of view. Focusing on an approach to human virtues and strengths that considers human potential, motivations, and capabilities—or studying people's positive experiences, as Seligman described (Seligman 1999, [2002] 2005)—fosters positive individual characteristics that inspire their development, institutions, and/or programmes, with the aim to improve people's quality of life. Interventions in this field aim to increase positive attitudes manifested in behaviours and thoughts, thereby achieving well-being and personal development (Chaves et al. 2017; Gil da Silva and Hofheinz 2020; Hendriks et al. 2019). According to Sheldon and King (2001), this approach allows intervention based on human potential, motivations, and positive capacities, including civic virtues that guide people's sense of responsibility towards their communities to become better citizens (Contreras and Esguerra 2006; Seligman and Csikszentmihalyi 2000).

The whole field of education, particularly higher university education, is a promising platform to work on this intervention. University education trains future social intervention professionals based on critical thinking, facilitating a new world vision and creating real contributions. We agree with De la Calle et al. (2003), that education is a catalyst for development, since it is the instrument for building social awareness and progressing towards a fair and supportive world. Enhancing competencies and modifying them to be human-rights-based and SDG-oriented will require investing time in training students in social disciplines.

To initiate the intended changes, future professionals must internalise the three aforementioned competencies and values, and apply their knowledge about SDGs to their professional performance (Albareda-Tiana et al. 2019). This dedication requires specialised training through a proactive and participatory methodology that avoids rejecting these issues in their professional future. The proactivity required for these necessary skills involves knowledge about SDGs and developing positive attitudes. Understanding and knowing how to combat others downplaying their importance or are openly contrary to them is also important; therefore, prior to their vision, the perception and interpretation of these issues must be known (Aleixo et al. 2021).

Designing and planning the skillset and capacities required to develop the 17 objectives is complex and extensive. For this reason, our research team selected specific transversal processes: (1) empowerment; (2) conflict resolution; (3) Prejudice elimination.

The concept of empowerment can be understood as a social phenomenon or psychological variable. Suriá's review (Suriá 2015) describes the concept of empowerment by different authors who treat situations similarly. Following Rappaport (1984) and Segado (2011), people have the potential to accomplish proposed goals by approaching life as a social opportunity—or, as indicated by Bejerholm and Björkman (2011) and Heritage and Dooris (2009)—as a set of personal attributes that manage to activate people towards achieving planned results and goals. According to Suriá (2015) and Musitu and Buelga (2004), the relationship between SDGs and empowerment is logical, and as Rappaport (1981) describes, strengthens the control and dominion acquired by individuals, their communities, and organisations, from autonomy and critical thinking. These values are necessary, in the researchers' opinion, to internalise and implement SDGs in the field of social intervention.

Conflict resolution is fundamental and necessary for achieving SDGs, as it transversally influences the 17 SDGs by reducing violence, specifically SDG 16—peace, justice, and strong institutions. The capacity for different actors to achieve a satisfactory resolution must be considered. Garaigordobil et al. (2016) claim that conflict resolution depends on the way in which it is managed. The solution can be positive and constructive if resolved properly; on the contrary, it generates tensions and Prejudices if the affected parties are not involved. It is necessary to identify the attitude students have towards conflict to progress the so-called peace culture. Adequate conflict management skills must be acquired to advance conflict management. This project includes conflict resolution in teaching programmes, both theory and practice.

Challenges for SDGs include community inclusion and eliminating discrimination. While all the goals, in a cross-cutting manner, work against all forms and manifestations of discrimination, SDG 5—*Gender Equality*—and SDG 10—*Reducing Inequalities*—focus specifically on these goals.

In this study, we followed the same reasoning provided for empowerment and conflict resolution, which highlights the need to identify Prejudices in the students to plan actions aimed at changing attitudes, through adequately programmed training. Our research aimed to analyse SDG knowledge, the degree of development for the competencies described, and their link to students at the University of Salamanca. We also designed specific training to facilitate the application of UNESCO goals in future work performance, incorporating the human rights perspective to develop all actions. This training is part of a teaching innovation project in which teaching methodologies for developing competencies and generating attitudes to implement SDGs in the professional sphere are proposed.

2. Materials and Methods

2.1. Instruments

The students responded to an ad hoc questionnaire for assessing knowledge of SDGs and their applicability in students' lives, as well as six true or false questions related to

SDG information, designed so that students could discriminate between "yes" and "no". In addition, a Likert scale (1–6) was used to evaluate the degree of SDG application in daily life, academic life, and future profession. In addition to the knowledge obtained in university, the following were also assessed:

(1) The Empowerment Scale (Empowerment) by Rogers et al. (1997). We used the adapted version of this work by Suriá (2015). It comprises 28 items measured on a Likert scale of 4 categories (1 = highly disagree, 2 = disagree, 3 = agree, 4 = strongly agree) that assess aspects of the students' perceived capacity in decision making. The theoretical and factorial structure of the questionnaire groups the 28 items into 5 latent dimensions: self-esteem/self-efficacy (esteem—items 5, 6, 9, 12, 14, 18, 19, 24, and 26), power/empowerment (power—items 7, 8, 10, 16, 17, 21, 22, and 23), community activism/autonomy (activism—items 3, 11, 20, 25, 27, and 28), optimism for/control over the future (control—items 1, 2, 13, and 27), and appropriate anger (anger; items 4, 7, 10, 15, 16, 17, 18, 19, 20, 25, 27, and 28).

(2) The Spanish adaptation of Kimsey and Fuller (2003) self-reported scale—"Conflictalk", by Garaigordobil et al. (2016)—consists of 18 items, measured on a 5-point Likert scale and structured around 3 latent dimensions: cooperative (cooperative—items 3, 5, 7, 11, 12, and 17), avoidant (passive—items 2, 4, 6, 13, 14, and 15), and aggressive (aggressive—items 1, 8, 9, 10, 16, and 18) resolution (passive—items 1, 8, 9, 10, 16 and 18).

(3) The Spanish adaptation of the Pettigrew and Meertens (1995) Subtle and Overt Bias Scale consists of 20 items rated on a 6-level Likert scale measuring 2 latent subscales—the blatant and subtle Prejudice Scale—which assesses 2 and 3 latent dimensions, respectively. The former consists of 6 items assessing the latent dimension of threat/rejection (threat and rejection—items 4, 6, 7, 8, 9, and 14) and 4 items measuring close relationships (anti-intimacy—items 3, 12, 13, and 18). The subtle Prejudice subscale comprises 10 items structured around 3 latent dimensions, which include the traditional values dimension (traditional values—items 1, 2, 10, and 17), cultural differences (cultural differences—items 5, 11, 15, and 16), and positive emotions (positive emotions—items 19 and 20).

2.2. Procedure

Ten teachers from the University of Salamanca and members of the teaching innovation project ID2020/046 granted us access to participants of the same university. The program was approved by a responsible committee at the University of Salamanca and presented in an annual call 5454/5545. Its main objective was to train students in different degrees of SDGs and human rights. For this reason, no ethical approval or specific consent procedures were necessary for this study, as the university's teaching innovation committee previously evaluated it.

The teachers involved in the project teach social sciences, law, and education at the academic institution. First, the research team designed the evaluation protocol considering the intended objectives of the research. The protocol was then adapted to a Google questionnaire to facilitate dissemination to the teaching staff and students. The teachers in charge explained participation in the research to their students and informed consent beforehand.

2.3. Statistical Analysis

The scales' internal consistency and dimensions were assessed through Cronbach's α reliability coefficient. This procedure was accompanied by McDonald's ω and greatest lower bound (GLB and GLBFA) coefficients, appropriate in the case of items measured on a Likert scale, and asymmetric distributions (Vega-Hernández et al. 2017). The factor structure of the questionnaires was examined through confirmatory factor analysis (CFA) using the maximum likelihood method. The fit for each of the three models was assessed using several indicators: RMSEA (root mean square error of approximation), where the model fit is considered adequate with a value of <0.08, SRMR (standardized root mean square residual), whose acceptable fit value is 0.08, goodness-of-fit Index (GFI), normed fit index (NFI), relative fit index (RFI), comparative fit index (CFI), and Tucker–Lewis index (TLI) coefficients, with values close to 1 considered adequate.

The university students' scores for each of the latent dimensions in the three scales were calculated. These scores were obtained from the sum of the corresponding items while considering the appropriate direction of the items and inverting those items posed inversely.

In addition, an index with knowledge about SDGs was obtained for each of the students. This index was calculated from individuals' correct answers to the following items: "The target date for achieving Sustainable Development Goals is 2025", "SDGs have a cross-cutting principle, i.e., different SDGs are correlated", "The motto of SDGs is 'leave no one behind'", "Improving HAPPINESS is one of the most important SDGs", "The implementation of SDGs is exclusively the responsibility of public administrations", and "SDGs are related to human rights". Thus, each student had a score from 0 to 6 points (from not scoring any item correctly to scoring all the items correctly).

The analysis of quantitative variables was conducted using measures of central tendency and appropriate deviation according to the data distribution (mean and standard deviation for symmetrically distributed variables and the median and interquartile ranges for asymmetrically distributed variables). Between-group differences in latent dimension scores were examined using the corresponding parametric or non-parametric test for two groups (Student's *t*-test, Mann–Whitney U test) or more than two groups (ANOVA, Kruskal–Wallis). Pairwise comparisons of groups were studied using Bonferroni post hoc tests where significant overall differences were found. Qualitative variables were analysed using frequencies and percentages.

The relationships between knowledge and opinion about SDGs and the latent dimensions of the questionnaires were examined using Pearson's correlation coefficients between pairs of variables. These coefficients were plotted on a correlation graph with a colour scale to differentiate between direct and inverse, and weak and strong relationships between variables. In addition, the variables were grouped using Ward's hierarchical clustering according to relationships between them.

A multivariate analysis was conducted to characterise these relationships using the HJ-Biplot technique (Galindo 1986). The HJ-Biplot is a multivariate data visualisation tool that allows the joint graphical representation of the rows (students) and variables (items/dimensions) in a data matrix. Just as a scatter plot examines the relationship between two variables, the HJ-Biplot interprets relationships between more than two variables and their implications for the behaviour of individuals in the sample. The HJ-Biplot was used in this study to understand the university students' behaviour according to the scale dimensions and relationship to their opinion and knowledge about SDGs. Therefore, this technique represents the students, the scale dimensions, opinion items, and knowledge of SDGs in the same scatter plot. Students are plotted as dots and the items associated with SDGs and scale dimensions as arrows on the graph. The relationships between them can be derived by the indications below:

- *Variability of items and dimensions*: The arrow length shows the variability of the variables represented. The longer the length, the greater the discrepancy in each opinion/dimension.
- *Similarity between individuals*: Students represented by close dots on the graph are students who scored similarly on SDG items and presented a similar profile for the dimensions of the questionnaires used.
- *Correlation between items and dimensions*: The relationship between SDG knowledge, opinion items, and the three scales' latent dimensions can be examined. It is necessary to study the angles that comprise the arrows representing them. Thus, items and/or dimensions presenting angles of <90° are variables with direct and strong relationships shown by how the small this angle is. This correlation implies that students with higher scores on one variable also have higher scores on the other. Conversely, angles

>90° imply inverse relationships between these items/dimensions. The closer the corresponding angle is to 180°, the stronger the relationship. Thus, students with higher scores on one variable will have lower scores on the other. Finally, angles closer to 90° imply independence of variables.

○ *Student profiling*: The behaviour of a set of students was characterised according to their scores on different scales and items considered. It is necessary to project each of the points (students) perpendicularly on the arrows (item/dimension), reproducing the order of the students' scores on that item/dimension. The closer the point is to the tip of the arrow, the higher that student's score on the corresponding item/dimension.

Data analysis was conducted using the free software R (R Core Team 2021). The biplotbootGUI library was used to conduct the HJ-Biplot analysis (Nieto-Librero et al. 2021).

3. Results

3.1. Psychometric Properties of the Scales

The reliability measures of each scale and its dimensions are shown in Table 2. The internal consistency of the different dimensions was acceptable, except for the control and anger dimensions (the Empowerment Scale) and positive emotions (the prejudice scale), where the internal consistency values were low. These lower values may be due to the number of items that comprise each dimension, which should be considered when interpreting results associated with the dimensions.

Table 2. Internal consistency of the Empowerment, Conflictalk, and prejudice scales, and their dimensions.

		n	Cronbach's α	$IC_{\alpha}^{0.95}$	McDonald's ω	GLB	GLB_{FA}
Empowerment		28	0.76	0.72–0.8	0.87	0.84	0.91
	Esteem	9	0.88	0.86–0.90	0.88	0.89	0.91
	Power	8	0.37	0.25–0.49	0.50	0.34	0.56
	Activism	6	0.63	0.55–0.70	0.65	0.70	0.72
	Control	4	0.36	0.23–0.48	0.36	0.23	0.48
	Anger	4	0.46	0.35–0.57	0.49	0.50	0.51
Conflictalk		18	0.72	0.67–0.77	0.76	0.81	0.88
	Cooperative	6	0.82	0.78–0.85	0.82	0.87	0.88
	Passive	6	0.63	0.56–0.70	0.64	0.65	0.73
	Aggressive	6	0.65	0.58–0.71	0.70	0.66	0.75
Prejudice		20	0.86	0.84–0.89	0.92	0.90	0.95
	Blatant	10	0.79	0.75–0.83	0.84	0.85	0.90
	Threat and rejection	6	0.76	0.72–0.81	0.79	0.80	0.86
	Anti–intimacy	4	0.60	0.51–0.68	0.64	0.73	0.73
	Subtle	10	0.77	0.73–0.81	0.84	0.85	0.86
	Traditional values	4	0.66	0.59–0.72	0.68	0.58	0.75
	Cultural differences	4	0.82	0.78–0.86	0.83	0.79	0.85
	Positive emotions	2	0.27	0.09–0.46	0.27	–	0.27

Note: own elaboration.

The CFA scale results are shown in Table 3. The Empowerment (RMSEA = 0.060, SRMR = 0.070), Conflictalk (RMSEA = 0.063, SRMR = 0.072), and prejudice (RMSEA = 0.077, SRMR = 0.074) scales showed adequate model fit.

Table 3. Fit indices of AFC factor models for the Empowerment, Conflictalk, and prejudice scales.

Escala	$\chi 2$	df	*p*	RMSEA	IC_{RMSEA}	SRMR	GFI	NFI	RFI	CFI	TLI
Empowerment	629.907	337.000	<0.001	0.060	0.053–0.067	0.070	0.839	0.692	0.654	0.824	0.803
Conflictalk	255.512	130.000	<0.001	0.063	0.052–0.075	0.072	0.896	0.788	0.750	0.881	0.859
Prejudice	371.140	153.000	<0.001	0.077	0.067–0.087	0.074	0.863	0.802	0.755	0.871	0.840

Note: own elaboration.

3.2. Descriptive Statistics

The descriptive analysis of the three scales and each of their latent dimensions are shown in Supplementary Tables S1–S3.

3.3. Influence of Sociodemographic Variables on Knowledge and Consideration of the SDGs

The possible influence of variables including gender, nationality, academic year, and sexual orientation was studied in the following items: "*I consider SDGs very present in my daily life*" (SDG: *Daily life*) "*I consider SDGs very present in my academic life*" (SDG: *Academic life*)", "*I consider SDGs very present in my future career*" (SDG: *future career*), "*In class, we were provided information about SDGs*" (SDG: *Information*), and "*Index of knowledge about SDGs*" (SDG: *Knowledge*).

Statistically significant differences were found for all items with respect to the students' current academic year. In particular, statistically significant differences were found in the SDG item *Daily life* according to the students' current academic year ($p = 0.020$), specifically between first- and fourth-year students ($p = 0.028$). Fourth-year students considered SDGs as more present in their daily lives (Me = 3, P25 = 3, P75 = 4) than first-year students (Me = 3, P25 = 2, P75 = 3). Statistically significant differences were also found in the STG *Academic life* according to the students' current academic year ($p < 0.001$), specifically between first- and third-year students ($p < 0.001$), fourth-year students ($p < 0.001$), and master's degree students ($p = 0.006$). Differences were also found between students in the second and third year ($p = 0.012$), fourth year ($p = 0.032$), and master's degree (0.040). In general, students in higher grades consider SDGs as more present in their academic lives (third: Me = 4, P25 = 3, P75 = 4; fourth: Me = 3, P25 = 3, P75 = 4; master: Me = 4, P25 = 4, P75 = 5) than students in lower grades (first: Me = 3, P25 = 2, P75 = 3; second: Me = 2, P25 = 2, P75 = 3).

As for the SDG item *Knowledge*, significant overall differences were found according to the students' year ($p = 0.042$), whereas no significant differences were found by group pairs in the post hoc tests. Overall, the knowledge scores of students in all grades were high, particularly in higher grades such as third, fourth, UD, and master's degree (first: Me = 4, P25 = 4, P75 = 5; second: Me = 4, P25 = 4, P75 = 5; third: Me = 5, P25 = 4, P75 = 6; fourth: Me = 5, P25 = 4, P75 = 5; UD: Me = 5, P25 = 5, P75 = 6; master: Me = 5, P25 = 4, P75 = 5).

Students from different grades had significantly different opinions on the SDG *future career* ($p < 0.001$), particularly between first- and third-year students ($p = 0.006$) and first- and fourth-year students ($p < 0.001$). Third- and fourth-year students anticipate SDGs in their future careers (third year: Me = 4, P25 = 3, P75 = 5; fourth year: Me = 4, P25 = 3, P75 = 5) more than first-year students (Me = 3, P25 = 3, P75 = 4).

Differences were found in the SDG *Academic life* according to the education of the student's father ($p = 0.026$), whereas no significant differences were found in pairwise comparisons of groups. In the student sample, higher scores were found for students with parents with doctoral degrees.

Highly significant differences were found in students' opinions on *Information* ($p = 0.001$), according to students' living situation in Salamanca and their current academic year ($p < 0.001$). Thus, students who lived alone felt that they received more information about SDGs in class (Me = 3, P25 = 2, P75 = 4) than those living in a residence hall ($p < 0.001$, Me = 2, P25 = 1, P75 = 3) or shared flat ($p = 0.043$, Me = 2, P25 = 1, P75 = 3). On the other hand, there were differences in their opinion about information received between first-year students (Me = 2, P25 = 1, P75 = 3) and third-year students ($p = 0.002$, Me = 3, P25 = 2, P75 = 5), fourth-year students ($p = 0.002$, Me = 3, P25 = 2, P75 = 5), fourth-year students (0. 036, Me = 3, P25 = 1, P75 = 4), and master's students (0.013, Me = 5, P25 = 3, P75 = 5). Master's students felt they received more information, followed by third- and fourth-year students, and finally, first-year students.

No significant differences in the scores for any item were found according to students' gender, nationality, sexual orientation, mother's education, father's profession, and whom they live with at their place of residence.

3.4. Relationship between Knowledge and Opinion about SDGs and Latent Dimensions

First, the pairwise relationships between SDG knowledge, opinion items, and latent dimensions were studied. A graphical representation of the correlation matrix is shown in Figure 1, where the variables are grouped according to the relationships between them using Ward's hierarchical clustering. A green and purple colour scale highlights direct and inverse relationships between each pair of variables, respectively. In turn, the strength of the relationships is captured by the intensity of the colour. It is worth noting that the SDG knowledge and opinion items show direct relationships with the control, esteem, and activism dimensions of the Empowerment Scale, cooperative of the Conflictalk Scale, positive emotions of the Prejudice Scale, and inverse relationships with threat–rejection and traditional Values of the Prejudice Scale. Different colours are used to differentiate each scale: SDG opinion and knowledge (green), empowerment (indigo), Conflictalk (red), and Prejudice (orange).

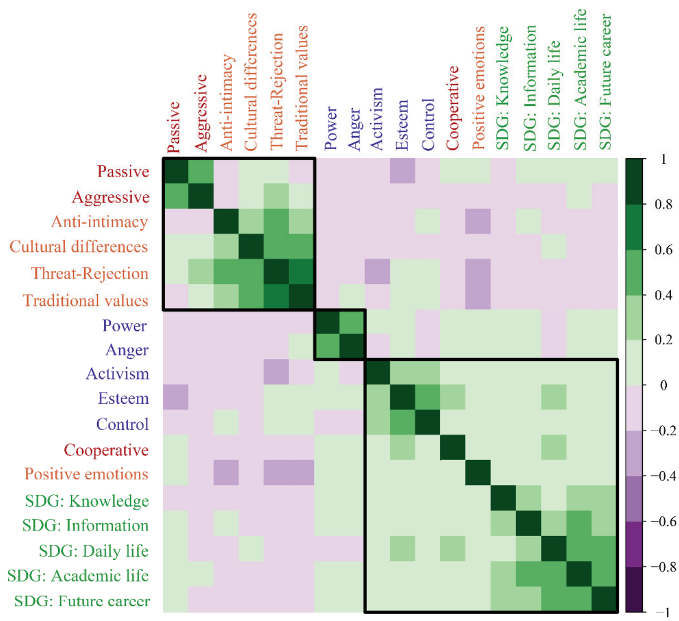

Figure 1. Correlation matrix between SDG opinion and knowledge items and latent dimensions of the Empowerment, Conflictalk, and Prejudice Scales. Note: green: direct correlations; purple: inverse correlations.

An HJ-Biplot analysis was conducted on the standardised data matrix to complement the characterisation of these relationships, retaining 2 principal components that absorbed 31.94% of the data's total variability. The factorial plane of components 1–2 is shown in Figure 2.

The HJ-Biplot interprets relationships between variables and allows us to study the association between latent dimensions and SDG attitude items.

As for the Conflictalk Scale, the aggressive dimension is independent of the cooperative and passive dimensions, whereas the cooperative and passive dimensions are inverse (i.e., students with higher cooperative resolution scores have lower passive resolution scores and vice versa).

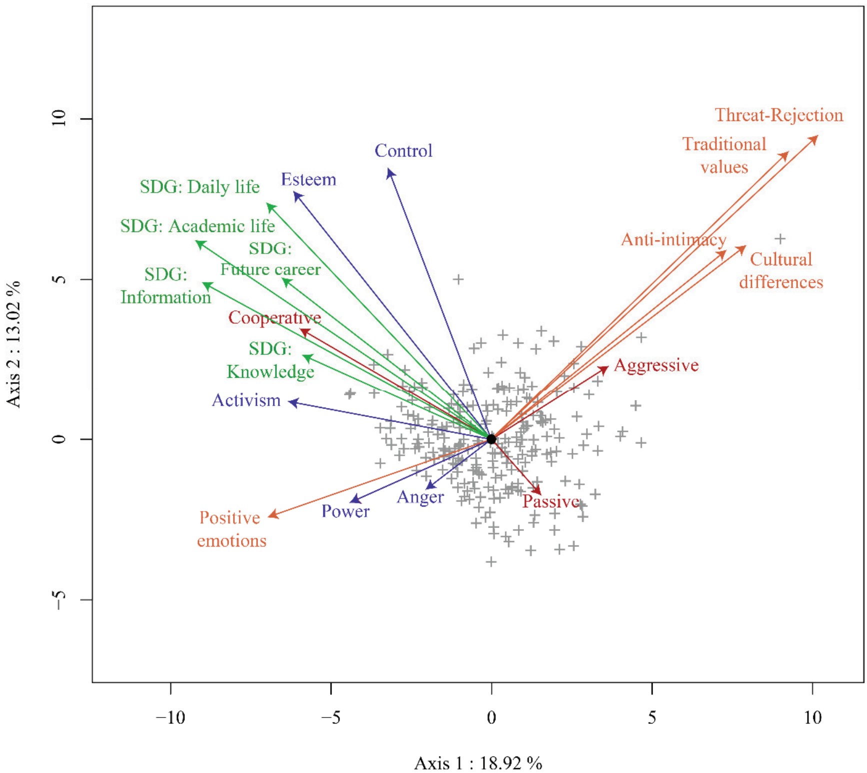

Figure 2. Factorial plane of the HJ-Biplot components 1–2. Colours used to highlight each scale: SDG opinion and knowledge (green), Empowerment (indigo), Conflictalk (red), and Prejudice (orange). Note: own elaboration.

The power and anger dimensions of the Empowerment Scale are directly and strongly related and independent of the esteem and control dimensions. On the other hand, activism is directly related to the previous four dimensions; however, these relationships are not very strong. As for SDG measurement variables, SDG knowledge and consideration items are highly related.

From the relationships between the different scale dimensions and knowledge/opinion of SDGs, it is worth noting that students with cooperative resolution have more knowledge and a better opinion about valued aspects of SDGs. These students were also characterized by higher esteem and control scores, especially concerning the SDG Knowledge index (SDG: *Knowledge*). It is worth highlighting its strong relationship with the activism and cooperative dimensions; university students with greater knowledge of SDGs have higher scores for cooperative resolution and community activism. Finally, the passive dimension is inversely related to variables related to SDGs. Thus, students with higher passive resolve have lower knowledge and opinions of SDGs.

The different dimensions of the Prejudice Scale are shown to be independent of opinion and knowledge of the SDGs, except for the positive emotions dimension, which is directly but not strongly related. Furthermore, the latter latent dimension is inversely related to the other dimensions of the Prejudice Scale. Furthermore, students with a higher aggressive resolution had higher scores in different dimensions of the Prejudice Scale, except for the positive emotions dimension, which was inversely related.

4. Discussion and Conclusions

Since the adoption of SDGs, the university framework has become an ally for implementing SDG-related measures for various reasons. SDGs aim to transform the world and, therefore, society. In this challenge, universities play an important role in training advanced human capital, generating knowledge, contributing to equity, and progressing development by responding to social demands (Rodríguez-Ponce 2009).

A university's capacity to build a culture around SDGs is more than proven; they have previously participated in other less ambitious challenges that have played, and continue to play, a fundamental role in society. The so-called "knowledge transfer" is part of a university's purpose, being one of the means to achieve the SDG of culturalization.

The university community has started engaging in the implementation of SDGs. Our research shows that students in higher education are more knowledgeable about SDGs than those in the earlier stages of their studies because they received training during their academic experience. Regarding the "integration" that university students perceive in their daily or future professional life, students in advanced courses consider themselves present in their daily life and future profession.

Our results show that students knowledgeable about SDGs and "more receptive" to their claims show a better relationship with optimism/control for the future, self-esteem/self-efficacy, and community activism. They also allow us to identify the development level of the three essential competencies for implementing these goals. Regarding conflict resolution, a cooperative approach stands out, implying interest in the cause of the conflict, identifying the problem in collaboration with others, and focusing on a unified solution. In terms of prejudices, they show positive emotions.

According to Ramos-Vidal and Maya-Jariego (2014), the psychological sense of community, citizen participation, and empowerment are fundamental concepts for implementing strategies to improve others' quality of life. As our results show, students consider SDGs an important instrument to them because they were designed to foster a psychological sense of community and participation, according to Chavis and Wandersman (1990). These authors considered the involvement of people from meso-social environments with participation dynamics and community empowerment as factors for encouraging participation and a sense of community. According to Perkins and Zimmerman (1995), psychological empowerment is interrelated with community involvement. Our research results coincided with those of Zimmerman (1995), in that psychological empowerment has interpersonal, interactive, and behavioural components. This relationship includes a greater belief in gaining knowledge and participating in their profession, especially for students who obtain higher scores with their future, self-efficacy, and community activism in mind.

These results suggest that student groups who relate empowerment with knowledge and include SDGs in their profession and daily life are more involved in community transformation. McMillan (2011) concluded that people who acquire greater control of their environment feel more independent and consider themselves responsible for their community, which are necessary aspects for bringing about change.

Conflict resolution is very present in SDGs, since the fulfilment of each one involves making decisions as situations arise. In our study, the collaborative resolution strategy influences student involvement in the knowledge and application of SDGs; in turn, this confirms that students with a passive conflict resolution strategy have less knowledge and a poorer opinion of SDGs. The cooperative conflict resolution strategy implies greater empathy and non-acceptance of aggressive and violent behaviour (Garaigordobil 2012, 2017).

Different studies have addressed the relationship between empathy and promoters of prosocial behaviours (Álvarez et al. 2010; Mestre et al. 2002). The conclusions of Luna-Bernal (2017) study are relevant to ours regarding the study of empathy and conflict management. In this case, their results showed that the problem-focused style, i.e., the cooperative strategy, has a positive relationship with global empathy. This finding is consistent with Davis (1980, 1983, 1996) definition of multidimensional empathy as perspective-taking, idealist, and empathic, with some personal discomfort.

Conflict resolution strategies oriented towards collaborative strategies influence greater internalisation of SDGs.

Regarding prejudice, our research shows a distinction between those with knowledge of SDGs and others with subtle and overt prejudice. However, it has been observed that students with aggressive conflict resolution have high scores on the Prejudice Scale.

It is necessary to further investigate the relationship between prejudice and SDG literacy. In our case, this distinction may be due to dissonance between SDGs' approaches and prejudiced attitudes or their cross-cutting perspective, which implies the equality of all people and defending human rights—issues that are incompatible with prejudice, both explicitly and subtly.

Our study's conclusions facilitated a series of seminars developed as a pilot experience for social work and criminology students. The content of this series included the following: knowledge of SDGs, managing emotions and problem-solving skills, empathy and decision making, and decisions related to SDGs and the immediate environment. The results encouraged us to continue working in the immediate future with these and other competencies linked to SDGs. There is still a significant amount of research needed; however, this study guides us on working in a transversal way and training future professionals to achieve our goals: eradicating poverty, protecting the planet, and guaranteeing peace and prosperity for all people.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/socsci11020067/s1, Tables S1–S3.

Author Contributions: E.M.P.-V., A.Y., and R.G.-O. proposed the research design and theoretical framework supporting this work. They also conducted the literature review and distributed the data collection in classrooms. The professors overseeing the projection, design, and statistical analysis of this project were A.B.N.-L. and N.G.-G. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: Within the different actions of the aforementioned research project, 10 professors of the research group apply and compete in the annual framework of educational innovation projects of the University of Salamanca in order to raise awareness and train students of different degrees in SDGs and Human Rights. This action, reviewed by the institution itself, was approved by the responsible commission of the University of Salamanca (teaching project ID2020/046 of the Usal, annual call 5454/554).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The datasets presented in this article are not readily available because the dataset remains for exclusive use by the authors due to participant privacy and informed consent. Requests to access the datasets should be directed to the author of correspondence.

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Developing Preservice Chemistry Teachers' Engagement with Sustainability Education through an Online Project-Based Learning Summer Course Program

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Abstract: The aim of this research was to develop the sustainability competencies of preservice chemistry teachers' through the use of a project-based learning model. Preservice chemistry teachers were engaged in a summer course program in collaboration with national and international universities. The summer course program was conducted online due to the COVID-19 pandemic. The research involved 26 preservice chemistry teachers from a pedagogical university in Jakarta, Indonesia, which joined with other university students from other universities in Indonesia, America, Thailand, and Malaysia. We used a qualitative methodology. Data were collected through interviews, questionnaires, observations, preservice chemistry teachers' portfolios, and reflective journals. The data were coded into themes and interpreted to reveal that all students engaged successfully in developing their sustainability perspectives, environmental awareness, project development engagement, communication, and collaboration skills. Meanwhile, the preservice chemistry teachers engaged in developing their project in an online summer course program within the framework of sustainability.

Keywords: sustainability; project-based learning; preservice chemistry teacher

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1. Introduction

In the current era of globalization, there is a heightened demand for student teachers to demonstrate 21st-century skills and environmental insights to foster a sense of responsibility towards the environment. Education for Sustainable Development (ESD) is a toolkit, developed by UNESCO, that can be used to increase environmental awareness. The ESD toolkit uses three pillars [1] to guide students to take responsibility and make decisions related to environmental, economic, and social problems [2]. Sustainable development is described as development that meets the needs of the present without compromising the future generation's ability to meet their own needs. ESD means creating and living a human life on Earth in a way that does not damage life, but that preserves its various life forms for the future—not only for future human life [3]. The purpose of ESD is to promote education as a crucial tool in preparing today's generation to become responsible citizens so that future generations can continue to shape a sustainable society.

The principle of sustainable development focuses at the same time on human livings today and in the future. Sustainable development is both a world view and a method of solving worldwide problems that emphasizes three dimensions: economic, social, and environmental [4], and distinguishes two approaches: analytical and ethical [3]. Sachs said that "Sustainability development is both a way of looking at the world, with a focus on the interlinkages of economic, social, and environmental change, and a way of describing our shared aspiration for a decent life, combining economic development, social inclusion, and environmental sustainability. It is in short both an analytical theory and a 'normative' or ethical framework" [4]. The evaluation of the impact of the Decade of ESD, that ESD was increased but a few states could report full implementation across education systems, as well as across policies and planning. However, the educational effort has not been radical enough to address the most urgent problem of time [5–7]. There is obviously still much to accomplish and many challenges to face [8] to improve ESD implementation.

All levels and domains involved in education, including chemistry education, can contribute to ESD [9]. Chemistry education can play an important role in promoting sustainable development. A practice known as green chemistry provides guidance in applying more sustainable chemistry practices to environmental issues [10]. Many areas of business have chosen to implement a green chemistry approach even though they are not compelled to. However, education is needed to build a society that is knowledgeable and concerned about negative media reports relating to social–science issues [11]. Future chemistry teachers must become more skilled at actively participating in public debates about chemistry and technology. They have a role to play in formulating social decisions towards a sustainable future and in changing societies' attitudes and behaviors towards a sustainable lifestyle.

The implementation of ESD-based pedagogy in schools remains limited in the face of more content and practice-based chemistry education designed to meet the demands of competence in a content-intensive curriculum. It is not enough to simply overlay environmental and basic chemistry issues related to sustainability onto the content and context of current chemistry curricula. ESD requires the application of a skills-oriented teaching paradigm to promote ESD practices, which is more than just education about sustainable development [12]. Therefore, a socio-scientific-based curriculum, specifically focused on sustainability issues, needs to be developed [13]. Chemistry education does not always describe the social and economic dimensions of sustainable development sufficiently, so making changes to the orientation of ESD is necessary [14,15].

Chemistry education should feature prominently in ESD due to the role played by chemistry and the chemical industry in everyday life [16,17]. Chemistry education students are expected to develop an understanding of the role of chemistry in society and be able to evaluate how chemistry can contribute to community sustainability and support the management of natural resources [9,18]. For decades, teachers have been cited as key agents in the sustainability process [19]. Analysts have asked for a stronger emphasis on teacher education to prepare them for this important task. Yet, most teachers still lack this respect [20–24].

Teachers' and students' knowledge of ESD was vaguely informed in the theoretical sense, and only a few of them possessed any clear theory-supported concept of either sustainability or ESD [25]. Education settings need to become more proactive in sustainability, and to make that happen, ESD needs to be a *core concept* in teacher education, and its implementation must be obvious in policy, campus practice, research, teaching, and learning [3], especially for preservice chemistry teachers. According to [26], teachers are the most important factor in education reform. What teachers think, believe, and know will affect their teaching. For this reason, the development of teacher competencies is an essential key to successfully growing the value of ESD in learning.

Knowledge about ESD is an essential element of 21st-century learning; therefore, it is crucial that preservice teachers understand how to implement it in schools throughout the learning process. The contribution of chemistry education to support ESD includes developing prospective chemistry teachers' understanding and their ability to apply appropriate pedagogies. Personal, social, and professional competencies are required for a paradigm shift, where knowledge about ESD is integrated and reflected in the preservice teachers' approach to chemistry education in a way that instills the value of sustainability into their students as early as possible. Burmeister at [16] present four strategies for implementing sustainable development issues in the field of chemical education by (1) applying green chemistry principles to practicum, (2) adding sustainability strategies as content in chemical education, (3) including socio-scientific issues and controversies in teaching, and (4) using chemical education as part of ESD-driven school development.

Successful 21st century learning demands competencies in critical thinking, collaboration, communication, and creativity. In order to achieve these competencies, students must be provided with a supportive process that values student-centered, active, and collaborative learning. Project-based learning (PjBL) is one example of a student-centered model where students learn to build their own learning experiences independently [27]. Learning is focused on solving challenging problems through a series of complex tasks which involve students investigating essential ideas, designing, solving problems, and making decisions by working independently and collaboratively to create realistic products or presentations. The PjBL process involves students using creative and critical thinking skills, developing opinions, and drawing conclusions [28].

In this study, 26 preservice chemistry teachers from a pedagogical university in Jakarta were engaged in a summer course to improve their understanding of sustainability project-based learning. The summer course involved students from other universities in Indonesia, America, Thailand, and Malaysia. Students worked on projects oriented to issues of sustainable development. The study was expected to develop preservice chemistry teachers' competencies through a sustainable-development-project-based learning model. The study created a competency development model for chemistry teacher candidates through project-based learning oriented towards sustainable development.

2. Materials and Methods

2.1. Research Design

A qualitative research method, adopted from [29], which defines a case study as "an in-depth exploration of a bound system such as an activity, event, process or individual", was used in the study. An interpretivist paradigm was used to produce descriptions and explanations about the participants' engagement throughout the program. Multiple data-collection strategies, such as observations during learning activities, interviews, reflective journals, documenting assigned tasks, video, photos, and observation sheets, were employed to explore the participants' engagement.

The participants in this research were preservice teachers who studied in a pedagogical university in Jakarta. A non-probability sampling strategy or criterion-sampling method was applied to measure their willingness to participate in this research. The study group consisted of 26 female undergraduate and master chemistry education students. No male students participated in the research project, which supports the literature that attracting men into the teaching profession is a real challenge. The subjects participated voluntarily in this study, and their identity was kept confidential. Descriptive information about the study group is presented in Table 1.

Table 1. Demographic characteristics of participans.

Characteristic	Parameter	Frequency (N)	Percentage (%)
Gender	Female Male	26 0	100%
Years of Studies	2017 2018	11 15	42.3% 57.7%
Cycle of studies	Bachelor's Degree Master's degree	25 1	96% 4%

The research was conducted online due to COVID-19 restrictions imposed in December 2019. The lessons and materials were delivered through a range of online platforms, such as ZOOM, WhatsApp, Google Classroom, and YouTube. The summer course program ran from 5 October 2020, until 14 November 2020. The research was conducted in three stages: a preliminary stage, a research implementation stage, and a final stage. The research flow is shown in Figure 1.

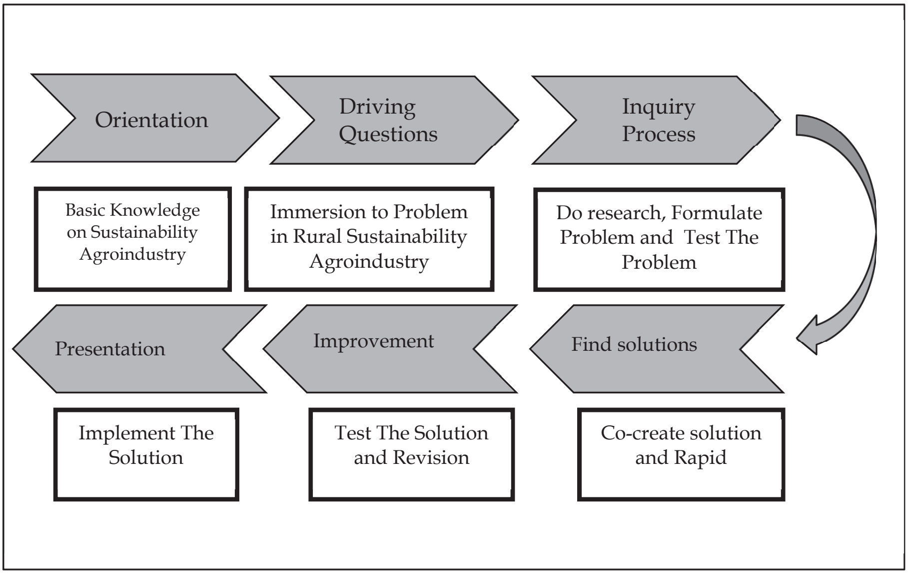

Figure 1. Summer course program outline and learning activities [30].

At the preliminary stage, two types of questionnaires were used to determine the participants' prior knowledge of ESD concepts and Project-Based Learning (PjBL). The course program followed an inquiry process where a driving question challenged students to find solutions, create a product with sustainable value, receive feedback from the teacher, and use it to revise their solution to present at the end of the course. The learning process began with a presentation of sustainable development material in general before focusing on a more detailed explanation of sustainable development in the agro-industry. Input from practitioners or entrepreneurs in the coffee, chocolate, and tea industry provided students with information regarding the sustainability of the agriculture industry (agro-industry). Virtual visits to coffee plantations provided the participants with a realistic feel for the atmosphere and conditions that occur in the agro-industry sector. The series of activities at this stage of the process enabled the participants to develop projects using agro-industry products that integrate with sustainable agro-industry business ideas. The participants worked collaboratively to develop the project over a two-week period. They elaborated on one or more lessons in detail, prepared relevant resources and materials, and carried out key parts of the project assignment to serve as a model for their peers. The activity was presented to the whole group and was followed by a discussion in a 2x2 hourly session. Both presentations were peer- and supervisor-rated.

Based on the first and second stages, the process was summarized during the final phase into a project plan to be included in a competition called the Festival of Agroindustry. The project plans were also presented at the end of the program to show appreciation for the best projects selected by the Summer Course Program Assessment Team. At the end of the program, an evaluation form was provided to all participants regarding the process, development, and results obtained by them during the online summer course program. Semi-structured interviews were conducted to determine participants' views regarding the program in more detail by providing several open-ended questions and additional questions to obtain in-depth answers. Reflective journals using guiding questions were also completed by the participants.

2.2. Online Summer Course Program

Online Summer Course program activities were held by a university in Indonesia collaborating with several national and international universities from America, Indonesia, Thailand, and Malaysia. The total participants were 75 students with 27 preservice chemistry teachers who joined the research. This program offered online classes and virtual field trips with the theme of sustainable development. The lecturers came from numerous universities and experts from the Indonesian enterpreneur and Research Institute.

The program was designed to provide students with the knowledge and ability to design a sustainable rural agro-industry chemistry project. Students would learn about the development of sustainable agro-industry products and processes, which add value to local commodities and support the rural agro-industry. The program teaches students sustainability concepts, engineering, and the business aspects of a sustainable agro-industry.

The research program was initially planned for delivery in a face-to-face learning environment; however, because of the pandemic, the intended participants, lecturers, and other stakeholders were unable to travel to Indonesia. The materials, assignments, and activities were, therefore, successfully adapted for delivery and administration online.

The program was designed to provide students with knowledge of sustainable development by integrating chemistry, industry, environment, and management processes. Students learned from hands-on experience and practice about product development and processes aimed at adding value to an environmentally friendly product, system, and management. Students were challenged to use design thinking and to apply it to the field of chemistry. The research team assessed the preservice teachers' competencies during and after the program.

2.3. Data Collection and Analysis

Data were obtained using a questionnaire, an observations sheet, an interview, a reflective journal, and an evaluation questionnaire.

2.3.1. Questionnaire

Questionnaires are useful for measuring observed natural or social phenomena. The natural or social phenomenon in question is a variable in a study. The questionnaire used in this research was self-administered online at the beginning of the study and before providing the program material to obtain the participants' perceptions and interest in learning ESD-based PjBL. The instrument was compiled based on the PjBL and ESD grids, each with its own criteria for ESD understanding, ESD and chemistry relations, PjBL in teaching chemistry, and PjBL understanding. The instrument used a Likert scale with "Very agree" to "Not agree" statements with a scale from 1 to 5. The questionnaire results were analyzed by counting the value of the questionnaire and distributing the value into "low", "middle", or "high" levels of understanding and interest in ESD and PjBL.

2.3.2. Semi-Structured Interview

To complete data collection, a semi-structured interview was used to elicit students' ideas and views on ESD, the online summer course, project development, and a multicultural environment. All interviews were recorded, and the results were fully transcribed by the researcher with a focus on the participants' engagement through the program. The following are examples of questions posed in the interview about ESD, online summer course, project development, and multicultural environment: "What do you think about ESD?"; "What impressions did you feel in the project planning process?"; "How about working, discussing, and collaborating with people you just met?"

2.3.3. Reflective Journal

A reflective journal was introduced in the middle of the program and at the end to capture the participants' reflections on the challenges they faced and their level of engagement during the learning process. One example of a prompt in the reflective journal was "write down your reflection in order to develop your understanding about sustainability relation with chemistry after joining this program".

2.3.4. Observations

Observations are useful for gaining a deeper understanding of the learning process and the participants' achievements. Observations were conducted throughout the summer course program with supporting documentation obtained from interviews, video presentations, photos, a themed schedule, and the participants' task assignments.

A qualitative data-analysis technique, including data reduction, data display, and conclusion drawing/verification, was used in this study [31]. The participants' engagement during the program implementation was analyzed from data collected by observations, reflective journals, interviews, and task assignment portfolios.

The findings, based on the research questions, were displayed and verified for validity and trustworthiness by using credibility techniques such as prolonged engagement, persistent observation, progressive subjectivity, and member checking [32].

3. Results and Discussion

This section reports the project-based learning descriptions, prior knowledge of students upon the project, perceptions on the online summer course, and impacts on preservice chemistry teachers. The impacts of preservice chemistry teachers are analyses based on thematic analysis of data from data collections in response to the research question: Can a Preservice Chemistry Teachers' Engagement with Sustainability Education improve Through an Online, Project-Based Learning Summer Course Program?

Thematic analysis of the impacts of preservice chemistry teachers indicates that there are four aspects, which are sustainability perspectives, environmental awareness, project development engagement, and communication and collaboration.

3.1. Project-Based Learning Descriptions

PjBL learning was applied in stages throughout the research project guided by experts on how to use a structured thinking pattern to come up with an idea to develop into a project or business plan, how to manage an idea, and create an innovative solution. An important part of this research focused on how prospective chemistry teachers could develop sustainable projects to develop students' skills. The project development or "mini project" created new approaches to agro-industry products based on sustainability. During the initial stage of developing an idea, the participants were asked to prepare a project plan (project charter) using design thinking to serve as a guide for developing their project.

During the following stage, the participants were asked to review their project charter to include desirable, feasible, and viable aspects of sustainability [33]. One of the project groups reported that their project was desirable because the project would reduce waste and generate alternative income for farmers. They claimed their project was feasible because of the continuous availability of raw materials and the antioxidant content in organic compounds. They considered that the product would benefit the health of users. This step confirmed how confident the students were about their project proposal (see Figure 2).

The participants developed many project plans through the program, including one called COHUMA (*Coffee Hush Mask*). The group created an innovative face mask made from coffee husks to reduce acne-causing bacteria, disguise black spots, and provide an anti-aging effect on the face. In addition to using coffee husks as the main ingredient and to maximize the performance of the mask, the participants added vitamin E to moisturize, soften, and brighten the facial skin and to fade acne scars. The product design can be seen in Figure 3 and the instructions for use can be seen in Figure 4.

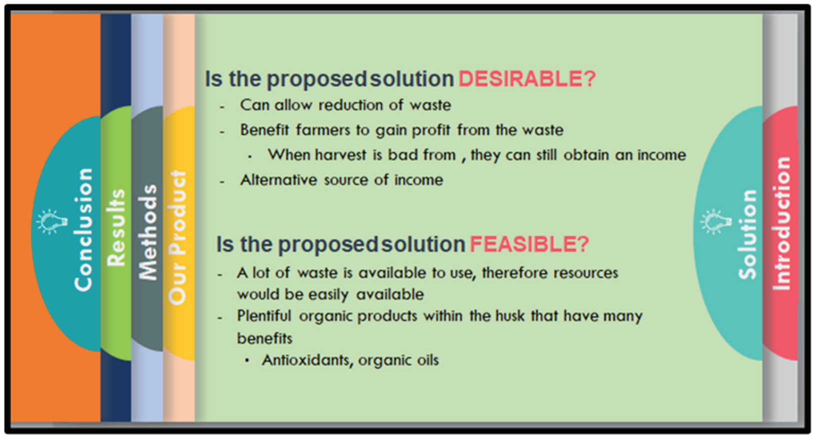

Figure 2. Participants' slide documentation, Green Tea Group, 15 November 2020.

Figure 3. Product design.

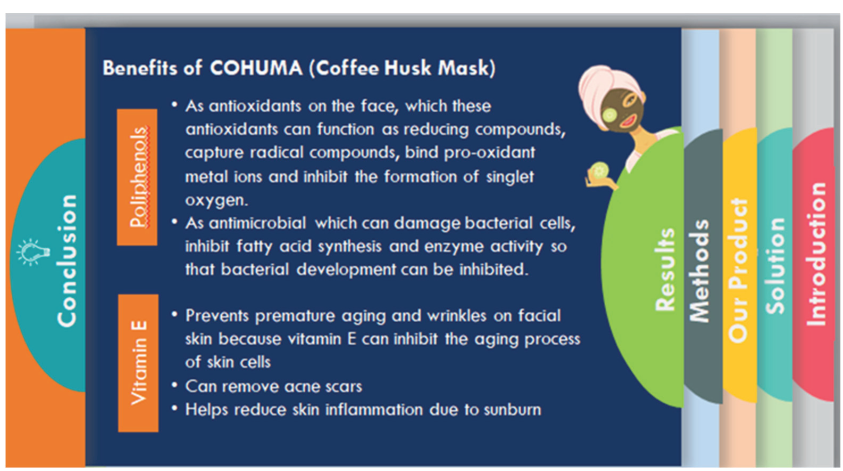

Figure 4. The benefits of using the mask.

As shown in Figure 4, the chemical concept that students explored in this project was the antioxidant value of coffee, which has the effect of reducing compounds, scavenging radical compounds, binding prooxidant metal ions, and inhibiting the formation of singlet oxygen. The project demonstrates the integration of chemical concepts with economic potential that contributes to reducing environmental impacts.

The picture below (see Figure 5) is one of the presentation documents the participant group provided to show their project development at the end of the summer course program.

Figure 5. Project development by preservice chemistry teachers [30].

After the program had run for two weeks, the participants were asked to complete a reflective journal. Reflective journals are a useful student-centered activity that provides opportunities for self-education. Journals can provide inspiration and motivation to students who use them purposefully to reflect on past experiences that were successful or meaningful for them, thus increasing their desire to continue learning [34].

The reflective journals were analyzed by coding the participants' responses to sustainability, project-based learning models, multicultural-environment-based learning, and online-based learning. The concept of ESD is in line with the idea of chemical education by Holbrook and Rannikmae in [2], which includes a shift from merely learning chemistry knowledge to developing skills.

The ESD process encouraged students to develop high-level cognitive skills through decision making, solving problems, taking responsibility, and evaluating their thinking during chemistry lessons. As shown in Figure 3, participants reported that their knowledge and awareness of sustainability improved, as did their problem solving, critical and creative thinking, communication, and high-order thinking skills (HoTS).

Various activities of the online summer course program were documented, as shown in Figures 6 and 7 below.

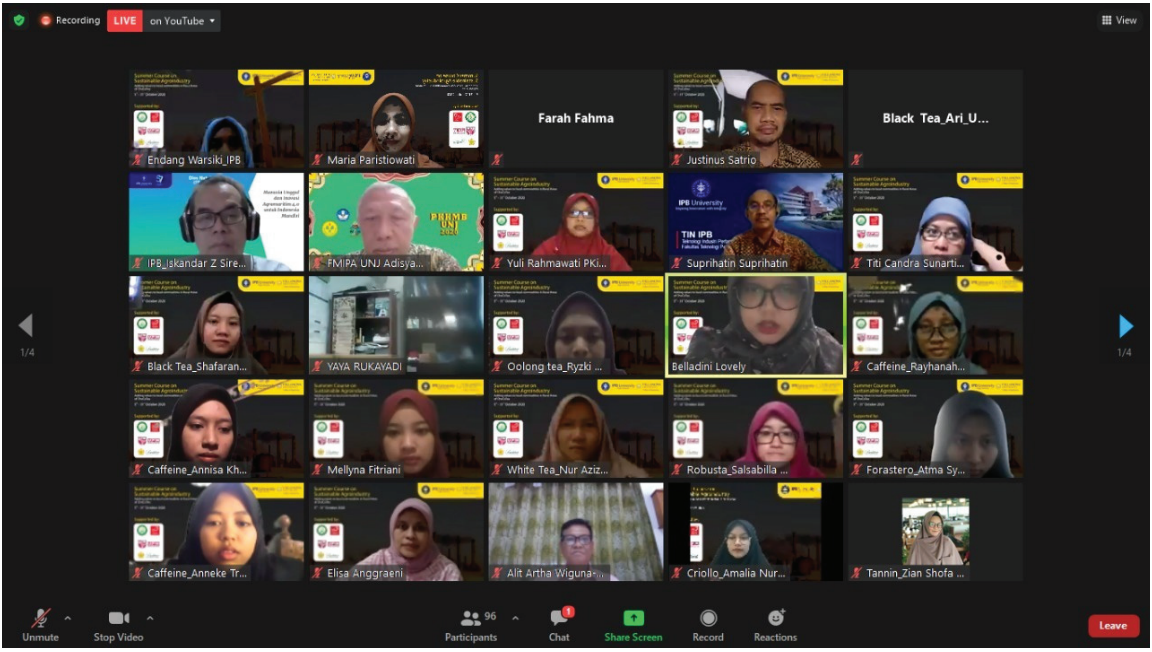

Figure 6. Summer course 2020, opening ceremony with all participants and lecturer.

Figure 7. Summer course activity, virtual field trip to cibulao coffee.

3.2. Prior Knowledge of ESD and PjBL

Before starting the summer course program, a more detailed picture of the participants' knowledge of chemistry, ESD, and PjBL, and how interested they were in participating in the competency development program, was created through the use of a questionnaire. A second questionnaire applied at the end of the program revealed whether the participants were fully engaged in the program or not.

The first questionnaire asked about (1) knowledge about ESD; (2) ESD in life; (3) relevance of ESD with chemistry; (4) relevance of ESD with chemistry education; (5) hope after learning ESD; (6) interest in learning ESD. The researchers considered these points important to determine preservice teachers' engagement in this program.

According to data analysis obtained from the first questionnaire, the participants' knowledge about ESD fell at the middle level (73.96%), while their interest in learning ESD was high (82.29%) (see Figure 8). The graph below shows that knowledge and integrated ESD in life scores at the middle level, while ESD relevance with chemistry, the participants hope in ESD, and ESD relevance with chemistry education score high, indicating that the participants were highly motivated to learn ESD at the beginning of the program.

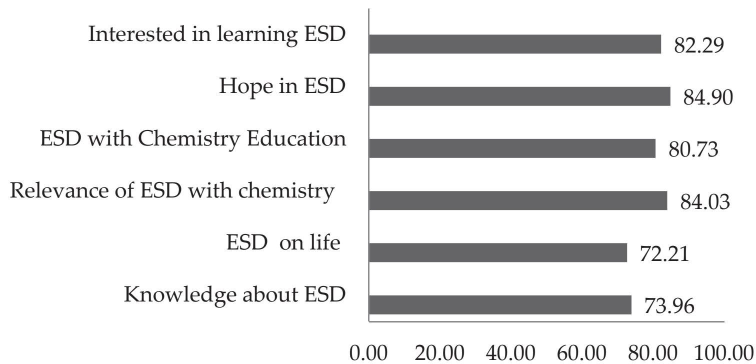

Figure 8. Participants' response toward ESD [30].

In-depth interviews revealed that students' knowledge of sustainable development (SD) prior to participating in ESD-based PjBL learning was only related to the chemistry field. One of the participants said that:

> *"Before, I was not very aware of sustainability, especially in the field of agro-industry. This program increased my knowledge about SD in the agro-industry field. I never thought that sustainability was also carried out in other fields besides chemistry."* (Participants 1 (P1), Interview 20 November 2020)

The interviews revealed that students did not know that the agro-industry can also contribute to developing SD values or that SD is a multidisciplinary field in which every field of science can be developed based on the socioeconomic–environmental principles of SD and other complex, interrelated aspects [3]. Sleurs at [35] suggests that " if the teacher has the intention to take the issue of sustainable development seriously they will also link the issue to the economic, social, cultural and political aspects", then sustainable education in the field of chemistry, for example, must be interrelated with other disciplines if sustainable values are to be developed.

According to the questionnaire data, the participants considered ESD relevant if integrated into the chemistry curriculum. The motivation for chemistry teacher candidates to join the program scored a high of 84.03%, as indicated by the following interview transcript.

> *"I think as a prospective chemistry teacher it is important to study SD because studying chemistry has something to do with the environment, so the students can use chemical concepts to solve problems in the surrounding environment"* (P3, interviewed 22 November 2020)

The participants could see that SD is necessary and useful to study and apply in chemistry learning, which motivated them to join the program even though the material was not fully relevant to the chemistry field. Through project-based learning, ESD can be included as a discussion theme, or students can work on projects oriented to the principles of ESD. Research shows that a project-based learning model can improve students' science process skills [36–38]. Participants' responses on knowledge of PjBL can be seen in Figure 9 below.

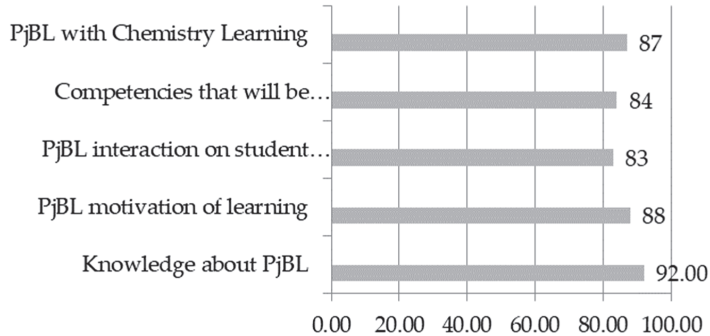

Figure 9. Participants' response through PjBL in chemistry learning [30].

The results of the PjBL questionnaire (see Figure 3) indicate that the participants were knowledgeable about PjBL (92%), PjBL motivated learning, participants understood the relationship to chemistry, and PjBL encouraged students to learn actively. On average, the preservice chemistry teachers were very familiar with the PjBL model. It has positive impacts as project-based learning develops students' critical-thinking skills more effectively than conventional learning models [39], develops students' 21st-century skills, and develops teachers' professional abilities in learning and assessing 21st-century skills [40]. Research conducted by Devkota et. al., [41] claims that implementing project-based learning can increase learning motivation and student engagement and change students'attitudes from passive to active learners.

3.3. Online Summer Course

The use of online learning systems has become necessary because of the COVID-19 pandemic dominating headlines since December 2019. School closures in over 180 countries have laid bare inequalities in education, deficiencies in remote learning, the cost of a digital divide, and have revealed the important role schools play in students' health and well-being [42]. UN Secretary-General Antonio Guterres has called upon governments to "build back better" after the current crisis by creating more sustainable, resilient, and inclusive societies. This must include education, as societies cannot transform if what we learn and how we learn it maintains the status quo.

ESD empowers learners of all ages to change their thinking and to work toward a sustainable future by addressing environmental integrity and economic viability and demonstrating how to work towards a more just society. ESD requires a reassessment of how education can form critically minded, empathetic students who can work together to solve problems and act on present and future local and global emergencies [42].

While studying online was not new for the students, they were, nevertheless, confronted by problems related to poor connectivity that made understanding the material presented during online classes difficult. Despite the challenges, students reported feeling enthusiastic about joining the class because they gained new insights, developed collaborative skills, and increased the scope of friendships, as demonstrated by a student's response below.

> *"It's interesting because you can be in groups even through ZOOM apps, do assignments at the GCR, have group discussions with the Whatsapp group, and maybe the network that has the most problems with climate or weather changes in Indonesia can determine a provider network. The quota that sometimes runs out is also a problem in implementing this online class. Overall, it is fun but sometimes a little boring if we have just paid attention for three hours. Maybe offline is more fun."* (P7, Interviewed 22 November 2020.)

The online summer course brought opportunities to the class that were different from those gained by face-to-face teaching. With the pandemic still underway, governments around the world must continue to reassess learning systems to improve education alongside the economy and to fight environmental problems with strategies such as ESD.

ESD can prepare students to learn effectively in complex situations to promote sustainable development. By using ESD as a roadmap for future education, teachers can strengthen their students' capabilities to tackle multiple challenges. The commitment to ESD must include learning for all learners in all contexts, regardless of gender, location, socioeconomic status, or access to technology. The online summer course provided participants with an opportunity to engage deeply with ESD principles at a time when the world was in crisis.

3.4. Impact on Preservice Chemistry Teachers

The impact on preservice chemistry teachers is found within four themes of sustainability perspectives, environmental awareness, project development engagement, and communication and collaboration, as explored below.

3.4.1. Sustainability Perspectives

ESD-based learning is expected to develop student competencies in knowledge, behavior, and attitude, which are collectively referred to as sustainable competence [43]. Sustainable competence relates to cognitive components such as knowledge and understanding related to environmental, social, economic, political systems, and higher-order thinking skills such as reasoning and synthesis, as well as social abilities, values, and emotions, also known as the affective domain.

The preservice chemistry teachers' competencies that emerged during and after the summer course program described values, beliefs, and judgements, as recorded in the excerpts below:

The summer course program identified that the participants' changed their mindset from being unconscious about the importance of sustainability to becoming more aware that applying sustainability to other fields is essential. This finding is shown by the participants concerned about the sustainability value of a product, as confirmed by the reflective journal and in-depth interview transcript below.

> *"One of the main things I learned was about the awareness of the importance of sustainability aspects in the production and development of a product . . . ."* (Reflective Journal P2, 19 October 2020)

> *"Sustainability is very good for human life."* (Reflective Journal P2, 19 October 2020.)

> *"After carrying out this summer course program, I have a new understanding of sustainable development, especially in the agricultural sector."* (Reflective Journal P11, 19 October 2020)

> *"I understand sustainability better, so I can be wiser in doing everything by minimizing things that are detrimental to the Earth."* (P2, Interviewed 22 November 2020)

The excerpts reveal that preservice chemistry teachers developed their awareness of sustainability through the program (*the importance of sustainability; new understanding*), found the value of using sustainability in life (*very good for human life*), and allowed them to be more concerned about ESD issues (*the production and development of a product*). ESD reassesses what we learn, where we learn, and how we learn. It develops the knowledge, skills, values, and attitudes that enable learners to make informed decisions and take action to solve global problems [42], such as in the agro-industry, which was a focus of this program. The program increased the preservice teachers' awareness of sustainable development by providing them with new experiences.

3.4.2. Environmental Awareness

In addition to raising sustainability awareness, the participants reported an increased awareness of their role in protecting the environment (minimizing the negative impact on the environment) by reviewing the product production process at maximum output to measure whether the impact on the environment was maintained because the process operated as a necessity. The participants' awareness grew by having to maintain, protect, and not contribute to damage (*reducing environmental damage; more environmentally friendly; bad for the environment*) as shown in the participants' reflective journal and in-depth interview responses. A UNESCO statement [42] states that "ESD can help us understand the global nature of today's challenges, it provides us with a concrete solution for the local living environment". The principles of ESD issued by the United Nations can be used to develop an environmentally sound chemistry education that fosters and equips students with environmental attitudes, knowledge, and awareness [44]. The research project can lead to empowering communities of preservice chemistry teachers to be more concerned about environmental issues (*environmental values as well*) that impact them daily and provide a method for planning a project that addresses economic, social, and environmental values. In their reflections and interview responses, the preservice chemistry teachers stated that sustainability is an interesting concept to discuss, is important to learn, and is useful for the future. Preservice teachers participated actively in their learning to gain the information, skills, and attitudes necessary to encourage sustainable practices in their community and in their daily lives (*apply this in my daily life*). ESD can help reveal the global nature of today's challenges. It provides concrete solutions for the local environment [42]. ESD provided the preservice teachers with an experience of ESD as a practice-based approach (*bringing my own*) and encouraged them to become more concerned about ESD issues (*reducing*, *reusable*) related to their way of life.

While this research focused on the environmental awareness of prospective chemistry teachers, it is anticipated that the knowledge and understanding gained from the experience will be applied to their future teaching.

Sustainable, development-based learning, known as green chemistry, has an important role to play in chemistry education. Fibonacci at [45] states that "various chemical concepts have close links with the environment to stimulate the creativity and innovation of students to be able to use chemical concepts to solve the environmental problem". Prospective chemistry teachers can use innovative pedagogies to instill the value of sustainability in their students, as identified in the transcript below:

> *"I think it is important as a prospective chemistry teacher to study sustainability development in school because studying chemistry has something to do with the environment so it can design creativity and innovation. They can use chemical concepts to solve problems in their environment. In addition, how to implement sustainable value that can be applied to chemicals such as electrolytes and nonelectrolytes, redox, colloids, petroleum hydrocarbons, electrochemical applications, adn polymers. It can be a supporter of teacher creativity on how to analyze a characteristic of material, so that the sustainable values are embedded in students' personalities. "* (P7, interviewed 22 November 2020.)

3.4.3. Project Development Engagement

Success in developing sustainability competencies, the learning must, of course, include supportive pedagogy. Sipos et al. at [46] stated that the most relevant pedagogy in enhancing the development of sustainable competence is a pedagogy that involves the head (cognitive domain), hands (psychomotor), and heart (affective domain). Project-based learning is a feasible model in developing sustainable competencies [43,47]. The way that project-based learning supports sustainable competency development is by encouraging students to develop sustainable competencies by providing a supportive learning atmosphere that encourages critical thinking, creative thinking, higher-order thinking skills (HoTS), problem-solving, collaboration, and communicating well.

Although the program was held online, students felt that joining the program provided them with meaningful experiences in using design thinking, discussing and solving problems, and conducting research and sharing information in discussion groups. The PjBL model offers preservice teachers a chance to experience the tangible reality of their communities, as well as to take ownership of a project as active participants rather than mere consumers of knowledge [48].

The following excerpt demonstrates how meaningful this program was for these students:

> *"It is very interesting because each group member conducts research first regarding the topic at hand. Then convey each of the ideas obtained. . . . "* (Reflective Journal, P2 19 October 2020)

> *"It's great for brainstorming to find solutions to existing problems. Furthermore, participants are required to carry out reliable research to construct a solution."* (Reflective Journal, P9 19 October 2020)

More detailed views were expressed during the semi-structured interviews.

> *"I think critical thinking plays a very important role in finding idea for this project, such as in the process of doing research first so it doesn't necessarily give idea, besides that creative thinking is also needed, for example in determining eye-catching project name, and in my opinion problem solving is also used such as from existing problem based on previous research and how to solve the problem by giving idea in the form of a project."* (P3, interviewed 22 November 2020.)

> *"Very effective learning model, because it invites the participants to think more actively. Not only analyzing but also imagining the application of the project, conducting a project, and presenting it to another member."* (P5, Interviewed 22 November 2020.)

PjBL provides a direct learning experience of diving into a problem, finding the solution, and constructing a plan to solve the problem. The prospective chemistry teacher feels fully involved in designing a project that uses agro-industry products, and they feel challenged, encouraged to think critically (critical thinking plays a very important role), brainstorm (think many things; brainstorm), conduct in-depth information searches (perform research), and think creatively through this PjBL (determining eye-catching project name).

PjBL improves the participants' capacity to address environmental and developmental issues, as well. A study conducted by [49] among preservice technology teachers in South Africa about their experience in using PjBL as a pedagogy for ESD reported that PjBL promotes social learning and a real-world context for learning about ESD. It can be used as a catalyst for raising preservice teachers' awareness of their role as agents of change.

PjBL ensures continuity with the learning experience (*to complete a group project*) in a pleasant learning atmosphere (*very exciting and interesting*), to actively develop students' critical thinking (*find* solutions), and to solve contextual problems (*to construct a solution*). This finding concurs with [40], who state that PjBL is not simply transmitted from teachers to students but is constructed in the mind of the learner as they actively engage in developing unique solutions to problems.

3.4.4. Communication and Collaboration

According to a body of research, collaboration and communication are key competencies in sustainability [50–52]. Students reported feeling enthusiastic about working in a multicultural environment because they could greet friends from different cultures and language groups. However, having to discuss the project compelled students to use foreign language skills while negotiating with friends from other countries. Many students stated the following:

> *"The multicultural environment that occurs during the summer course is very interesting. I can communicate with people from various backgrounds. However, the biggest problem I feel is the ability to communicate in English."* (Reflective Journal P13, 19 October 2020)

> *" . . . ..Collaboration between members is an important aspect during project work. Even though it is virtual, because they have several group assignments, the members can be closer to one another"* (Reflective Journal, P2 19 October 2020)

"It's very interesting because each group member conducts research related to the existing topic. Then, convey each idea obtained. Collaboration between members is an important aspect during project work." (P8, Interviewed 22 November 2020)

The excerpts above confirm that using PjBL challenged the participants to improve their communication and collaboration skills, deepen their thinking, and gain a better understanding by performing research and presenting it to others (*conduct research related to the existing topic*). Excerpts from the reflective journals showed how the participants developed ways to communicate that improved their language skills and enabled them to effectively collaborate with their working group (*convey each idea obtained*); this ability is described as interpersonal skills to work with others and is an interpersonal competency [50,51,53,54]. Collaboration is the ability to motivate, activate, and facilitate collaboratively and participate in ongoing research and problem solving [52]. In this research,, the participants already worked collaboratively with their peers in a good and correct way, so their collaboration and communication skills were used actively.

The onset of the COVID-19 pandemic demonstrated the importance of individuals' and societies' ability to respond rapidly to unexpected risks. Collaborating to find solutions, anticipating different scenarios, negotiating trade-offs, and being ready to act quickly based on limited information are essential skills for a 21st century, global society [42]. The participants in this research project believed that collaboration is important for solving problems to produce better outcomes (an *important aspect during project work*). ESD encourages collaborative outcomes by encouraging students to work together. Collaboration means having a belief in the good of others, and, as Singh-Pillay [49] points out, it allows for individual self-introspection whilst maintaining a working relationship with people from different socioeconomic statuses. Collaboration can develop a participant's self-confidence (*I can communicate*), team-building skills (*each group member conducts research, communicate with people*), and increase tolerance related to perceptions of race, culture, and a commitment to the group.

Due to the different cultural backgrounds and participating countries, several obstacles, such as time differences, constrained the scheduling of discussions. Time management was another issue that needed to improve, as did a stronger commitment to the value of working together.

Mastering global languages, as well as an occasional unstable internet connection, caused some issues, as reported below.

"Because during a pandemic, it is less pronounced. But still exciting. The biggest problem at hand is the timing. Because I have a group of friends from Villanova who are 11 hours apart from us, so it is challenging to match the discussion time, language is also a problem when discussing. Internet connection sometimes becomes a problem too." (P10, Interviewed 22 November 2020)

" ... But the biggest problem I feel is the ability to communicate in English." (Reflective Journal P7, 19 October 2020)

"Compared to the language barrier, I feel more constrained by time. Classes held are sometimes too early or late at night so that it is not optimal when listening to the presentation. However, I try my best in every meeting." (P12, Interviewed 22 November 2020)

Since the participants showed their engagement throughout this program, we can say that this summer course program encouraged them to practice and make improvements in areas such as communication and collaboration skills and obtain better knowledge about sustainability and environment awareness. Being able to collaborate well in a group and the multicultural environment also provided opportunities to link their point of view of other fields outside of chemistry. The working teams across disciplines encouraged the conceptualization of innovations and creative approaches from different perspectives towards solving the same problem [43], Ref. [55] because sustainability competencies can be implemented with scientific discipline abilities, such as social science, engineering, and business [43]. A multicultural learning environment encourages success in sustainable preservice chemistry teacher competency development because it provides a learning atmosphere in multidisciplinary groups.

4. Conclusions

The findings of this study show that preservice chemistry teachers can improve their awareness of sustainability through an online ESD program. They were able to think more broadly about the idea of sustainability in many aspects of life. They become more concerned about ESD issues, which lead them to empower their communities (preservice chemistry teachers) to be more concerned about environmental issues that impact them daily. The program provided a method for planning a project that addressed economic, social, and even environmental values to slowly change their way of life. PjBL ensures continuity with the learning experience in a learning environment that actively develops students' critical thinking and the ability to solve complex contextual problems. PjBL allows students to engage and interact with diverse communities, gain more information, instill collaboration skills, and develop team-building strategies that give rise to emotional learning. These skills are critical for the future success of education to provide society with sound responses to sustainability issues. The online summer course brought new opportunities and a commitment that ESD must be included in the learning in all contexts, for all learners, regardless of their gender, location, socioeconomic status, or access to technology. In conclusion, the preservice chemistry teachers engaged in creating a project-based learning solution through an online summer course program that developed students' sustainability perspective and environment awareness, higher-order thinking skills, and communication and collaboration skills.

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Section 2—INCLUSIVITY

sustainability

Article

Poverty and Gender: Determinants of Female- and Male-Headed Households with Children in Poverty in the USA, 2019

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Abstract: Attaining economic parity and reducing poverty between the genders are critical steps toward attaining the United Nations' Sustainable Development Goals. Despite progress, women in the US still earn USD 0.83 for every USD 1.00 that a man earns. With rising shares of single/female-headed households with children in American society in recent years, such gaps in earnings exacerbate the misery of children living in such households. In 2019, female-headed households with children had poverty rates almost twice (36.5%) that of single/male-headed families (16.3%). This paper uses five-year American Community Survey estimates from the National Historical Geographic Information System to empirically examine the spatial distribution and determinants of female-versus-male-headed households with children living in poverty in the counties of the USA. Lower levels of educational attainment are associated with higher levels of poverty for both genders. A bachelor's degree in education is associated with higher poverty for female-headed households, whereas majoring in business, sciences, engineering, and arts/humanities is associated with lower poverty for male-headed households. Service-sector occupations inherently contribute to higher poverty for both groups. Over-representation in management/professional and natural-resources, construction, and maintenance-type occupations works well for male-headed households, whereas management/professional, sales/office, and service-based occupations associate with higher poverty for female-headed households—pointing toward the "working poor"—comprising largely of the active female labor force in the new economy. Full- and part-time work status alleviates poverty for female-headed households, whereas part-time work is associated with higher poverty for males.

Keywords: economic parity; poverty; United Nations' Sustainable Development Goals; female-headed households; American community survey; National Historical Geographic Information System

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1. Introduction

On 8 March 2023, the United Nations' Chief Guterres made international news when he noted that it would take another 300 years to attain gender equality in the world [1]. Despite this harsh reality for women all around the world, this statement should be accepted with humility, as disproportionate levels of income inequality and gender poverty have remained major concerns well into the twenty-first century. While significant economic growth and progress have been made all over the world, income inequality and a lack of upward mobility have remained important topics of academic scholarship for quite some time. Even with visible economic growth and progress since the recession of 2007–2009, the gaps between the rich and the poor have continued in the US, and these gaps have become more exacerbated for women compared to men in all age groups and far worse for women of color compared to men of the same races/ethnicities.

Income inequality is unavoidable in any society, but too much inequality can permanently damage the fabric of a social system. A society where the rich become richer and the poor become poorer can have serious consequences for the overall health and wellbeing of its population [2–4]. The negative consequences of such gaps manifest through numerous social, economic, and cultural break-ups in a society, and inadvertently, women are impacted by these much worse compared to men across all racial/ethnic groups, including increased rates of divorce, a rise in single-parent households, negligence of children involved in broken marriages, and the like. Even now, women continue to earn only USD 0.83 for every USD 1.00 that a man earns [5]. Based on the US Census Bureau, there seems to be a strong "motherhood penalty" [1]. Despite reasonable success in educational and occupational attainment, women have still been unable to fully translate their human capital skills and credentials into economic success [6–8]. Globally, never-married women are the fastest-growing cohort in the labor market, yet their median earning is 92.1% of what never-married men make, and this gap has increased during the last decade, when they earned 95.8% of what men earned [1]. In the USA, single women with children have a median family wealth of USD 7000 compared to USD 59,000 for single men with children; these statistics for single women versus single men without children are USD 57,000 and USD 65,000, respectively [1,9]. However, whether these earnings and wealth gaps between single male-headed households and single female-headed households translate differently in terms of poverty levels is still unknown. This paper specifically focuses on this aspect of contemporary poverty and inequality across the genders—an everyday truth of American society where the share of single/divorced (Since the data pertains to female-headed households, with or without children (no-spouse present), for this analysis I am assuming that these might be the divorced, single-mom/single-dad cases, and hence I use single/divorced in the text for simplicity) women and female-headed households has been increasing, with much greater financial burdens felt by them and especially by those who have children.

This paper, thus, examines the spatial patterns of single-male-headed households with children and single-female-headed households with children living in poverty in the counties of the USA. Further, it also attempts to empirically explain the varying levels of poverty for these groups by exploring their association with detailed categories of select explanatory variables pertaining to educational and occupational attainments and their work status—all of which are critical toward improving one's earnings potential. This paper uses data from the five-year (2015–2019) American Community Survey (ACS) estimates available from the National Historical Geographic Information System (NHGIS) [10]. In addressing the above purposes, I use county as the scale of analysis, whereas three types of dependent variables include: (1) female-headed households with children living in poverty; (2) female-headed households without children living in poverty; and (3) male-headed households with children living in poverty. This research finds that higher levels of poverty among single female-headed households correlate strongly with the black population in the country. Additionally, while lower educational attainments associate with higher poverty for both genders, female-headed households have disadvantages if they graduate with education majors whereas majors in science, engineering, business, and arts/humanities associate with lower poverty among male-headed households. An interesting finding of this research points toward the "working poor"—largely the female-headed households (with and without children), comprising an active labor force in the new economy, who suffer the greatest risks of living in poverty.

2. Background Context

2.1. A Brief Overview of Gendered Work and Wage Gaps

Throughout the world, extreme levels of wealth and income concentration have strengthened the economic and political power of a few individuals—largely males, comprising the topmost segment of society [9]. Globally and within the US, women are underrepresented in the highest-paid and best-quality positions [9,11]. Women are overrepresented in service sectors and other occupations such as restaurant services, retail, tourism, front-desk clericals, care activities, and hospitality that are traditionally associated with lower wages [6,12]. The enormous amount of time spent on unpaid activities could have been utilized toward productive and income-generating livelihoods, which could have contributed to their economic wellbeing [13,14]. Even now, based on the U.S. Department of Labor and Fortune, female-dominated occupations such as childcare and restaurant service work continue to occupy the lower rungs of the U.S. wage ladder, and women make up 63% of total workers earning the federal minimum wage—a wage rate stuck at USD 7.25 since 2009 [15]. In 2016, women still represented only 5% of CEOs at Fortune 500 firms, whereas CEOs' average take-home salary was USD 13.1 million [15,16].

Regarding gender equality, the United Nations indicated that in order to achieve gender equality and parity, women must be included in technology and innovation industries such that the United Nations' Sustainable Development Goals (UN-SDGs) can be achieved—the only blueprint toward creating a just and equitable future by 2030 [17]. It is expected that by mid-century, almost 75% of all jobs will be related to STEM (science, technology, engineering, or math) disciplines, yet women comprise only 30% of the workforce in the world's 20 largest global tech companies [17]. Within the US, even though women comprise almost half of the country's workforce, men comprise an overwhelming majority of the top earners. Women hold only 27% of the top 10% of income-earners, 17% of the top 1%, and only 11% of the top 0.1% [11,12]. An analysis of the topmost earners in the US labor force suggests that the share of women in the top 10% earners has increased from about 5% in 1962 to 27.5% in 2014; these figures for the top 1% earners changed from 3% (1962) to 16.5% (2014), and those in the topmost 0.1% changed from 2% (1962) to 11% (2014) only [18]. Such disparities in income/wealth and an overwhelming control of the politically and economically elite top 1% genre are not only confined to the US; instead, they exist all over the world, including several developing economies. Based on a survey conducted during 2010–2014 by the National Bureau of Economic Research and the London School of Economics, in the eight richest/highest-income countries of the world, males comprised the largest shares of the top-paying positions; the same survey also concluded that within the US, in 2012, women comprised only 14–22% of the top 1% earners [19].

Concerning wage gaps, the Economic Policy Institute, the Institute for Women's Policy Research, and other scholars suggest that in 2016, women working full-time still earned an average of 81 cents for every dollar that a man earned, and these gaps were much wider when part-time workers were included in the sample [20]. These gaps are wider for racial/ethnic groups and for women of color, with the largest pay gaps between men and women of white and Asian groups [21]. This occurs not because Latina and black women have made more progress toward equity; instead, this occurs because the average pay for men in these groups is far below those of whites and Asians, even in 2020 [21]. Further, women generally end up doing a considerably higher amount of unpaid work—from housekeeping to caring for children and the elderly, cooking, cleaning, and everything else, voluntarily or involuntarily, that needs to be carried out to efficiently manage their homes and their household finances [6–8,13,14,22]. Recent research has shown that women working in professional/management types of jobs tend to earn a better income [17]. Based on the U.S. Census Bureau (2020), the largest pay gaps between males and females occur in management positions, with men making an average of USD 88,000 in 2016 as against only USD 55,000 for women; the smallest gaps appeared in construction—an industry perceived as masculine, with women comprising only 9% of its total labor force. According to the Institute for Policy Studies's analysis of World Bank and World Development Indicators, even though the gendered wage gaps in the USA are quite large, they are not the worst, as there are numerous other countries where women do far worse. For example, among the OECD group of higher-income countries, the gap is the highest in South Korea, with men earning 37% more than women; Luxembourg, in contrast, has the narrowest gap, with men making only 3.4% more than women. The gender gaps in OECD countries are smaller because a good proportion of workers are covered by collective bargaining (i.e., union) agreements [15,17].

Based on the International Labor Organization's (ILO) analysis of data from 21 countries, using data for at least one year from 2013 to 2015, the two countries with the highest imbalance were the West Bank and Gaza, with men devoting only 16% of their time on unpaid domestic and caregiving activities; in contrast, Belgium had the fairest distribution, with men spending 63% of their time on these activities, and they ranked at the top [23–25]. While the ILO agrees that more work is needed to develop more accurate global gender gap analyses, in reality, the availability and accessibility of good-quality data have remained a problem for a long time in the majority of the world, and this has dissuaded researchers from engaging in quality and timely research on gender gap analyses. In addition, The Washington Center Report and other scholars suggest that despite numerous policies proposed by the Think Tanks, their approval by Congress, and on-the-ground implementation and abidance, contemporary capitalism is quite challenging [5,26].

2.2. A Factual Overview of Gender Gaps in Poverty

The US, despite being one of the richest economies in the world, still has a significant share of its population living below the poverty line. Though the official poverty rate in 2020 was 11.4%—1% higher than its 2019 level, what is surprising is that this rise in poverty level occurred for the first time after consecutive annual declines during the last five years. About 37.2 million people lived in poverty in 2020—an uptick of 3.3 million since 2019 [21].

When evaluating the long-term change in poverty for the overall population in the US, the Census 2020 income and poverty report indicates that while the statistics changed from 40 million (23.5%) in 1959 to 34 million (10.5%) in 2019, the poverty gap between the genders had indeed widened during these 50–60 years. In 2016, almost 13.4% of adult women (18–64 years), which is about 13.4 million, lived in poverty compared to 9.7% of adult men (9.4 million); in 1968, these statistics were 10.8% (6.1 million) for women and 7.2% for men (3.7 million)—indicating a steep rise for women living in poverty. The poverty rates for females and males in 18–64 years were 10.8% and 8.1%, respectively, in 2019; these figures were 14.5% and 14.4% for children $\leq$18 years, and 10.3% versus 7.2% for $\geq$65 years—confirming disadvantage for females across all ages and much worse among the oldest.

Based on reports and figures compiled by the US Census Bureau 2019 and 2020 Annual Social and Economic Supplements (CPS ASEC), the poverty rates between males, females, and married families are significantly different. The poverty rates for married couples as well as female-headed and male-headed households in 2019 were 4.0%, 22.2%, and 11.5%, respectively—indicating the benefits of being in married status and the significantly higher poverty rates for female-headed households [27]. These figures for married couples, female-headed households, and male-headed households when children below the age of 18 lived together were 6.4%, 36.5%, and 16.3%, respectively [27]. According to the National Women’s Law Center, these figures were not much different in 2016, with a poverty rate of 35.6% for single-women headed households with children—more than twice the 17.3% for single-men headed households with children. Based on the Census 2020 report, however, poverty rates also increased for married-coupled families during 2019–2020, from 4% (2019) to 4.7% (2020); these statistics for families with a female head were significantly high—22.2% in 2019, which increased to 23.4% in 2020; the figures for male-headed families during 2019 and 2020 were at about 11.4%, far below female-headed families. Such gaps in poverty rates among families, especially because of their female-versus-male-headed status, can have severe negative impacts, especially when children are involved. Given that most often women are the caretakers of children involved in broken/divorced households, and/or if a woman decides to have children regardless of marriage/partner, they end up suffering from the “motherhood penalty”.

Such exacerbated rates of poverty and unequitable earnings between the genders also have severe implications for their wealth accumulation, retirement savings, and other health insecurities. In the US, men have three times more retirement savings funds compared to women, and when one adds up different types of savings, the gap widens further [28]. Based on the statistics provided by Collinson, the CEO of Transamerica Center for Retirement Studies, in 2017, American women held a median retirement savings of USD

42,000 compared to USD 123,000 for men; the figures for less than USD 10,000 in retirement were 21% for women versus 12% for men. Thus, lifelong gender pay gap translates into old-age insecurities and ailments since the pension plan and Social Security payouts are based partly on their past earnings, and given their old age, a large share of women are physically incapable of contributing toward their finances—which forces them into higher poverty.

2.3. Origin of Gender Inequality and Theoretical Conceptualization

Post-Fordism has been associated with the beginning of the most severe forms of inequality in the USA. While the economic restructuring in the American Manufacturing Belt (AMB) benefitted the Southeastern and Western regions of the USA, it also triggered varied levels of socioeconomic inequalities among different population groups and communities of color, furthering the divide between the richest and the poorest segments over time [3,29–33]. The post-Fordist processes were likened to the decline of middle-class jobs, along with the bifurcation between high-paying jobs that required considerable investment in education and human capital skills versus low-end jobs that required fewer-to-no skills [33–39]. Given a relatively higher share of women, immigrants, and minorities possessing lower levels of skills and education, they ended up experiencing disproportionate shares of discrimination in the labor market that aggravated already existing inequalities and poverty [40–43]. The new economy demanded newer, flexible skills, which were accessible to the upper-middle and wealthier segments of society, and those with money, time, and enthusiasm were able to upgrade their skills to fit in and reap the largest margins of the benefits [44–46]. However, given the overburdened status of women largely in low-wage paid activities, pulling out time for skill development was difficult. These led to the cyclic reproduction of gendered gaps in earnings. Since the restructuring of the 1970s, several states in the USA have also undergone severe cuts in state-supported welfare-activities, which have had adverse consequences for the poor, minorities, and women, including female-headed households with children [33–35,37,39,47].

Finally, in their scholarly endeavors to explain the under- and over-representation of women in low-wage occupations—the crux of earnings gaps and poverty—scholars have used a variety of theoretical lenses. These include Becker's (1994) Human Capital Theory (HCT), which likens the demand and supply aspects of labor with their over-/under-representation, and the Neoclassical Economic Theory (NET), which attributes pure economic incentives as the driving force in picking up jobs/occupations [22,48]. Both of these theories, however, ignore the complex ways in which the demographic, socio-economic, historical, and cultural contexts of a person's upbringing impact his/her acquisition of human capital skills that might affect his/her occupational choices. Anne Bonds (2013) and other Feminist Political Ecology (FPE) theorists questioned such simplistic/binary perspectives provided by the HCT and the NET since these masked the complex processes of feminization (and racialization) of economic practices in the contemporary world [49]. The Labor Market Segmentation Theory (LMST) rejects the binary/linear connection between gendered labor market outcomes and their educational skills; instead, it attributes the institution-specific rules and regulations and the socially constructed policies as instrumental in reproducing disparities that best fit their narratives [22]. Thus, the LMST aligns with the critical perspectives of FPE theorists in explaining the nuanced ways in which gender intersects with race/ethnicity, religion, caste, nationality, immigration status, sexuality, etc. that produce complex and nested layers of hierarchy and power dynamics that impact gender labor participation in complex ways [50–54].

To sum up, this detailed review of the literature identifies gender gaps in earnings and poverty in the USA and globally. However, the spatial distribution of poverty among gender-based single-parent households with children and their determinants is still unknown. Additionally, whether similar types of determinants (e.g., educational, occupational, and work status categories) impact gendered poverty outcomes similarly or differently is unknown. This research addresses these gaps by empirically examining the association between detailed categories of select determinants and gendered poverty outcomes in the USA.

3. Research Design

3.1. Study Area and Scale of Analysis

This study analyzes the spatial patterns and major predictors of single male-headed and single female-headed households with children living in poverty across the 3142 counties of the USA. While the study area includes the conterminous USA and counties from the states of Alaska and Hawaiian Islands, I exclude Puerto Rico due to its lopsided demography and extreme poverty, which could distort overall findings. At a total population of 324,697,795, non-Hispanic whites comprise 60.70% of the total, followed by Hispanics (18.01%), blacks (12.31%), and Asians-with-Hawaiian and Pacific Islanders (5.62%) (Table 1).

Table 1. Racial/ethnic composition of the study area (3142 counties of the USA, excluding Puerto Rico).

Population by Race, 2019	Total by Race/Ethnicity	Percent of Total Population
Total Population	324,697,795	100.00
Non-Hispanic-Total Population	266,218,425	81.99
Non-Hispanic-white	197,100,373	60.70
Non-Hispanic-black	39,977,554	12.31
Non-Hispanic-American Indians	2,160,378	0.67
Non-Hispanic-Asians with Hawaiian and Pacific Islanders	18,249,465	5.62
Non-Hispanic-All-Other Races	8,730,655	2.69
Hispanics	58,479,370	18.01

I use counties as the scale of analysis due to the size of the entire USA—my study area—and the consistency of the spatial boundary of counties over time, enabling its temporal analysis in the future. Given the size of the USA, counties serve well in adequately capturing the localized variations in gendered dimensions of poverty, inequality, and other parameters.

3.2. Data and Methodology

Detailed categories of data for educational attainment and major fields of specialization in bachelor's degrees, occupational attainment, income, poverty, and work status by gender are extracted from the five-year (2015–2019) ACS estimates available from the NHGIS. I compute selected categories of explanatory variables required for this research. These include the share of males and females with various categories of educational attainment and majors in bachelor's degrees, and the share of females (out of the total labor force) with various categories of work status based on total hours worked per week and total numbers of weeks worked per year, and male-female ratios for work status categories. Thereafter, I also compute ten additional explanatory variables—occupation-based over/underrepresentations for males and females both—measured by Location Quotients-(LQs), and these are used in correlations and regression models based on the Y-dependent variable being analyzed. To compute the LQ-values for five major occupations for both genders, I follow Moineddin et al. (2003)'s specifications [55]:

$$LQ_i = (e_i/e)/(E_i/E) \quad (1)$$

where e_i is the employment (all employment figures are in numbers, not percentages) in occupation $_i$ in the local region/county for a specific gender; e is the total employment in the county; E_i is the employment of the specific gender in occupation $_i$ at the national level and E is the total employment in all five occupations at the national level.

After running basic descriptive statistics to gain a feel for gendered dimensions of major variables, I make choropleth maps for select variables of poverty-by-gender and for work-status ratios (Figures 1 and 2) and examine their spatial patterns. This is followed by Pearson's bivariate correlations to identify a shortlist of variables that make sense for further use in the regression models. For example, my decision to exclude all income variables from three regression models and to exclude male-to-female ratios for work status categories from females' regression models was based on the complexity of explaining specific associations and the redundancy of income variables in predicting poverty. The correlation analysis provided meaningful associations with work status variables for females (e.g., share-females, worked $\geq$35 h/week, 50–52 weeks/year, and other categories). Thus, I decided to use these in the regression models pertaining to female-headed poverty (with and without children), whereas I retained the male/female work status ratio variables for use in the regression model for male-headed households with children living in poverty. I chose the share of five major racial/ethnic groups in all three regression models. For female and male-specific poverty models, however, I chose gender-specific values for the LQs and educational categories (all except bachelor's) and majors in bachelor's. After running a few iterations of Ordinary Least Squares models, I opted for the stepwise regression method for finalizing the best fit models for the three dependent variables. The regression models have the following generic specification:

$$Y_i = \alpha + X_1 \times \beta_1 + X_2 \times \beta_2 + \ldots \ldots \ldots \ldots + X_n \times \beta_n \ldots \ldots \ldots + e \tag{2}$$

where $_i$ = 1, 2, and 3—represents the three dependent variables of Y_1, Y_2, Y_3 as illustrated below:

Y_1: Female-headed households with children, living in poverty in 2019,
Y_2: Female-headed households without children, living in poverty in 2019,
Y_3: Male-headed households with children, living in poverty in 2019,
whereas
X_k—are the select independent variables, with $k = 1, 2, \ldots \ldots .n$,
α is the intercept (constant) on each model,
β_k are the coefficients on each independent variable, with $k = 1, 2, \ldots \ldots .n$, and
ε is the residuals in each model.

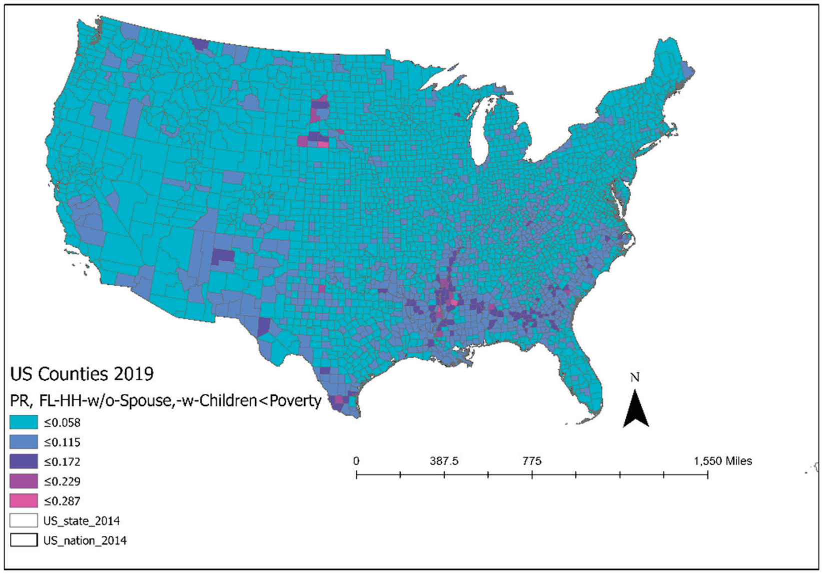
Each of these best-fit models explains the variance in the Y-variable with the R-square value. When interpreting these coefficients, a positive or negative Beta value would imply the strength and direction of each explanatory variable, with negative Betas implying lower poverty rates and positive Betas implying higher poverty rates.

4. Analysis and Findings

4.1. Visual Analysis of Major Variables: Gendered Poverty and Work Status

Choropleth maps were made for male-headed and female-headed households living in poverty (with children) and for select categories of male-to-female work status ratios and interpreted for their spatial patterns. As obvious from Figure 1, the female-headed households with children living in poverty have spatial clusters along the Mississippi Delta, the southeastern USA along the Black Belt, the Appalachian region, the Cotton Belt, southwestern USA, patches of central California where agriculture is the main occupation (Bakersfield, Portville, etc.), and random countries in other parts of the USA.

These patterns corroborate other prior research—with higher poverty in counties with relatively higher shares of diversity (largely blacks and Hispanics) and, as indicated by the Census reports, in random counties of reservations (Native Americans) [56–58]. The historical contexts of slavery and plantation economies and long decades of racial/ethnic discrimination, without doubt, have manifested into clusters of racialized poverty, and female-headed poverty shows up accordingly.



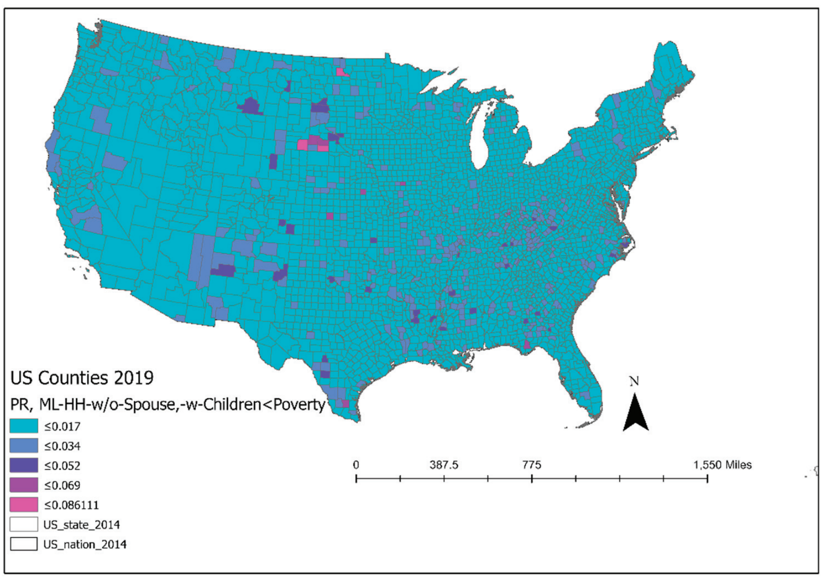
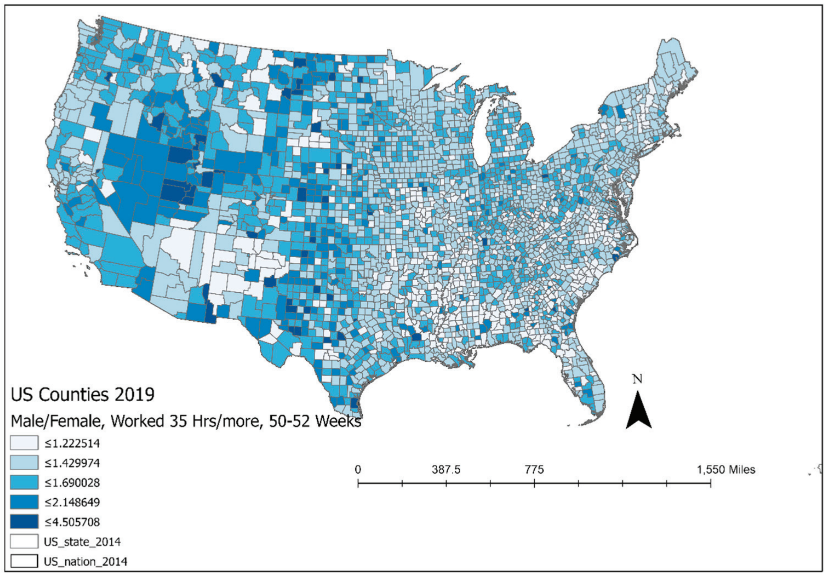


Figure 1. Female-headed and male-headed households with children living in poverty (no spouse), 2019.

The male/female work-status ratios for those who worked above 35 h/week and other categories of work (≥35 h/week, 15–34 h/week, 1–14 h/week) for up to 40 weeks/year only are illustrated in Figure 2. The most obvious patterns emerging from a visual analysis of these maps are that as the number of hours worked/week decreases, the shades of blue become lighter and lighter—implying male advantage regarding full-time work status for the majority of the year (worked 40 weeks or more/year). The ratio of male/female work status for 1–14 h/week for up to 40 weeks/year, likewise, shows lighter shades of blue. Additionally, male/female ratios for those who did not work at all obtained a maximum value of 11.78, illustrated by the darkest blue counties (last map, Figure 2), which have a spatial randomness to them. However, some of these darkest shades of blue mirror the spatial patterns of overall poverty, with numerous counties along the Mississippi Delta, the Black Belt, Appalachia, and the like. A few of the random dark blue counties also show high poverty among the Native Americans. Finally, maps for those who worked less than 40 weeks/year are not presented here for brevity; likewise, maps for various categories of educational attainment, including majors in bachelor's, and location quotients are also not presented here and are available upon request.



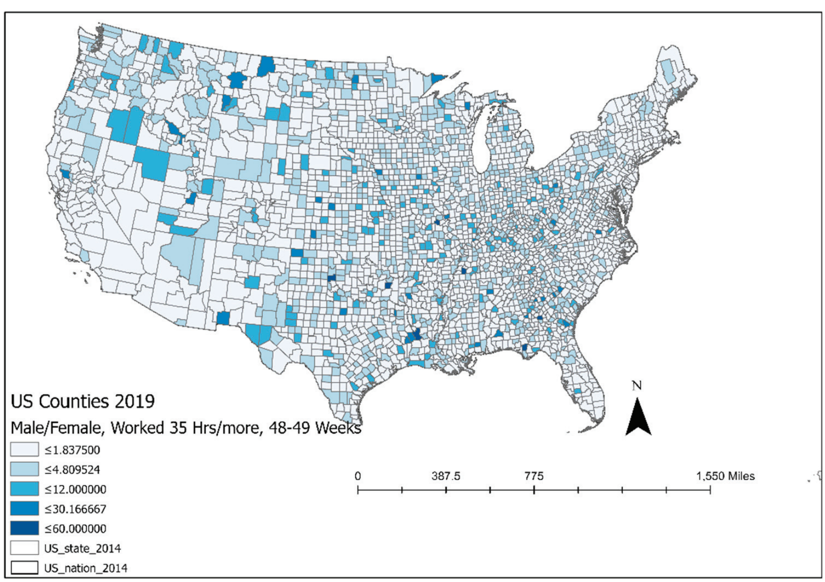
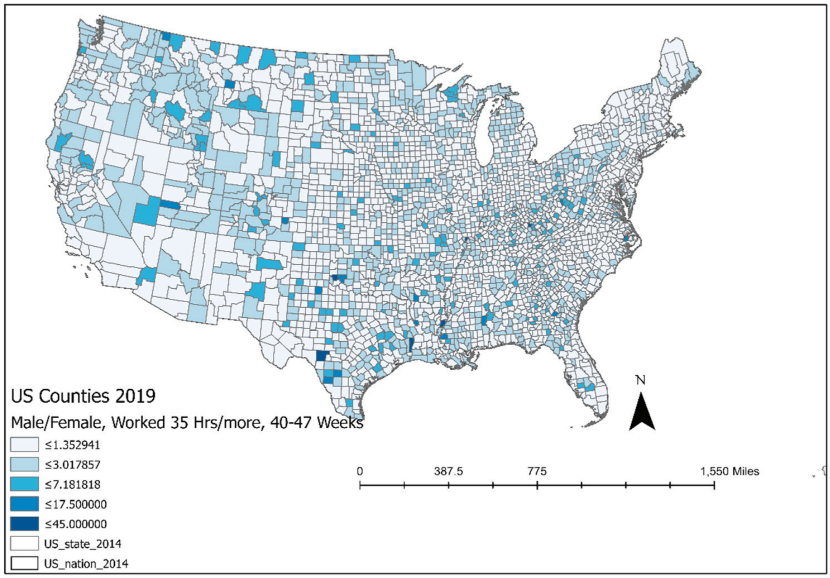
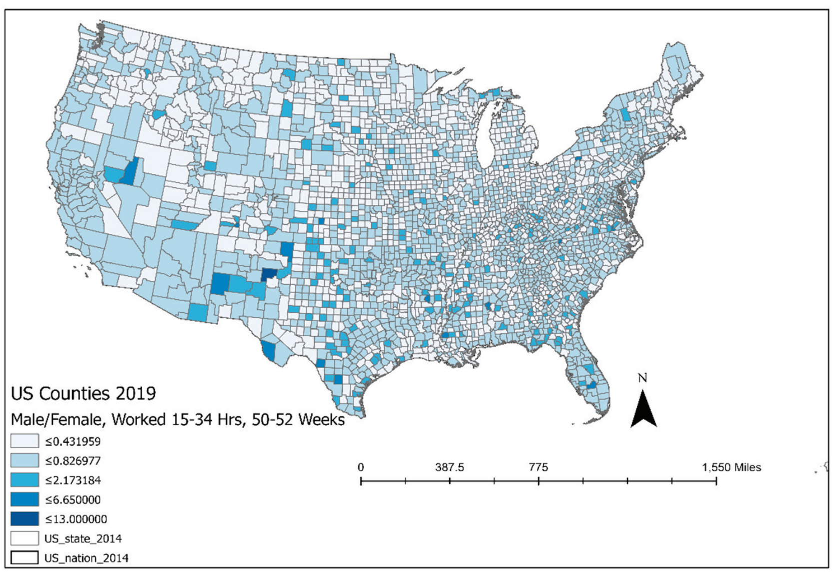


Figure 2. *Cont.*





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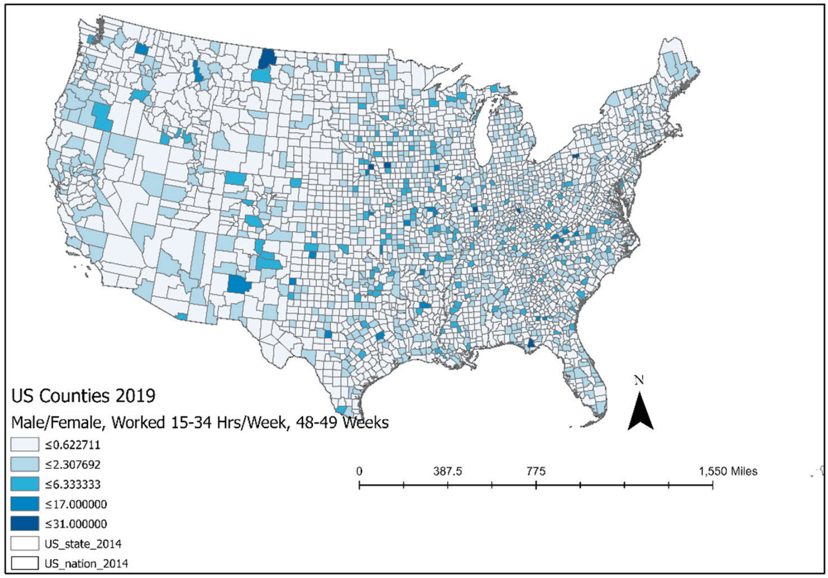

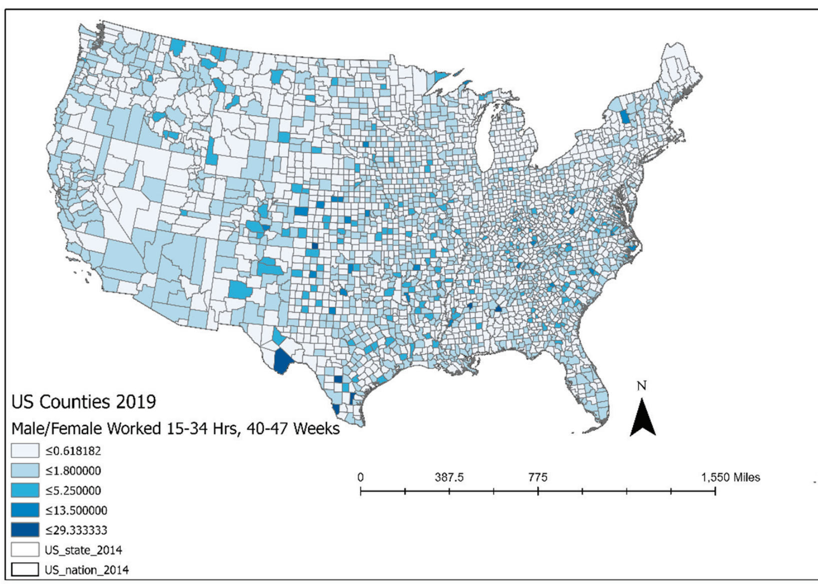

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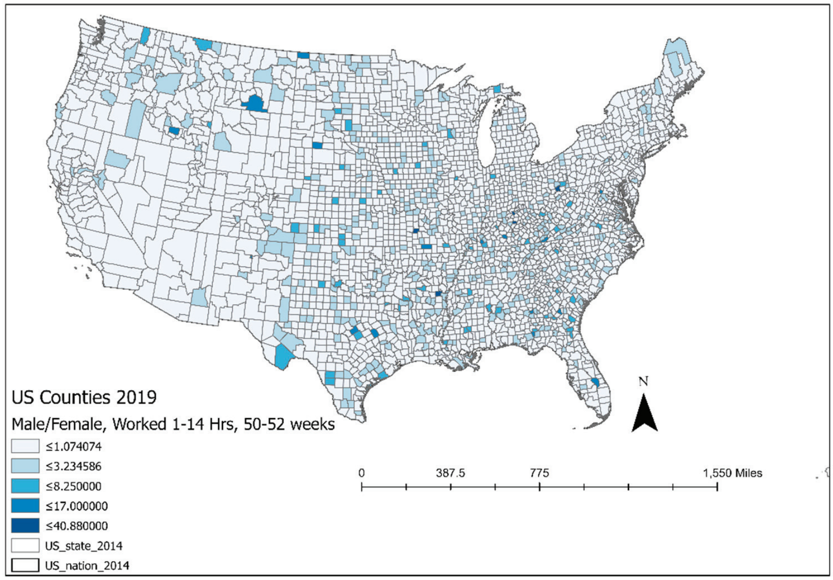


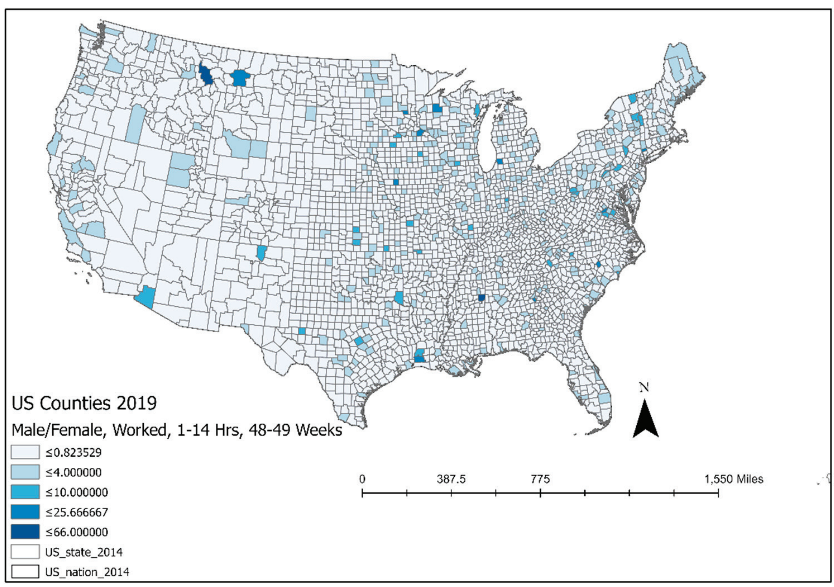
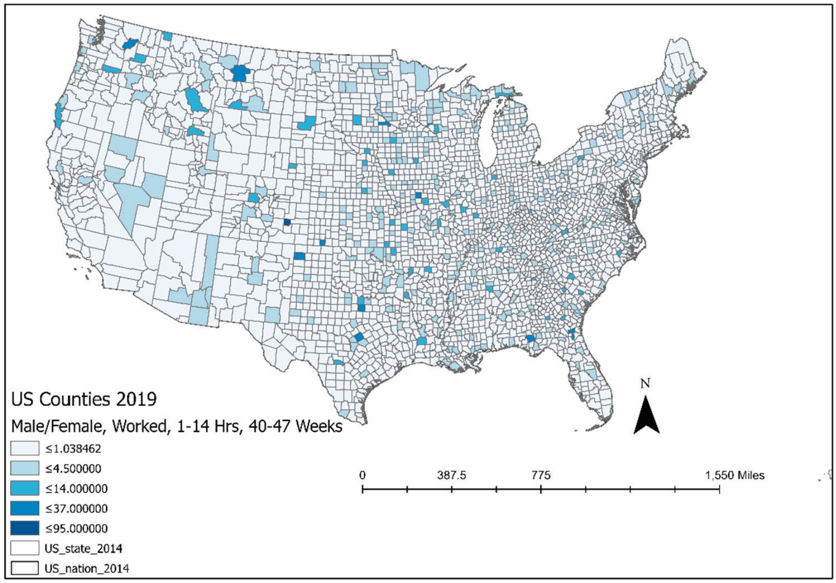


Figure 2. *Cont*.



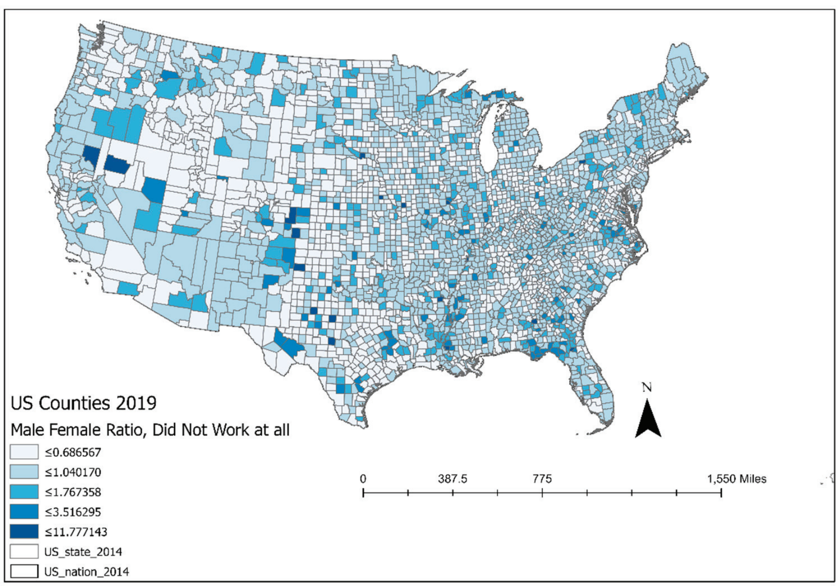


Figure 2. Male/female work ratios (≥35 h/week, 15–34 h/week, 1–14 h/week, did not work at all).

4.2. Educational Attainment across Gender, 2019

A basic descriptive analysis of the entire data indicates wide gaps in educational attainment across the genders, especially in STEM and professional disciplines (Table 2A,B). The maximum values for males occur in the categories of High School Diploma, No High School Diploma, Some College/Associate; then those with Bachelor's, Master's, and Doctorate Degrees. In contrast, the maximum values for females occur for No High School diploma (39.3%), Some College/Associate (32.4%), High School diploma (27.2%), Bachelor's (20.4%), Master's (14.4%), Professional (4.0%), and Doctoral Degrees (4.0%).

As is obvious from this table, males have significant advantage in terms of Doctoral and Bachelor's Degrees, alongside High School Diplomas.

Table 2. Educational attainment (A) and majors in bachelor's (B) by gender, 2019.

A: Broad Categories, 25 Years/Older	Males		Females	
	Mean	**Max.**	**Mean**	**Max.**
Share, No School at all	0.006	0.063	0.005	0.091
Share, No HS Diploma	0.065	0.343	0.055	0.393
Share, HS Diploma	0.179	0.437	0.163	0.272
Share, Some College/Associate	0.143	0.282	0.165	0.324
Share, Bachelor's	0.066	0.251	0.077	0.204
Share, Master's	0.023	0.148	0.034	0.144
Share, Professional	0.007	0.057	0.005	0.040
Share, Doctorate	0.005	0.137	0.003	0.040
B: Major in Bachelor's Degree	**Mean**	**Max.**	**Mean**	**Max.**
Share, Science and Engineering	0.183	0.571	0.111	0.545
Share, Science and Engineering-related field	0.029	0.166	0.081	0.271
Share, Business	0.095	0.312	0.082	0.426
Share, Education	0.056	0.459	0.164	0.477
Share, Arts, Humanities, Others	0.088	0.750	0.109	0.432

Concerning majors in a bachelor's degree, the maximum values for females occur for science and engineering (54.5%), education (47.7%), arts/humanities/others (43.2%), business (42.62%), and science and engineering-related fields (27.1%); for these same majors, males have much higher maximum values in science and engineering, followed by education, business, and science and engineering-related fields. Mean values for these educational categories suggest higher percentages of women majoring in education (16.4%), arts/humanities (10.9%), science and engineering (11.1%), business (8.2%), and finally science and engineering-related (8.1%) disciplines (Table 2B). Men overwhelmingly major in science and engineering (18.3%), business (9.5%), arts/humanities (8.8%), education (5.6%), and lastly, science and engineering-related (2.8%) disciplines. These statistics are important to understand as the earnings capacity and poverty levels among men and women are intricately tied together. Even though the earnings and poverty levels of single women with children cannot be entirely explained by their educational attainment or skills, their different levels of education and skills are also manifestations of the societal, cultural, and policy contexts of a society, and I hope these will show up in the regression models with meaningful results.

4.3. Bivariate Correlations Analysis

The bivariate correlation analysis (Table 3) shows that the presence of blacks and American Indians is associated with higher poverty levels for all three dependent variables, whereas the share of Hispanics is associated with higher poverty among female-headed households, both with and without children. These indicate the sad reality of contemporary American society, where female poverty and overall poverty have a very strong aspect of color to them—and these concern blacks, Hispanics, and Native Americans—as noted in the Census report as well [9]. Regarding education, in general, lower levels of education (high school diploma and below) associate with higher poverty for all three dependent variables; in contrast, better educational levels associate with lower poverty, albeit the strength of r-values depends on the major in a bachelor's degree. Majoring in science and engineering among both genders is associated with lower poverty for all three dependent variables.

Table 3. Bivariate correlation analysis for female and male-headed households in poverty, with and without children and explanatory variables, 2019.

Explanatory Variables and Dependent Variables	Y_1:FHwC	Y_2:FHNC	Y_3:MHwC
A: Share of Major Racial/Ethnic Groups (out of Total Population, 2019)			
Non-Hispanic white	−0.539 **	−0.547 **	−0.202 **
Non-Hispanic black	0.597 **	0.622 **	0.102 **
Non-Hispanic American Indians	0.224 **	0.222 **	0.383 **
Non-Hispanic Asians-w-Hawaiian and Pacific Islanders	−0.120 **	−0.119 **	−0.099 **
Non-Hispanic All-Others	−0.043 *	−0.050 **	0.033
Hispanics	0.073 **	0.060 **	−0.004
B: Share, Educational Attainment and Majors in Bachelor's Degree, Males and Females (≥25 Years)			
No-School, Male	0.257 **	0.265 **	0.074 **
No High School, Male	0.471 **	0.497 **	0.264 **
High School Diploma, Male	0.163 **	0.175 **	0.210 **
Some College/Associate, Male	−0.311 **	−0.336 **	−0.118 **
Bachelor's Degree, Male	−0.415 **	−0.431 **	−0.316 **
Master's Degree, Male	−0.313 **	−0.320 **	−0.245 **
Professional Degrees, Male	−0.212 **	−0.214 **	−0.193 **
Doctorate, Male	−0.162 **	−0.157 **	−0.152 **
No School, Female	0.234 **	0.242 **	0.060 **
No High School, Female	0.525 **	0.546 **	0.282 **
High School Diploma, Female	0.204 **	0.214 **	0.167 **
Some College/Associate, Female	−0.110 **	−0.128 **	−0.036 *
Bachelor's Degree, Female	−0.394 **	−0.413 **	−0.306 **
Master's Degree, Female	−0.182 **	−0.186 **	−0.166 **
Professional Degrees, Female	−0.130 **	−0.123 **	−0.132 **
Doctorate, Female	−0.132 **	−0.130 **	−0.142 **
Science/Engineering, Male	−0.318 **	−0.324 **	−0.222 **
Science/Engineering-related field, Male	−0.02	−0.022	0.028
Business, Male	−0.025	−0.019	−0.123 **
Education, Male	−0.048 **	0.038 *	0.149 **
Arts/Humanities/Others, Male	−0.002	0.000	−0.025
Science/Engineering, Female	−0.114 **	−0.110 **	−0.079 **
Science/Engineering-related field, Female	−0.038 *	0.040 *	0.092 **
Business, Female	0.120 **	0.121 **	0.002
Education, Female	0.266 **	0.268 **	0.207 **
Arts/Humanities/Others, Female	−0.034	−0.034	−0.048 **
C: Location Quotients by Gender, Five Major Occupations			
LQ-Male, Management, Business, Science and Arts	−0.410 **	−0.424 **	−0.260 **
LQ-Male, Service Occupations	0.203 **	0.217 **	0.174 **
LQ-Male, Sales and Office Occupations	−0.122 **	−0.121 **	−0.101 **
LQ-Male, Natural Resources, Construction and Maintenance	−0.038 *	−0.042 *	0.011
LQ-Male, Production, Transport, Material Moving	0.188 **	0.188 **	0.113 **
LQ-Female, Management, Business, Science and Arts	−0.135 **	−0.137 **	−0.083 **
LQ-Female, Service- Occupations	0.272 **	0.275 **	0.169 **
LQ-Female, Sales and Office Occupations	0.105 **	0.121 **	0.027
LQ-Female, Natural Resources, Construction and Maintenance	−0.018	−0.025	−0.029
LQ-Female, Production, Transport, Material Moving	0.216 **	0.221 **	0.098 **
D: Income Characteristics by Gender by Work Status (Inflation Adjusted), 2019			
Median Household Income, Overall	−0.564 **	−0.585 **	−0.365 **
Median Household Income, Male, Overall	−0.441 **	−0.457 **	−0.305 **
Median Household Income, Male-Worked Fulltime	−0.421 **	−0.434 **	−0.275 **
Median Household Income, Male-Worked Parttime	−0.219 **	−0.224 **	−0.099 **
Median Household Income, Female, Overall	−0.340 **	−0.345 **	−0.213 **

Table 3. *Cont.*

Explanatory Variables and Dependent Variables	Y_1:FHwC	Y_2:FHNC	Y_3:MHwC
Median Household Income, Female-Worked Fulltime	−0.394 **	−0.401 **	−0.225 **
Median Household Income, Female-Worked Parttime	−0.221 **	−0.229 **	−0.122 **
E: Share, Female Work Status: Hours Worked/Week, #of Weeks Worked/Year (Out of Total Labor)			
Worked 35 h or more/Week, 50–52 Weeks/Year	−0.304 **	−0.328 **	−0.243 **
Worked 35 h or more/Week, 40–49 Weeks/Year	−0.143 **	−0.157 **	−0.072 **
Worked 35 h or more/Week, 14–39 Weeks/Year	0.074 **	0.060 **	0.064 **
Worked 35 h or more/Week, 1–13 Weeks/Year	0.124 **	0.118 **	0.099 **
Worked 15–34 h/Week, 50–52 Weeks/Year	−0.317 **	−0.345 **	−0.179 **
Worked 15–34/Week, 40-to-49 Weeks/Year	−0.249 **	−0.264 **	−0.149 **
Worked 15–34 h/Week, 14–39 Weeks/Year	0.074 **	0.060 **	0.064 **
Worked 15–34 h/Week, 1–13 Weeks/Year	−0.341 **	−0.357 **	−0.199 **
Worked 1–14 h/Week, 50–52 Weeks/Year	−0.208 **	−0.220 **	−0.112 **
Worked 1–14 h/Week, 40–49 Weeks/Year	−0.203 **	−0.210 **	−0.138 **
Worked 1–14 h/Week, 14–39 Weeks/Year	−0.271 **	−0.280 **	−0.172 **
Worked 1–14 h/Week, 1–13 Weeks/Year	−0.209 **	−0.222 **	−0.105 **
Did Not Work at all	0.513 **	0.550 **	0.303 **

Note: ** Correlation is significant at the 0.01 level (2-tailed); * Correlation is significant at the 0.05 level (2-tailed). Y1:FHwC: Share, Female-headed households—with children, living in poverty in 2019; Y2:FHNC: Share, Female-headed households—without children, living in poverty in 2019; Y3:MHwC: Share, Male-headed households—with children, living in poverty in 2019.

Concerning five major types of occupations, overrepresentation of males and females in service and production/transport/material moving is associated with higher poverty for all three dependent variables; the same holds true for females in sales/office occupations. Other occupation-types for both genders (management/professional and natural resources/construction) are associated with lower poverty for all dependent variables, though these are insignificant for LQ-values among females, likely due to their severe under-representation in this industry. Median household incomes (overall) and for males and females—all associate with lower poverty—as expected. Given its direct association with reducing poverty, I do not use any income variables in the regression models.

Regarding work status, in general, full-time working women have lower poverty rates with or without children, as is the case with men. As expected, the association is positive (i.e., higher poverty for female-headed households) for women working 39 weeks/year or less; so is the case with men—which is not surprising. Interestingly, women working 15–34 h/week and for 14–39 weeks/year are also associated with higher poverty. All other categories of work status for women are associated with lower poverty, which points toward the fact that a fuller work status for females is critical to alleviating female poverty, with or without children.

4.4. Regressions Models for Female-Headed and Male-Headed Households with Children in Poverty

After attempting OLS models with select variables of importance, I used the stepwise method to derive the best-fit regression model for each Y-variable. As noted in Table 4, A and B, the presence of blacks, and the share of those with lower levels of education (i.e., no High School diploma, with high school diploma, some college/associate) receive positive Betas for female-headed households with children and without children living in poverty. These findings reiterate the effects of historical and contextual issues pertaining to race and gender in the USA, where limited educational outcomes particularly impact female poverty rates. The share of whites, Asians, Hispanics, and all other groups receive negative Betas, whereas the share of blacks receives positive Betas (0.047 and 0.060) in both models A and B. This is indicative of the intersectionality between race and gender, and given the positive Betas for blacks, it becomes more obvious that a large part of female poverty correlates strongly with the black population—implying higher poverty among black women. Higher poverty rates also corroborate strongly with the poverty clusters in

Figure 1. Additionally, females with lower levels of educational skills are likely unable to translate them into better-paid jobs and financial well-being, and as noted in other research as well, having children pushes them further into poverty [8]. However, the share of females with a master's degree also receives positive Beta for female-headed households in poverty, with and without children. This result is surprising, as one would expect better educated women to have a better capacity to safeguard against poverty. This new finding points toward the possibility that the presence of children and/or the single/divorced status of women might be extra stressors, even among the better educated. However, this will require further testing through targeted case studies.

Table 4. Regression models for female-headed households in poverty, with and without children (no spouse), 2019.

	Y: Share, Female-Headed Households in Poverty (With Children)				**Y: Share, Female-Headed Households in Poverty (No Children)**				
Variables	**B**	**Beta**	**t-Value**	**Sig.**	**B**	**Beta**	**t-Value**	**Sig.**	**VIF**
(Constant)	0.014		1.696	0.090	0.016		1.748	0.081	
Share, Non-Hispanic White	−0.090	−0.598	−19.283	0.000	−0.103	−0.586	−20.238	0.000	8.326
Share, Non-Hispanic Black	0.010	0.047	1.930	0.054	0.015	0.060	2.629	0.009	5.112
Share, Non-Hispanic Asians-w-Hawaiian/Pacific Islanders	−0.098	−0.098	−6.909	0.000	−0.101	−0.087	−6.555	0.000	1.745
Share, Non-Hispanic All Others	−0.086	−0.049	−3.646	0.000	−0.119	−0.058	−4.637	0.000	1.566
Share, Hispanics	−0.063	−0.285	−11.375	0.000	−0.078	−0.305	−13.054	0.000	5.415
Share, No High School, Female	0.289	0.264	15.612	0.000	0.345	0.270	13.713	0.000	3.847
Share, High School Diploma, Female	0.143	0.167	9.817	0.000	0.149	0.150	8.056	0.000	3.432
Share. Some College/Associate, Female	0.133	0.122	8.582	0.000	0.130	0.103	6.759	0.000	2.289
Share. Master's Degree, Female	0.184	0.103	5.711	0.000	0.182	0.088	4.811	0.000	3.297
Share, Education, Female	0.047	0.091	6.831	0.000	0.050	0.084	6.676	0.000	1.554
LQ-Female, Service Occupations	0.035	0.153	12.117	0.000	0.043	0.159	13.215	0.000	1.438
LQ-Female, Management, Business, Sc. and Arts	0.068	0.189	10.389	0.000	0.084	0.201	11.791	0.000	2.879
LQ-Female, Production, Transport, Material Moving	0.023	0.123	8.226	0.000	0.028	0.126	8.882	0.000	2.006
LQ-Female, Sales and Office	0.024	0.075	5.964	0.000	0.034	0.093	7.888	0.000	1.379
Share, Females, Did Not Work at all	x	x	x	x	0.022	0.026	1.279	0.201	4.077
Share, Females, Worked 15–34 h/Week, 1–13 Weeks/Year	−0.164	−0.055	−4.254	0.000	−0.196	−0.056	−4.394	0.000	1.616
Share, Females, Worked >=35 h/Week, 50–52 Weeks/Year	−0.182	−0.202	−15.850	0.000	−0.226	−0.215	−14.078	0.000	2.317
R-value		0.799					0.828		
R-squared value		0.638					0.685		
Adjusted R-square		0.636					0.683		

When examining the majors in bachelor's degrees among females, those majoring in education receive positive Beta—indicating higher poverty. Thus, "education" as a major is not the best way to safeguard against poverty, especially for single women, with or without children. This also points toward the fact that in the USA, teachers/education sector, generally perceived as feminine occupations, remain one of the lowest-paid occupations regardless of the instructor's qualifications. Indeed, several media and news channels continue to run documentaries on the financial woes of teachers and how the schoolteachers work multiple jobs to make ends meet—largely because of their exceptionally low salaries.

The LQs in management, service, sales/office, and production/transportation-type occupations are associates with positive Betas, implying higher poverty levels among women engaged in these occupations. Some of these findings point toward the relative lower pay in these occupations, as noted in other work [6–8]. However, this new finding points toward the working poor—that section of society—largely the women who comprise an active labor force in the new econony and are living in poverty.

Regarding work status, it is a no-brainer that full-time work all throughout the year (35 h/week, 50–52 h/year) attributes toward reducing poverty among women (negative Beta), albeit the Beta is slightly stronger for single females compared to those with children. Even the share of females who worked only 15–34 h/week for 1–13 weeks/year also receives negative Beta, implying lower poverty. The share of females who did not work at all does not show up in the model for female-headed households with children, whereas this variable shows up for those without children but is insignificant. The R-Square values are very good for both models—0.638 (with children) and 0.685 (without children). The new findings from these models point toward the fact that full-time and even part-time work for single women helps reduce poverty, especially for those with children. Finally, the VIF values point toward some multicolliearity between major population groups (whites, blacks, and Hispanics), all of which are critical to measuring poverty in the entire country. Since removing them would drastically reduce the sample size and produce unreliable results, they were retained in the models.

When modeling male-headed households with children living in poverty (Table 5), four major categories of race variables show up in the model, and they all receive negative Betas—implying lower poverty. The strength of Betas is strongest for whites (−0.934), followed by blacks (−0.532), Hispanics (−0.527), and Asians (−0.265). Regarding educational attainment, lower levels of education are associated with higher poverty and receive positive Betas, with no high school diploma having a stronger Beta (0.180) compared to a high school diploma (Beta = 0.065). Regarding majors in bachelor's, science and engineering (Beta = −0.107), business (Beta = −0.182), and arts/humanities (Beta = −0.078) all associate with lower poverty, with the business major being the strongest.

Regarding occupation, LQ-management (Beta = −0.221) and LQ-natural resources, etc. (Beta = −0.197) associate with lower poverty for male-headed households with children, with management-type occupations having a stronger impact. LQ-Service, however, receives positive Beta (0.122), implying higher poverty—same as those for females (with or without children). What is clear and new from this model is that the over-presence of men in natural resource extraction/construction, etc. plays to their advantage, given its highly *masculine* nature and potential higher incomes. This research also finds new knowledge that being in management occupations protects single male-headed households with children from falling into poverty, whereas it does not in the case of female-headed households, with and without children.

Finally, the male-versus-female work status ratio for those who worked 35 h/more per week for 48–49 weeks/year associates with a negative Beta (lower poverty) whereas other two categories (1–14 h/week, 50–52 weeks/year, and 15–34 h/week, 50–52 weeks/year) representing part-time work status for males receive positive Betas, implying poverty, even though the strength of these Betas is small. This finding is new since the male/female ratios for part-time categories of work show a trend toward attaining parity with women, especially concerning poverty, which is an unpleasant situation. Finally, the R-square value for this model is 0.373, which is lower than 0.50. However, all the explanatory variables are significant and provide meaningful results. Regarding lower R-square values, scholars have suggested that it happens because of more noise in the data. Frost illustrates two different models to explain how the output does not change even when the R-square value is 0.147 (i.e., explaining only 14.7% of the variance) and that the higher variability of data around the regression slope line is what produces a lower R-squared value [59]. In the past, numerous scholars who have worked on rural women's livelihoods and economic patterns in Bangladesh have published their results with lower R-squared values, explaining 11–13% of total variance [60,61]. In this study, the R-square value is far better, and the explanatory variables provide meaningful results.

Table 5. Regression Model for Male-Headed Households with Children in Poverty, 2019Y_3= Male Headed Households with Children in Poverty.

	B	Beta	t-Value	Sig.	VIF
(Constant)	0.042		14.469	0.000	
Share, Non-Hispanic White	−0.026	−0.934	−12.782	0.000	17.414
Share, Non-Hispanic Black	−0.023	−0.532	−10.682	0.000	7.683
Share, Non-Hispanic Asians-w-Haw/Pacific Islanders	−0.036	−0.265	−8.682	0.000	2.338
Share, Hispanics	−0.023	−0.527	−10.109	0.000	8.848
Share, No High School, Male	0.038	0.180	5.987	0.000	2.177
Share, High School Diploma, Male	0.008	0.065	1.719	0.086	2.476
Share, Science and Engineering-Major, Male	−0.015	−0.107	−3.403	0.001	2.310
Share, Business Major, Male	−0.035	−0.182	−7.323	0.000	1.426
Share, Arts and Humanities Major, Male	−0.020	−0.078	−3.206	0.001	1.391
LQ-Male, Management, Business, Science and Arts	−0.010	−0.221	−5.010	0.000	3.155
LQ-Male, Service Occupations	0.006	0.122	4.704	0.000	1.605
LQ-Male, Nat-Resources, Construction and Maintenance	−0.003	−0.197	−6.527	0.000	2.166
M/F-Work-Ratio, ≥35 h/Week, 48–49 Weeks/Year	0.000	−0.077	−3.710	0.000	1.061
M/F-Work-Ratio, 1–14 h/Week, 50–52 Weeks/Year	0.000	0.056	2.696	0.007	1.047
M/F-Work-Ratio, 15–34 h/Week, 50–52 Weeks/Year	0.002	0.049	2.122	0.034	1.242
R-value		0.611			
R-squared value		0.373			
Adjusted R-square		0.367			

Note: In this table, VIF has a high share of whites, blacks, and Hispanics. However, given their significant roles in predicting poverty and the size of their population in the entire sample, I kept them in the model.

5. Conclusions and Policy Implications

This analysis aimed at examining varying levels of poverty among male- and female-headed households, with and without children, living in poverty in the counties in the USA. By using a multi-level empirical analysis of county-scale five-year ACS estimates from the NHGIS, this analysis finds some expected and some surprising results. Sadly, the presence of black population associates with higher levels of poverty (positive Betas) for female-headed households, with and without children, whereas most of the race variables associate with lower levels of poverty (negative Beta) for male-headed households with children. This points toward the fact that a large part of female poverty is likely due to the larger share of black women in the black population being captured in positive Betas in the model.

This analysis also finds that, in general, lower levels of education (some college/associate degree or lower) are associated with higher poverty for both genders. One new finding from this analysis is that for females with a master's degree, the Beta is positive—hinting toward the presence of children and/or their single status as the "stressors" of poverty. This finding, however, will need further investigation through a case study/qualitative approach. This research also finds that for females, majoring in education does not provide a pathway toward alleviating poverty. Indeed, for a long time, the lower salary of teachers specifically has remained a widely discussed topic in news channels/media in the US. At the policy level, raising the salary of teachers and providing them with other benefits is critical, as many women work as educators, and timely intervention will help reduce poverty and create a more equitable society. For males, majoring in science and engineering, business, and the arts/humanities—all associated with lower poverty—and the strength of business was the highest. This points toward the fact that encouraging more women to major in science, engineering, and business could be a potential pathway toward alleviating poverty and achieving equity. This was also emphasized at the most recent convention of the United Nations, where it was emphasized that even though 75% of all job growth will be in STEM-related disciplines, women comprise only 30% of the global workforce in the world's 20 largest global tech companies [17]. This gap in educational and human capital skills needs to be narrowed, as this is the only pathway toward creating a just and equitable future by 2030 and achieving the UN's SDGs [17]. In the U.S., this needs policy-level intervention so that universities can provide special scholarships to attract female students into science and engineering, business, and other professional degrees/majors. Further, recruitment of graduated female students by employers at local, regional, and national levels could be encouraging steps toward achieving equity and reducing female poverty.

In terms of relationships between poverty and gender-based occupations, the service sector is associated with higher poverty for both genders, regardless of children's presence at home. For male-headed households, however, management and natural resources/construction-based occupations are associated with lower poverty, but management has a stronger role. For women, however, management, sales/office, and service-type occupations—all associated with higher poverty—point toward the emergence of a new class—the "working poor"—largely comprised of women—an active part of the contemporary US labor force and yet living in poverty.

These findings point toward a sad reality of the US labor market where similar types of occupations yield different levels of earnings (and poverty) across the genders, with males having an advantage in specific industries and with specific educational backgrounds. This finding reemphasizes the role of Labor Market Segment Theory in capturing the subtle/unwritten rules that still prevail in specific industries where females are systemically paid lower wages compared to males. This research also adds a new dimension to the Human Capital Theory since majoring in "Education" does not yield enough earnings to single females (with and without children both) to reduce poverty, whereas majoring in science and engineering, business, and arts/humanities works quite well for single males with children. I call it the "Neo-Human Capital Theory", which accounts for gender-based variations in skills and earnings by adequately weighing regional and cultural variations.

In terms of policy, these findings call for the state and federal governments' legal intervention in ensuring equal pay for equal work in the U.S. labor market. Implementing these can be very challenging in a large and diverse country such as the USA. However, this is the only pathway toward ensuring gender equality in earnings and lowering poverty for women, especially for those with children. Single parents/single female headed households with children are the reality of contemporary America. Ensuring legal protection for "equal pay for equal work" can provide a decent upbringing to the children involved in such families—a critical necessity toward creating a healthier society and a healthy nation. This is the only way forward toward attaining the SDGs of the United Nations.

In terms of work status, higher male-female ratios for those working more than 35 h/week, 48–49 weeks/year, were associated with lower poverty for males, whereas for females, the share of females working 35 h/more, 50–52 weeks/year, worked toward alleviating poverty. Both of these cases are not surprising as they point toward fuller work status for both genders. However, what is surprising is that part-time work status for females also associates with lower poverty, albeit at reduced strength compared to full-time work status; in contrast, the male/female work status ratios in part-time categories associate with higher poverty for males—pointing toward an "equalizing" trend regarding poverty. This finding is concerning, especially since some men might have to work part-time to accommodate specific needs, but its eventual manifestation in terms of heightened poverty might have opposing effects.

In terms of policy, this research reemphasizes the need for creating opportunities for full-time employment for both genders, and more specifically for females, due to the positive contribution of full-time employment to alleviating poverty. This implies providing subsidized care facilities, family/maternity leave benefits, flexible work hours, tax credits for families with children, and other types of gender-inclusive work environments such that women can participate fully in the labor market and are able to focus on their work and family both without any feeling of guilt. This will ensure a happier and more positive work culture, and women will be able to contribute to the economy without worrying about the "motherhood penalty" and the consequential restricted/limited career growth.

This study, despite its new and interesting findings, has some limitations. Creating a good R-square model for males with children was difficult due to the scattered nature of the data points. This highlights the noise in the ACS estimates, likely due to the difficulties in measuring and capturing the socioeconomic and labor-market variables—most of which are private information. Other limitations include the difficulties in assessing the reasons that produce different poverty outcomes for males and females with similar types of educational backgrounds. These point toward the limitations of the data in capturing cultural and regional nuances. These can be remedied to some extent by adopting mixed-methods/qualitative approaches, which are time-consuming, case-specific, and not generalizable. Given the size of the data analyzed in this study and weighing the pros and cons of quantitative versus qualitative methods, these limitations outweigh the science and knowledge gained in this research.

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Commentary

Gender Trends in Healthcare and Academia—Where Does the University of Malta Stand?

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Abstract: A current and pertinent topic is that of gender studies within healthcare students and academic staff of healthcare courses. This commentary explores the feminization of healthcare studies and the extent to which women in Malta hold key roles in academia within the faculties of Health Sciences, Dental Surgery, and Medicine and Surgery at the University of Malta. Data were publicly available from the university website. Gender (male: female ratio) trends were elicited from the data representing each level of qualification as offered by each faculty, while top academic roles within each faculty were noted. As a general trend, the number of students studying healthcare courses has increased, with an increased female-to-male ratio. Yet, in academia, men still occupy top roles. Efforts should be made to cater for all races, ethnicities, genders, sexual orientations, and socioeconomic levels within the healthcare workforce to allow delivery of the best possible service.

Keywords: gender equality; gender issues; gender bias; working women

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1. Introduction

"Achiev[ing] gender equality and empower[ing] all women and girls" is one of the United Nations' Sustainable Development Goals (United Nations 2022). Identifying and addressing gender inequalities and gender equity is paramount to ensure good stewardship of health systems (Payne 2009). This commentary sheds light on gender trends within academia and health studies at the University of Malta. There is only one state university in Malta where both local and international students are enrolled. We explore the feminization of healthcare studies and the extent to which women in Malta hold key roles in academia within the faculties of Health Sciences, Dental Surgery, and Medicine and Surgery. Understanding the situation in Malta's only state university is therefore of key interest to gender studies in healthcare and academia on a global scale.

This commentary is an observational piece that provides a representative overview of the gender trends in academia at university level within the country and may be compared with other international universities. We describe trends in healthcare courses across the years, starting from 2009 and continuing up to 2022, as well as the current gender imbalances (academic year 2022–2023) within different levels of academic staff.

Understanding gender trends in universities and the possible driving forces for these trends is essential as it allows human resource planning and may stimulate the development of policies or benefits that suit the needs of the workforce, both in health academia and healthcare itself (El Arnaout et al. 2019).

Our commentary aims to understand the gender trends in Malta's university so that our findings may be applied to the wider international scientific community. This would allow a better understanding of how universities contribute to the attainment of Sustainable Development Goals in terms of gender equality and women's rights.

2. Data Collection—Staff and Students

All data used were publicly and freely available and were taken from the University of Malta website. Data pertaining to students included the list of available courses for the faculties of Health Sciences, Dental Surgery, and Doctor of Medicine and Surgery for each academic year, and the number of male and female students admitted to each course yearly. Data relating to staff were found by accessing the website of each faculty and inputting the gender of the dean, deputy dean, and heads of department into an Excel spreadsheet. These represent the top academic roles within each faculty.

Gender (male: female ratio) trends were elicited from the data representing each level of qualification as offered by each faculty. Data for academic staff were organized into a table.

2.1. Gender Trends: Students in Healthcare

Female enrolment increased relative to that of males within the Faculty of Dental Surgery over time across all educational levels. In contrast, diploma-level courses have been consistently dominated by the female gender. This can be seen in Table S1.

Diplomas and Bachelors qualifications are dominated by female students within the Faculty of Health Sciences. However, males appear to be more inclined to undergo post-graduate courses such as Masters and PhDs. This is illustrated in Table S3.

Vertical and horizontal occupational segregation is present when looking at healthcare positions and gender. Women tend to be underrepresented when it comes to managerial and decision-making roles, with females in the healthcare workforce usually concentrated in professions to do with “care” such as nursing and midwifery. These occupations tend to be perceived as “low-status” jobs when compared to medicine, dentistry, and pharmacy. These “high-status” occupations tend to be occupied by men (European Institute for Gender Equality 2019). The trends seen within the faculties of Dental Surgery and Health Sciences echo this observation.

The course of Doctor of Medicine and Surgery within the Faculty of Medicine and Surgery is one of the largest courses, in terms of the number of students, that exists within the University of Malta. It shows an interesting trend in that male dominance existed until 2013. From then onwards, the number of males to females remained virtually equal, with the only exception being the 2021–2022 academic year, where there were more females than males. Conversely, a female predominance was observed across all academic years in post-graduate courses, i.e., Masters and PhDs, within the Faculty of Medicine and Surgery. This can be seen in Table S5.

The feminization of the medical course in Malta follows global trends where data show more women have entered medical school compared to men in the past two decades. There is evidence that the growing global feminist movement, in which women triumphed over prejudices and sexism, has helped women to gain their place within this labor market (Perinni 2021). Participation of women in the medical profession has in fact been shown to have increased over the past four decades, as can clearly be seen within the University of Malta (Jagsi et al. 2006).

Census data from Canada and the United States are congruent with Maltese findings in that the feminization of women in healthcare professions is clearly evident (Adams 2010). A greater proportion of female physicians compared to males was also demonstrated in Bangladesh in 2019. Student admission data also showed a female majority (Hossain et al. 2019). Although Japan has a relatively low proportion of female physicians, female participation in the medical field has been shown to have increased over the past decade, a trend that matches that in Europe, including Malta (Nomura et al. 2010). The proportion of Scandinavian women in medicine relative to males has surpassed that of the United States, although underrepresentation of the female sex in higher administrative positions exists in Finland (Riska 2001). Soviet history resulted in the feminization of the medical profession in Russia earlier than in the West; however, studies have demonstrated that only a small number of women are found in prestigious specialties and in academic medicine (Harden 2016; Ramakrishnan et al. 2014; Riska 2001).

It is a well-known fact that medical teams with greater gender diversity among senior roles perform better (European Union of Medical Specialties 2020). Yet, it appears that this is still not reflected in undergraduate enrollment choices, especially among allied healthcare students, which will make up the next generation of workers. Strides towards achieving this should thus be made on a global scale and would require worldwide collaboration of institutions involved. Dealing with phenomena such as the gender pay gap, where women in the health sector earn 20% less than their male counterparts, would encourage women to join the profession and decrease turnover rates (United Nations 2022). Although the past decade has seen an increase in the female medical workforce, they occupy most of the lower-status and lower-paid jobs compared to men. International collaboration is required to develop a health care system that recognizes and celebrates the contributions of the female sex (World Health Organization 2022).

2.2. Gender within Academia—A Snapshot

A general male predominance is present within the positions of dean and deputy dean for these faculties. When it comes to heads of department, a significantly larger proportion within the Faculty of Health Sciences are female while an equal number of males and females are present in these roles in the Faculty of Medicine and Surgery. A female predominance in heads of department exists in the Faculty of Dental Surgery. This is shown in Tables S2, S4 and S6.

The field of medicine and surgery is one that has traditionally been commanded by men, and more men tend to occupy more senior positions. This occurs in almost all departments, but more so in the field of surgery and anesthesia. The issue of lack of opportunities that prevents women from continuing their education is one that should be explored worldwide (Ayomi 2021). Women remain significantly underrepresented in the roles of senior doctors and full professors on a global scale (Kuhlmann et al. 2017). This is concordant with the observations within this commentary as although many women are indeed heads of department, the more senior roles of dean and deputy dean remain male-centric. Women in academic healthcare fields experience inequity because of sexism and other issues, such as carrying a greater burden of domestic responsibilities and the need for caregiving leave and facilities. As a result, it is generally difficult to keep up with their male colleagues (Carr et al. 2018). Globally cooperative strategies and responses are needed to counteract this issue (Morgan et al. 2018). These may include, but are certainly not limited to, childcare provision, ensuring fair and equal pay, and better representation for women at all levels. Such strategies will provide women with more autonomy over the management of their lives and will allow women to progress in their career while also balancing domestic duties (Berlin et al. 2019; Freund et al. 2016; MacDonald 2003). These measures serve to overcome challenges brought about by women's historical and social disadvantages that prevented them from operating on a level playing field alongside men.

In conclusion, parity for all healthcare workers is essential for productivity and the provision of a good service (Valantine 2020). Given that healthcare workers treat diverse patients, having a diverse workforce as a reflection of that would allow delivery of the best care possible. Efforts should be made to cater for all races, ethnicities, genders, sexual orientations, and socioeconomic levels within the healthcare workforce to allow delivery of the best possible service through a workforce that is a reflection of the diverse patients that it caters for (Stanford 2020).

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/socsci11100463/s1, Table S1. Students within the Faculty of Dental Surgery across 15 academic years; Table S2. Academic Staff within the Faculty of Dental Surgery for academic year 2022/2023.; Table S3. Students within the Faculty of Health Sciences across 15 academic years.; Table S4. Academic Staff within the Faculty of Health Sciences for academic year 2022/2023. Table S5. Students within the Faculty of Medicine and Surgery across 15 academic years. Table S6. Academic Staff within the Faculty of Medicine and Surgery for academic year 2022/2023.

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The Satisfactions, Contributions, and Opportunities of Women Academics in the Framework of Sustainable Leadership: A Case Study

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Abstract: Women's empowerment is one of the targets of Sustainable Development Goal 5, gender equality. However, little research has highlighted the contributions of sustainable female leadership in academic governance. In order to fill this gap, this study identifies and analyses the satisfactions, opportunities, and contributions of women academics to university governance and their perceptions of the potential impact of gender in this process. Forty-eight women leaders participated in the study. A purposive sampling technique was used because the research involved leaders who had held a management position in the university. The research methodology was qualitative, the instrument used for the collection of information was a semi-structured interview, and the analysis of the narratives was carried out with Aquad v. 7 software (Günter Huber, Tübingen, Alemania). The study revealed that the leadership style of the female academics is framed within the sustainable leadership approach. Beyond personal satisfactions, the main reward derived from the performance of the position lies in becoming transformative and catalysing agents of the institution, who try to find a balance between the economic and social interests of the organisation. The functions these female academics perform, within the framework of sustainable development, have a technical and, at the same time, humanised vision, as they focus on people and on personal and social values. Gender issues have not been a determinant in the satisfactions, opportunities, and contributions that the leaders make to the institution; however, participants emphasise that this was a strength for leadership.

Keywords: sustainable leadership; governance; Sustainable Development Goals; sustainable women's leadership; university; equality gender

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1. Introduction

From a theoretical perspective, sustainable leadership (SL) is a combination of different leadership approaches in the context of sustainable development [1]. It is based on equity, and its central objectives are: (1) to achieve a balance between economic, social, and environmental interests in the organisation, and (2) to lead the institution and its members towards sustainable development by adopting and implementing socially responsible activities and strategies [2]. This basically implies that sustainable leaders have to be able to implement sustainable development policies in their organisations [3], solve problems, and drive a sustainable institution, promoting behaviours and practices that benefit all stakeholders, including future generations [4–6]. SL assumes that issues linked to sustainability are interrelated, that they cannot be addressed in a piecemeal fashion, and that any member of the organisation can take responsibility for fostering sustainable environments.

In the last two decades, there has been some interest in academia in investigating the set of competencies and values that makes a leader committed to leadership in terms of seeking to preserve the planet [7,8]. In fact, Visser and Courtice [1] have already addressed SL at the individual level through a model based on situational leadership [9,10], which is based on three dimensions: the individual as a leader (with their traits, styles, skills, and knowledge), the internal and external context of leadership, and the internal and external actions of leadership. In accordance with these dimensions, sustainable leaders should have general skills (emotional intelligence and a caring attitude, a concern for organisational culture, pursuit of goal achievement, and the ability to generate trust) and specific ones that contribute to sustainable practices (an inclusive, fair, and impartial style) [1], systemic and interdisciplinary understanding, willingness to innovate and a long-term perspective on impacts, respect for ethical principles [11], a capacity for the pursuit of goal achievement, systems thinking [7], innovative thinking [12], vision [13], creativity [14], and altruism [15]). With these skills, leaders are able to guide organisations towards a more sustainable state by facing complexity and conflicts in the social, economic, and environmental domains [16].

In addition to individual characteristics, leadership context and internal and external actions are also determining factors in SL [17]. In fact, Visser and Courtice [1] argue that the SL must take into account the external context (ecological, economic, political, cultural, and social) and the internal context (organisational culture). Added to this, the sustainable leader has to be consistent in both internal and external actions. This means that the typical internal actions of the organisation—for instance, making informed decisions, empowering people, and incorporating learning and innovation—must be aligned with sustainability challenges and opportunities through external actions, such as fostering cross-sector partnerships, or contributing to the awareness of sustainability in society.

Research on women's leadership in academia is in its infancy and has focused on highlighting the absence of women in top decision-making positions. In this vein, Abalkhail [18] conducts a study in which she examines female managers' perceptions of the factors that influence their rise to leadership positions in Saudi Arabian higher education. The author concludes that women face a number of challenges that prevent them from achieving equal representation in relevant decision-making positions. In addition, she analyses in detail legal, socio-economic, and cultural aspects that are reflected in organisational practices and that limit women's access to university leadership positions. Jane et al. [19] interviewed 35 women academics to investigate women's leadership in higher education in Hong Kong and concluded that there are institutional gaps that limit equality. The study shows the tensions women academics experience in living with and within political contexts. Moreover, Burkinshaw and White [20], through the analysis of two case studies in the context of Australian and UK Higher Education, conclude that gender power relations in universities maintain entrenched inequalities. Therefore, and taking into account the growing resistance to women's participation in leadership, especially from the younger generation, they argue that it is the universities themselves that must be corrected and not the women. In the Spanish context, Gallego-Morón and Montes López [21] analyse the influence of the organisation itself on the careers of female academics. To do so, they conducted 48 interviews with men and women, and concluded that there is a tendency towards homosociability. This means that the traditional masculinisation of power networks favours the trajectories of men and negatively affects the trajectories of women. Along the same lines, Campanini and Pizarro [22] investigate how the formal and informal norms of the university impact on gender relations, particularly for those in leadership positions. To this end, they interviewed members of the board of directors of the University of Deusto (northern Spain) and confirmed the impact caused by gender dynamics at both the individual and institutional level. While the authors recognise the importance of formal institutional commitments to gender equality (e.g., legislation), they highlight the importance of informal environments (customs, traditions, etc.), as they have a decisive influence on the implementation of formal policies.

1.1. Women's Sustainable Leadership

Gender-responsive sustainable development is essential in the current global context, where issues such as poverty, war, and environmental degradation are expected to persist, and there is an urgent need to do things differently [23]. Nevertheless, in the area of leadership, women still face major barriers to becoming leaders. These include unequal access to economic opportunities, lack of political representation, barriers in access to education, stereotypes that limit their performance in important positions, as well as weak self-expectation and devaluation of their successes [24–28].

Barriers to women's leadership have been addressed theoretically from both a cultural and institutional perspective [29]. According to the latter, when genders develop outside expected socio-institutional norms, women and men may engage in negative attitudes [30]. For this reason, leadership skills, such as the ability to delegate, confidence, and assertiveness, are often considered masculine qualities [31], and women are often even less liked when they are successful leaders, especially in male-dominated fields [32]. Consequently, female leaders have to walk a fine line where there are a number of traditionally masculine-prevailing traits [33]. Therefore, ascending to leadership positions remains difficult for women, and most organisations, even educational ones, still have leadership based on gender differences.

The theory of gendered organisations makes gender inequality in leadership explicit [34]. It recognises that workplaces, such as in the university context, are not gender-neutral, but are spaces where gender is deeply embedded, as power networks favour men [35]. In such contexts, women may be seen as weak and incompetent in leadership roles due to culturally defined gender norms [36]. This can cause them, among other things, to internalise doubts, mistrust themselves, and, thus, question their own leadership ability [37].

Traditional gender roles are also an additional barrier for women who have a responsibility for family and domestic affairs [38]. Women, on average, still spend proportionally more time than men in the household and in raising children [39]. Because of these imbalances, women advance more slowly in their careers and are less encouraged to take on leadership positions [40]. In short, women's paths to leadership in sustainable development are not clearly mapped out. While the literature provides guidance on what we expect to be the main barriers and contributions of women leaders in sustainable development, there is still a need for a deeper understanding of their personal perceptions and perspectives, since, as recognised by the UN General Assembly [41], their participation as leaders in sustainable development is critical.

1.2. Satisfactions and Opportunities in the SL

SL can be an extraordinary opportunity for the professional and personal enrichment of the leader [42]. Despite this, the opportunities and satisfactions that female sustainable leadership (FSL) generates in women have been scarcely investigated. At the professional level, some of the benefits derived from FSL, in addition to professional prestige and recognition, include greater integration into the university community, knowledge of the institution from another perspective, and the discovery of the organisation's operating mechanisms. To this must be added the high degree of satisfaction generated by having been able to contribute to the improvement and development of the institution [43].

In relation to personal satisfactions, Bianchi et al. [44] argue that women seek personal satisfaction more than monetary reward. Furthermore, Divya et al. [45] add that there are a number of emotional elements that have to do, for example, with the female leader's commitment to the organisation and to the people she leads. With FSL, the achievement of planned goals through a technical vision is humanised, and is brought closer to people, thus bringing together technical and personal dimensions in a farsighted, friendly, and lasting harmony [46]. In this vein, Acker [47] stresses that professional experience allows leaders to overcome their internal barriers and limitations, in order to discover their true leadership skills and to acquire greater self-confidence. Those who are mothers also see the managerial role as an opportunity of extraordinary value to offer a model and a reference at a professional level for their children [48]. However, according to Armstrong [49], this responds more to an adaptation mechanism to achieve a balance between family and professional life without remorse or frustration, as it is usually one of the strategies most used by women to alleviate their feelings of guilt for violating the mandates of traditional gender roles.

1.3. SL Contributions to the Institution

The sustainable leader can effectively contribute to the transformation and progress of an organisation [50,51], as long as their roles are focussed on addressing institutional challenges with sustainability in mind [1]. In the case of FSL, Fernández-Carvajal and Sequeira-Rovira [48] highlight the drive of women to transform the body they lead, and the implementation of new innovative projects. A manifestly similar situation can be seen in the study by Proctor [52], where leaders highlight the changes they have managed to introduce to the institution as their main source of motivation. Thus, they emphasise the achievement of new facilities and resources, or the resolution of some of the problems faced by the organisation, leading them to obtain a high level of professional wellbeing. The value of learning and experience tends also to be highly rewarding, as it allows women to make themselves known within their organisations, especially given the scarce opportunities that female academics usually find to participate in male networks of influence [53]. Indeed, according to the results of Fernández-Carvajal and Sequeira-Rovira [48], the exercise of a managerial function, and the greater visibility that comes with it, offers female leaders the possibility of promotion and advancement to other positions of higher rank.

The contributions of women's leadership to the university contrast with what this institution offers women leaders, for, despite its claim of being an institution based on equality, in reality, it is strongly influenced by stereotypical disciplinary cultures [54]. On this basis, it is possible to state that the university is still the focus of a gendered scientific culture. This academic culture or tribe [55] reflects a set of norms and values developed and internalised over time that govern the way its members interact. To help solve issues of inequity in the STEM and academic leadership fields, in 2001, the National Science Foundation (NSF) launched ADVANCE IT [56], an institutional transformation programme initially consisting of nine US universities. The goal of the programme was to increase the participation of women in science and engineering (S&E) and to promote their full participation at all levels of academic administration, particularly in leadership positions, through the transformation of institutional practices, policies, and culture. The purpose of ADVANCE was to increase both the percentage of women in senior faculty positions, such as tenure and professorships [57], and to help achieve gender equity in STEM with professional development grants for women scientists in engineering [58,59]. In subsequent years, ADVANCE was expanded to 37 universities [60]. The rationale for ADVANCE is based on the growing recognition that the lack of women's participation at senior levels of academia is a systematic consequence of academic culture [61]. Thus, while the NSF specifically notes the importance of recruitment, retention, and advancement of women in STEM fields in changing the academic culture, a process of institutional transformation is needed. This process involves not only changing day-to-day actions, but organisational culture, customs, norms, communication style, management, and ways of thinking. In sum, ADVANCE, while seeking changes in the number of women in STEM fields of representation, addresses the issue of equity through deeper institutional change.

1.4. Influence of Gender on Sustainable Leadership Satisfactions and Opportunities

The debate on women's leadership style has attracted increasing interest in academia [62–69]. Traditionally, leadership has focussed on the role of a leader who, in most cases, is a 'great man' [70,71]. In this 'heroic, masculine' conception, the leader bears all the burdens and works hard to achieve goals. This approach assumes that leaders are born to lead and the rest to follow. It seems this model is still valid [72], as organisations, in general, are still a long way from valuing women's leadership [73].

Leal-Filho et al. [3] conducted a study with 50 leaders from different universities around the world. The findings show that the problem of underrepresentation of women in leadership positions is persistent in university education. Thus, only 36% of the respondents indicated that women held more than 30% of the positions. In addition, respondents were not aware of gender-related issues and related actions that are necessary to achieve sustainability. When asked whether women were more effective sustainable leaders than men because of their greater concern for sustainability, almost half of the respondents (44%) remained neutral. However, 68% of participants noted that there is a greater focus by women on designing and implementing sustainability. These findings are not isolated, as they have been corroborated by other studies [62,69,74,75], some of which show that women in leadership positions consider their experience as leaders to be based on their sacrifice and hard work [76].

The satisfaction, opportunities, and contributions of women academics to the university would not be possible without a regulatory framework that promotes equality between men and women. For this reason, Spain has developed a set of laws and policies that seek to guarantee the right to gender equality in higher education institutions. Among them is the Spanish Organic Act 1/2004 of 28 December on Integrated Protection Measures against Gender Violence [77]. This legislation aims to provide a complete and comprehensive response to the different types of violence against women. In addition, it contemplates the implementation of a set of actions in the educational sphere to promote gender sensitization and awareness.

It is also important to mention the Spanish Organic Law 3/2007, of 22 March, for the effective equality of men and women [78]. This law pays special attention to the eradication of inequalities experienced by women in the professional environment and in labour relations. To this end, it introduces some key concepts such as parity, the reconciliation of personal, family, and working life, and the promotion of co-responsibility. It also recognises the principle of balanced presence in positions of responsibility. This is intended to guarantee the equal representation of women and men in these positions. Based on this, the Spanish Organic Law 4/2007, of 12 April, which modifies Organic Law 6/2001, of 21 December, on universities (LOMLOU) [79] raises the importance of contributing to the achievement of real equality between women and men. According to this law, the academy must not only assume the principles of tolerance, equity, and equality as an essential part of its aims and activities, but must also establish a series of mechanisms to guarantee the equal composition of representative bodies and the promotion of female participation in research groups. Similarly, it is envisaged that university authorities should remove possible obstacles and barriers that limit the presence of women in governing bodies and at the highest levels of the academic career. Special mention should also be made of the Royal Decree 1401/2018, of 23 November, which creates the Women, Science and Innovation Observatory (OMCI) in the Spanish science, technology, and innovation system [80]. Its main objective is to evaluate and diagnose the effectiveness of the policies implemented to increase the presence of women in the scientific field.

Despite the existence of the aforementioned policies, gender equality is still far from being achieved in Spain. While they have shown their potential to reduce gender inequalities, they have not succeeded in dismantling university power hierarchies [81]. To overcome the obstacles, barriers, and challenges to achieving gender equality in academic leadership, it is necessary to go beyond the legislative approach. This means implementing practical approaches that include equal treatment, positive action, and effective gender mainstreaming [82]. Equal treatment means eradicating the idea that women can succeed in academic leadership as long as they behave like men. Affirmative action measures are based on the recognition that there are differences between men and women and that a level playing field must therefore be created for both men and women. Finally, gender mainstreaming can be described as the promotion of gender equality in the institutional structure, policies, and ways of seeing and doing in the university.

While the academic literature has addressed a people-oriented model of women's leadership [83] and the limitations women face in accessing positions of power in academia, there is a gap in the research on the potential for sustainable women's leadership, characterised as holistic, technical, and innovative, with ethical values and principles. These capabilities could enable women leaders to guide organisations towards a more sustainable state in the face of social, economic, and environmental complexity and conflict [16]. Equally few qualitative studies have investigated the impact of gender on the benefits, contributions, and opportunities of sustainable women's leadership for both the university institution and for women themselves. Against this backdrop, the objectives of this study are (1) to identify and analyse the satisfactions, opportunities, and contributions of female academics to university governance, and (2) to learn about their perception of the potential impact of gender on these possible outcomes.

2. Materials and Methods

In order to achieve the stated aims, the study was designed using a qualitative research approach. The use of the latter is justified by the concern to understand how leaders interpret and make sense of their particular reality [84]. Another reason for its choice is the rebalancing of power and control in favour of greater horizontality and equality between the researcher and the phenomenon under study [85]. Furthermore, the qualitative tradition is particularly suited to penetrate the experiential and to understand the richness of nuances of the socially constructed reality of the leaders [86].

2.1. Participants and Context

The study included 48 female academics from the University of Alicante (UA) (Spain) who had headed academic governing bodies. Of these, 50% were between 51 and 60 years old, 31.25% were between 41 and 50 years old, and 16.67% were over 60 years old. Only one of the female academics (2.08%) was between 31 and 40 years old. In terms of length of service at the university, 52.08% had professional experience ranging from 21 to 30 years, and 16.67% had been working at the UA for more than 30 years. Regarding the management responsibility of the interviewees, 54.16% of the participants had been in management positions in a university department. The remaining 45.84% were distributed among those who had assumed a deanship or the direction of a centre (16.67%), a research institute (16.67%), or a vice-rectorate (12.50%). Most of the participants (60.41%) had a seniority ranging from 0 to 4 years. Only 33.34% of the women leadership academics had experience of between 5 and 8 years. This implies that few women persist in leadership after a first term.

The UA is geographically located in Alicante, a Spanish province in the southeast of the Iberian Peninsula and part of the Valencian Community. It is a public institution of higher education with an international projection, whose mission is the integral education of students [87]. This necessarily entails respecting, defending, and promoting the right to effective equality between women and men in all the dimensions and practices of the institution. During the 2019–2020 academic year, the number of students enrolled in its official studies (Bachelor's, Master's and Ph.D.) was 25,635, and 3941 people worked at the university, including administrative staff (1383) and teaching and research staff (2558) [88]. Currently, this higher education centre offers a wide range of courses, including 54 official undergraduate studies, 62 postgraduate and master's degrees, and 31 doctoral programmes, 87 specialisation degrees, and a wide range of complementary training courses, especially in languages and languages.

This institution is firmly committed to the promotion of gender equality and the integration of sustainable development in all its spheres of action (teaching, research, and knowledge transfer). It currently has a wide range of instruments and strategies to raise the awareness of equality and sustainability among the university community. With regard to the empowerment of women, the UA has been able to provide itself with a broad regulatory framework that aims to guarantee the balanced composition of men and women in management teams [89]. It also has a Vice-Rector's Office for Social Responsibility, Inclusion and Equality, which designs and implements policies linked to sustainable development and the promotion of the role of women in academic life (https://bit.ly/3MuCtmd, accessed on 14 January 2022). In the field of research, it has the University Institute for Gender Studies Research, an interdisciplinary centre dedicated to the promotion of scientific research in the field of equality (https://ieg.ua.es/, accessed on 11 February 2022). Furthermore, in order to promote gender mainstreaming in teaching and to guide the governing bodies, services, and units on the principle of equality, the UA has an Equality Unit (https://web.ua.es/es/unidad-igualdad/, accessed on 25 March 2022), an Observatory for Equality between Women and Men (https://bit.ly/3O3ej3d, accessed on 27 March 2022), and four equal opportunities plans, the latest of which was recently published [90]. With regard to its commitment to the 2030 Agenda, its full integration into the institutional Strategic Plan (2022–2024) [91] should be highlighted. In practice, this is reflected in actions as diverse as the establishment of agreements with other organisations in the area of sustainability, the organisation of training courses on sustainable development, the announcement of the master's degree awards to stimulate research on the Sustainable Development Goals (SDGs), and awareness campaigns for more sustainable campus management. Based on the characteristics of the context, it is considered that the study of the satisfactions, opportunities, and contributions of academic leaders to SL may be of particular interest to other realities.

2.2. Instruments

We chose to employ the semi-structured interview [92,93] as the data collection technique. This has been particularly valuable for leaders to relate their life experiences around SL performance because of its situated nature and its suitability for making veiled aspects of human and organisational behaviour visible [94,95]. The interview script consisted of 18 questions. In this study, we analyse those that focussed on inquiring into the satisfactions, opportunities, contributions, and gender of female academics (four questions):

- What satisfactions have you found in your performance as a leader?;
- What opportunities have you had in your performance as a leader?;
- What do you think you contribute to the institution through your work as a leader?;
- Do you think your gender has had an influence on these issues?

In order to contextualise and deepen the issues investigated, the following socio-demographic data were added to the instrument: age of the participants, period of professional relationship, management position held, and professional experience in the position.

2.3. Procedure

Initially, the academics were contacted by e-mail. They were informed of the objectives of the study, and of the anonymous, voluntary, and confidential nature of their participation. Subsequently, a schedule of available dates was created according to their availability. The data collection process was carried out over a period of four and a half months. The interviews were conducted orally and were audio-recorded. At the beginning of each interview, participants were reminded of the purpose of the study in order to obtain informed consent. In addition, it was emphasised that, as prescribed by the ethical principles of research defined in the Declaration of Helsinki, all data provided would be confidential and anonymous. After the collection of the information, an initial content analysis process was initiated to check the validity of the information, and to establish the first connections between the emerging concepts.

2.4. Data Analysis

The interviews were transcribed into separate documents using the Microsoft Word 2010 word processor software (Microsoft Corporation, Washington, DC, USA). Given the cyclical and reflexive nature of qualitative research, its flexibility, and the segmentation of the data into units of meaning [96], a first draft of codes was made based on the four questions that made up the interview.

In the first phase, the starting point was the reduction of the data by segmenting the text and coding with repeated variations. To do this, the text was classified into parts according to the characteristics of the phenomenon under study, and a code was established for each significant unit. The categorisation process was based on intensive and repeated reading to improve the comprehension of the content and, consequently, to distinguish the emerging units of meaning. In order to carry out this coding, a practice that was useful during the first readings of the transcripts was the constant questioning of the text. Such questions were particularly suitable for formulating codes that were not only descriptive, but also explanatory and interpretative in nature. Another substantially valuable element was the description and exemplification of each of the emerging codes. The organisation and representation of the data was then addressed through the use of different double-entry matrices. These were particularly beneficial for a visual understanding of the ordering of the phenomena, the identification of cause–effect relationships, and the connection between the different categories. On this basis, and with the knowledge accumulated through the analysis of the narratives, the initial outline of codes was modified, completed, and validated by the three experts in gender and management, and by two researchers who were specialised in a qualitative methodology. The systems of analysis followed were the retrieval of the coded text and the study of frequencies. The former allowed access in an ordered way to sections of the text that share the same label, i.e., that are related to each other. In addition to the analysis of the coded text, a frequency study was carried out. This was used to collect the aspects most emphasised by the participants in their narratives. Specifically, a content analysis of conventional and summative information was carried out [97]. Each of the female academics interviewed was assigned an alphanumeric coding (ACA_XX), representing the participant's number. Subsequently, the data were processed with the Aquad 7 software [98]. This program made it possible to categorise and organise the data, and to draw conclusions through the relationship of categories.

3. Results

Table 1 presents the results of the absolute frequencies (AF) and the percentage of these (%FA), where AF is the number of times participants allude to a unit of meaning and %AF is the ratio of that code to the total AF (AF $\times$ 100/total AF). In addition, the presentation of the qualitative results is supported by the narratives extracted from the participants' voices, which illustrate the meaning of each of the emerging codes.

The structuring of the inferred codes responds to the desire to know, not only the satisfactory experiences that the leaders find in the development of their function, but also their perception of the impact that gender may have had on them. Table 1 shows the occurrence of these significant units in their speeches.

The issues most highlighted by the participants were: types of professional (AF = 90; %AF = 22.73) and personal (AF = 44; %AF = 11.11) satisfactions and opportunities, such as the contribution to the institution consistent with their personal qualities and values (AF = 56; %AF = 14.14), and the extension of networks (%AF = 46; %AF = 11.61). In contrast, subcode 2.3., 'No opportunities', had a smaller number of cases (AF = 10; %AF = 2.52).

Table 1. Codes and sub-codes for satisfactions, opportunities, contributions, and gender.

Category	Codes	AF	%AF
Satisfactions, opportunities, contributions, and gender	1. Types of satisfactions		
	1.1. Personal	44	11.11
	1.2. Professional	90	22.73
	1.3. No satisfaction	15	3.80
	2. Types of opportunities		
	2.1. Learning	29	7.32
	2.2. Expanding networks	46	11.61
	2.3. No opportunities	10	2.52
	3. Type of contribution to the institution		
	3.1. Boosting staff	9	2.27
	3.2. Experience and knowledge	16	4.04
	3.3. Network building	19	4.80
	3.4. Personal qualities and values	56	14.14
	4. Perception of the conditioning influence of gender		
	4.1. Neutral perception	31	7.83
	4.2 Positive perception	31	7.83
	Totals	396	100

AF = Absolute frequency; %AF Absolute frequency percentage.

3.1. Code 1. Type of Satisfaction

One of the main elements that seems to influence the attitude towards professional responsibilities is the degree of satisfaction that a person finds in the performance of their function. This, in turn, is particularly significant for the commitment and motivation felt in the task to be performed. The interviewees feel proud of their trajectories as leaders and allude to satisfaction of a professional nature (and, to a lesser extent, personal satisfaction). Lastly, there are some stories which, although not very frequent, are indicative of the disenchantment that leaders seem to experience with the exercise of their managerial function.

3.1.1. Subcode 1.1. Personal

In this subcode, we have categorised the narratives alluding to the socio-emotional enjoyment that the leaders find in academic governance. Although this type of satisfaction is not the most reiterated by the interviewees, it has a significant presence in their discourses (%AF = 11.11). In inferring the semantic nuclei referring to these satisfactions, it is possible to highlight a series of nuances derived from the causes of them. Thus, the participants insist on the personal enjoyment they derive from the recognition, respect, and support of the people they lead. As one interviewee stated,

> Well, both in the positions I have held in the direction of the school and the department, the truth is that you have many satisfactions. Because first, if you treat people well and respect people, then people respect you a lot. What you give, you receive, and that is nice (Aca_19).

One should not lose sight of the need that some women traditionally have to be recognised and valued by others:

> So, people value that a lot, and say to you, man, the first woman! You think it was not because of that, but they kind of value it above other things, and then you feel satisfied (Aca_26).

On the other hand, some leaders emphasise the achievements they have been able to accomplish through their own effort and personal sacrifice. That is, they focus on the self-improvement aspect of a personal challenge, especially when they see that, despite their initial doubts and insecurities, they have been able to face the challenge successfully:

> Then, I have managed to overcome obstacles that I thought were insurmountable on a personal level, also when it comes to relating to people and all that, for me it is very satisfying (Aca_44).

Leaving these kinds of barriers behind and becoming aware of their true leadership competencies ultimately leads them to experience a deep sense of personal fulfilment:

> But at the same time, as things have been going well for me since then, it has paid off and I have had a good and important sense of personal fulfilment that has been worthwhile (Aca_26).

3.1.2. Subcode 1.2. Professionals

The reason for the enthusiasm experienced by the participants lies in the transformation they have been able to implement in the organisation they lead. The high level of insistence with which they allude to this issue in their interviews (%AF = 22.73) is evidence that this type of achievement becomes, in practice, the main source of satisfaction. Thus, they emphasise the optimisation of the work climate and the cohesion of the group they lead. One interviewee puts it this way:

> In other words, I am happy because I think that when I left management, I left a department that was more united than it was initially, I think. So, in that sense I am very satisfied (Aca_34).

The participants also highlight the improvements they have achieved in terms of equipment, both material and in relation to economic resources:

> Before we had no money, no computers. Now we have a good library. To be able to do in this sense, and to be able to ensure that those who now enter the department have a better infrastructure . . . that gives me great satisfaction (Aca_04).

Some of them feel that their work has promoted the recognition and presence of the organisation within the campus and also outside it:

> One enormous satisfaction was that this centre has become a reference point outside the university (Aca_28).

> Well, it was satisfying to see that the department was growing, that everything was working well, that we were a model at that time, which is not the case now. We were a model in the university, a model of [a] department, of organisation, of academic results, of research results. I think everything was going very well (Aca_40).

Moreover, they especially highlight the work of a whole team.

> Well, we have been able to create an institute that is doing very well, that is working, [where] . . . there is a powerful team of people with very good synergy, and I think that this is the reading that is made at the end (Aca_22).

The training of the teaching staff and the opportunity to have an outstanding teaching staff is also an important source of satisfaction.

> And then the experience of the part-time teaching staff is also very satisfactory, which constantly connects us with reality, and, in addition, I am lucky to have a very high [level of] qualification in all of them, in all of them. Yes, yes, true (Aca_08).

However, as far as teaching is concerned, the main source of the leaders' pride seems to lie in the improvements they have implemented in the design of the degrees:

> When I took office, the centre had a three-year degree, and students could not go beyond the bachelor's degree. At the end of my term of office, the centre had two degrees, [including] a master's degree, [and] the students could already do a doctorate (Aca_12).

Finally, some participants emphasise, albeit with a lesser degree of insistence, the satisfaction they experience as a result of the improvement of research. In this context, they emphasise above all their work in promoting and strengthening the research activity of the body they lead, thus positioning it in the international arena.

> The first, then, is to be the most cited department in the Ibero-American area. Of the researchers in this area, we are the most cited in Ibero-America. Maintaining this position is important and very satisfactory (Aca_08).

3.1.3. Subcode 1.3. No Satisfaction

A group of participants claim that they do not feel attracted to university governance and that, consequently, they do not find it a pleasant task (%AF = 3.80):

> Man . . . I have already told you that it was not my desire to be a director either, because I don't like it, I don't like it, I don't like to command, I don't like to be in positions like that (Aca_48).

These women took the position because the circumstances required it; however, they admit that they do not feel attracted to this professional field.

> The truth is that I didn't feel like it, I don't like being a department director. No, but well, you have to accept it because it was the right thing to do (Aca_06).

> But I have not applied myself because I do not like university management, of course. I would not like to be a rector or vice-rector or anything like that (Aca_05).

3.2. Code 2. Type of Opportunities

One of the main opportunities leadership seems to provide for women is the possibility of access to a wider circle of people, information, and resources. Indeed, in subcode 2.2., 'Expanding networks' is the most prominent. It is important to underline that the exercise of leadership also seems to represent, in practice, a particularly valuable learning experience. With a lesser presence, those allusions to not enjoying any kind of advantage are noticed.

3.2.1. Subcode 2.1. Learning

The performance of a professional task usually entails the acquisition of new knowledge and skills, especially in a field with such disparate and diversified profiles and conditions as academia. In this context, SL can become an extraordinary learning opportunity for female academics, who are usually entering a space of absolute novelty for them. This subcode accumulates 7.32% of absolute frequency, from which it can be inferred that academic governance constitutes a magnificent learning path for leaders:

> Well, I think that yes, maybe at the first moment you don't realise it, but you realise that there are things to learn, that you learn from it. When a little time has passed, you realise that there are very important things that you learn (Aca_14).

3.2.2. Subcode 2.2. Expanding Networks

The women academics argue that leadership has been useful for increasing and expanding the networks they have in the institution. As a result of their positions, they have been able to access people, resources, and information that they otherwise would not have been able to. This seems to be the main benefit that the leaders have found in academic governance (%AF = 11.61). Thus, it is possible to note constant mentions in their accounts of the possibility that the position gives them to meet and interact with new people within the institution itself.

> Man, maybe, look, what it did allow me to do was to meet more people, because there were many directors of other institutes, both in the arts and sciences, that I did not know (Aca_10).

However, this broadening of the network of contacts is not limited to the university itself, but transcends it, and goes much further. Thanks to their managerial roles, some of the leaders are able to establish new links with professionals and scientific collaboration with other institutions.

> But on the other hand, I have met more people that we could collaborate [with] in research tasks, and in fact, things have come out of there, more multidisciplinary works, with points of view that can be more interesting (Aca_29).

In turn, this greater prominence within the institution has opened certain doors for them much more easily and quickly:

> As for those above me, I do have more access. So when I think it is convenient, I say who I am and ask to speak to whoever it is, and what I notice is that they give me appointments much more quickly than before (Aca_36).

Moreover, it is possible to identify a set of voices that are better enabled in their knowledge of everything that happens in the institution:

> Then, well, hey you don't stop being part of the Governing Board, you don't stop having interviews with people who are at the level, let's say broader management, . . . [and] you [therefore] have better information of what is happening (Aca_17).

On other occasions, the knowledge provided by their advantageous position is used for more effective decision-making and for the promotion of the body they lead.

> On the one hand, you can be in the places where there is more information, know what is going on, and that also helps you to make decisions or, at least, know what is happening in the university (Aca_32).

3.2.3. Subcode 2.3. No Opportunity

There are also voices that recognise that they do not find any type of benefit associated with leadership (%AF = 2.52). At this point, it is important to remember the feminine tendency to repel any formula of extra benefit at the work level for fear of rejection. Therefore, the incidence of this topic in their interviews could be conditioned by that social image they wish to avoid:

> It is that, let's see. I never see any post or position that I have to perform as a platform or opportunity for other things. I just don't see it, I don't understand it that way (Aca_01).

In fact, their determination not to be identified as beneficiaries of some kind of prerogative leads some of the participants to insistently deny the enjoyment of, or desire for, additional opportunities.

In an exercise of professional honesty, they make every effort to disassociate themselves from those who, in their opinion, are kept in governance by some kind of interest.

3.3. Code 3. Type of Contribution to the Institution

The study of SL necessarily involves the analysis of those elements with which the participants contribute to the development and growth of the institution. Through this exercise, it is possible to identify how the women evaluate their own contribution, and what the contributions are with which they signify their work. In this sense, the main concessions that the narrators make to the organisation are located, above all, around their personal attributes. Subcode 3.4., 'Personal qualities and values', accumulates the highest number of versions of expression. In second place, and with an ostensibly significant difference, are the allusions to network building and to experience and knowledge. With the lowest absolute frequency rate, interviewees refer to the help and guidance offered to the members of the organisation they lead.

3.3.1. Subcode 3.1. Encouraging Staff

One of the effects that has traditionally been attributed to female leadership, inside and outside academia, is the help and guidance given to the members of the group they lead. Thus, women in management positions in the university are considered to have a special concern for promoting the growth and professional advancement of their staff.

However, the number of occurrences of this subcode is the smallest, with a 2.27 absolute frequency. From this, it can be inferred that either the interviewees are not fully aware of the motivation they give their team members, or that motivating staff is not among their main contributions. Even so, a number of voices emphasise their contributions to boosting the research activity of their group members:

> And to see how people who started as assistants, who are doctoral assistants, who are hired as doctors, who are in the process of being accredited for a tenured position, and to see how you have been able, in some way, to help this trajectory (Aca_08).

Closely related to this type of contribution is the achievement of new positions for colleagues who are in a position to be promoted.

> My contribution? For example, getting a position [of] assistant doctor for a person who had been asking for it for years and had not been granted it. It is true that times have changed, and things are better, at least in the vice-rectorate or rectorate. But it is true that for years we had no vacancies for young people, and we got one. Not as many as we wanted, but listen, we got one (Aca_16).

Likewise, it is necessary to emphasise that female academic managers' determination to favour the encouragement of others even leads them to support people who do not belong to their group:

> I also encouraged all colleagues, even those not in my team; for example, I supported and helped them all study for a master's degree (Aca_43).

3.3.2. Subcode 3.2. Experience and Knowledge

This refers to the textual segments that circumscribe the participants' contribution to the knowledge they have accumulated throughout their professional careers in different areas. Their narratives show that this type of contribution is not one of the main concessions that the leaders make to the institution (%AF = 4.04). In the first place, testimonies are identified that insist that their most significant contribution to the institution is due to the previous knowledge and experience they have gained in the field of leadership.

> I think that covering, suggesting certain possibilities in this line that I am talking about, of a little bit of promoting research activities, which I also have experience as director of an R&D project (Aca_13).

The narratives that highlight the value of the knowledge they have of the University of Alicante also stand out. These women have had a long career in the institution. Therefore, they are expert connoisseurs of its culture and its operating mechanisms.

> I have known the University of Alicante since its beginnings, [and] since ... 1980 when I started studying there. So, I bring a very useful knowledge of the university (Aca_26).

Other testimonies emphasise, in a specific way, the interviewees' contributions to the field of research and teaching. The participants highlight their trajectory in these areas, and state that, thanks to this, they can adopt a broader vision in the exercise of their function, as well as taking into account other aspects, or even better contributing to the promotion of the institution.

> Well, I believe that experience, because I had many years of teaching and professional experience as well, with experience in research. So, I think this was also important because it was a broader vision (Aca_32).

3.3.3. Subcode 3.3. Network Building

The possibility of establishing new links and contacts with other institutions is also among the main contributions adduced by the participants. The findings show a low presence of contributions corresponding to this coding (%AF = 4.8). Despite this, a number of testimonies allude to the leaders' efforts to reinforce the feeling of unity within the team itself, their contributions to achieving a common goal, the sum of efforts, and the creation of synergy to stimulate coordinated action.

> And above all, try to involve. I believe that we have to involve people a lot. We made a great effort to get everyone to go hand in hand. I think it was important (Aca_23).

The main contribution of the participants is also the linkage with other agencies within the institution. The leaders have a greater degree of openness and a conviction that this type of contact allows the organisation to move forward.

> Then I also try to maintain close relations with departments equivalent to my own, so that this is also good for our faculty (Aca_33).

Likewise, the leader facilitates the possibility of establishing new relationships with other entities and structures in society. This allows a greater transfer of knowledge:

> But I have also managed to get many people from outside the university to join. That is to say, we cannot underestimate either. On the contrary, all the signs of support . . . we have been able to gather. Of course, that is obvious (Aca_18).

3.3.4. Subcode 3.4. Personal Qualities and Values

This covers all the narrative segments alluding to the characteristics and principles by which their work has been distinguished, according to the participants. The analysis of their testimonies shows that this type of contribution is the most reiterated by the leaders (%AF = 14.14). Therefore, when it comes to estimating their most significant contributions, they emphasise attributes of a personal nature. However, sometimes, their adherence to the stereotypical image of modest and humble women is such that it is difficult for them to recognise this type of contribution.

> Well, I don't know. I don't know if I contributed. I don't know. Maybe that's for someone else to say, right? Me contribute? I don't know, I think that the way of management was different, wasn't it? And maybe [there's] a little bit of nuance . . . in the management [that] may be more my personal stamp (Aca_10).

Likewise, there are stories that emphasise the contribution of those qualities that favour the improvement of the work environment, among which the capacity to empathise with others stands out.

> Well, look, now talking to you, I believe that empathy. That is, I believe that things are achieved not so much with force or belligerence, but with the ability to empathise with others, and that is what I think I contributed (Aca_35).

There are also frequent allusions to their capacity for listening and dialogue—qualities with which they claim to be able to create an atmosphere in the organisation characterised by trust, closeness, and the understanding of others. As one interviewee puts it,

> So, I believe that I am a good listener. I know how to listen, and I know how to accept that your opinions or decisions are not accepted by everyone (Aca_07).

Some highlight their negotiation skills, as well as the achievement of shared understanding among all members of the group. Once again, however, the difficulties they seem to have in valuing their contributions are noticeable:

> Well, I couldn't tell you what my personal touch was either, because I wasn't aware that I was imprinting any personal touch on anything, was I? I think that my touch was a little bit the consensus, and on the other hand it was also the dedication, being very aware of things (Aca_41).

This is in addition to believing that emotions and affection also play a transcendental role for the work to flow and for the team to grow beyond individualities.

> And then, I believe that affection also plays a role, eh? Because here emotions and feelings also count (Aca_16).

In contrast to this type of contribution, those stories that emphasise the principles and values with which the female academic managers contribute to the sustainable development of the organisation are also noteworthy. In this context, their statements of the responsibility and professional ethics with which they claim to carry out their work are particularly significant.

> Well, not much, but basically something important. I believe that if each one, in the scope of their responsibility, has an ethical requirement with their work, is concerned about moving the university forward, as a sustainable university, in all aspects, "another rooster would sing for us in general" (Aca_04).

Some of the leaders emphasise their commitment and dedication to their work, especially the time invested in the development of their function.

> I contributed many hours, many days, many weekends, vacations, and a lot of work in general. I strive to transform and improve the functioning of the university, and I believe that I can and must do this very well (Aca_04).

In addition, they emphasise their deep sense of justice and impartiality, temperance, serenity, and solidarity. According to them, these qualities allow them to face complex situations in the performance of leadership.

> If you only ask me about the direction of the department, what I brought was, I believe, fairness. That is to say, a fairer, more supportive operation and that there was no nepotism (Aca_30).

> I don't know, maybe serenity and temperance when things get a bit ugly, that's what I contributed (Aca_37).

These qualities are in addition to the transparency with which they claim to face possible disagreements with colleagues.

> I liked it very much . . . I think we are in a different era now, for example. I liked to inform everyone about every step that was taken, everything that was done, everything that happened, so that everyone was informed, could participate, and could decide whether to enter or leave, to get involved. I think that's what I contributed the most (Aca_45).

3.4. Code 4. Perception of the Conditioning Influence of Gender

In the analysis of this code, it is possible to know the assessment that women academics make of the influence of gender regarding their satisfactions, opportunities, and contributions and, consequently, the degree of critical awareness they have in this regard. The study of the testimonies reveals the existence of two subcodes: 4.1., 'Neutral perception', which brings together all those narratives that reject the possible influence of gender on the participants' satisfactions, opportunities, and contributions, and code 4.2., 'Positive perception', which compiles the narratives that recognise the existence of a gender perspective among the satisfying experiences.

3.4.1. Subcode 4.1. Neutral Perception

Women academics consider that gender has not had any influence on the satisfactions or opportunities they find in the management function, nor on the contributions they have made to the organisation. This coding obtains 50% of absolute frequency. Those who adopt this position deny that gender could have mediated the satisfying experiences they have found in the exercise of leadership.

> As I have always been a woman, of course, since I have not been a man, I cannot compare. I don't know if others have the same satisfactions as me. But come on, I don't think there is any influence, I don't think so (Aca_12).

They believe that these have not been affected in any case by gender dynamics, but that any effects are due to personal issues, such as character or professional effectiveness:

> On opportunities? Well, I think that sometimes, more than gender, it's the way you are, your personality, your attitudes, the way you are, more than gender. Because I do have female colleagues who have handled it badly and male colleagues "who have developed rashes", that is to say, there is a bit of everything. For me it is a little bit about how you are and how you manage it (Aca_04).

In the case of contributions, they do not seem to believe that these are in any sense mediated by gender.

> Well, I contribute my work and what I can humbly contribute, but I don't think it has to do with gender bias (Aca_22).

3.4.2. Subcode 4.2. Positive Perception

Leaders recognise the impact of gender on their satisfactions, opportunities, and contributions. In fact, 50% of the narratives point to the conditioning influence of gender. Therefore, it is possible to affirm that, a priori, a broad set of voices highlight gender as a strength for leadership. There are numerous accounts that distinguish between men's and women's ways of doing things when both occupy management positions.

> When there is a women's meeting, unless something happens, you go to the meeting and you want to finish the meeting, right? I go to a meeting to finish the meeting. Men, however, go slower. I think that this marks a way of conceiving work, of conceiving time, of conceiving everything (Aca_20).

This is especially the case with regard to the use of time and priorities at work, where the female leaders claim there are significant differences. While they seem to be more interested in networks of power and influence, they focus mainly on performing daily tasks and fulfilling daily commitments.

> In those moments the men, take advantage to continue doing politics and to talk, while I use that moment to advance in my work, to rest, to call my mother, to try to finish earlier because I want to leave earlier, because my mother is sick, etc. (Aca_39).

Furthermore, this participant also highlights her constant search for consensus in decision-making processes and her more integral and holistic perspective of problems:

> Surely, we women do more of that, we tend to analyse and look for more integral solutions, and not to solve something that is momentarily resolved (Aca_20).

Finally, in the same terms, participants refer to women's capacity for teamwork, which is, in their opinion, notably superior to that of their male counterparts.

> It is possible, I think, that maybe the ability of women to work as a team is much more developed than in the case of men (Aca_11).

4. Discussion and Conclusions

Concerning the three dimensions of SL identified by Visser and Courtice [1], it is possible to conclude that the leaders possess traits, skills, and knowledge, both general and specific, that are characteristic of this leadership. In this sense, they emphasise concern for the organisational culture and the achievement of objectives. Likewise, they develop inclusive, fair, and transparent leadership, and have a systemic understanding of the problems affecting their organisations. Their willingness to innovate, their ethical principles, and their innovative systemic thinking are remarkable. They have shown themselves to be visionary, creative, and forward-thinking, and they try to deal with complexity and conflicts, especially socio-economic ones, prospectively.

It should be noted that the participants' main source of pride is of a professional nature, namely, they feel satisfied with their contributions to the improvement of the institution. In a way, they have the feeling of having fulfilled their duty, especially given that their main motivation for access is their deep commitment and desire to participate in institutional construction and development [3]. This type of satisfaction has also been highlighted in other similar studies, such as that of Sánchez Moreno and López-Yáñez [99] and Wroblewski [100], which illuminate the pleasure generated by female university leaders in becoming transformative agents and catalytic agents of the organisation. More specifically, they are particularly proud of having been able to improve the institutional climate, increase resources, and implement structural changes, as well as projecting and promoting the image of the body they represent, while trying to find a balance between institutional interests of an economic and social nature [101]. In short, their actions focus on developing the organisation by adopting socially responsible strategies [2].

On the other hand, monetary reward is not an encouraging factor with regard to the leadership of female academics. On the contrary, the participants point to the emotional motivations highlighted in the studies of Bianchi et al. [44] and Divya et al. [45]; these are exemplified by the relationships they have been able to forge, or the self-improvement of possible challenges. Ultimately, and although there is a majority of positive evaluations of the experience, there are also those who openly state their rejection of these types of activities. The reasons for this, they argue, lie in their disaffection with the managerial function, their identification of leadership with models of a more personalistic and individualistic nature, or their lack of vocation for this type of task. The study by Fernández-Carvajal and Sequeira-Rovira [48] ratifies this trend, stressing that the administrative nature of the function, and the political component, constitute some of the reasons that may lead women to show disinterest in these types of tasks.

However, this does not prevent women leaders from recognising the opportunities that the exercise of leadership has offered them. They recognise that they have enjoyed multiple and varied advantages, among which the possibility of widening the circle of people, information, and resources on which they have been able to rely stands out. Undoubtedly, occupying a position in the academic structure allows them to interact with others, both inside and outside the institution, to access first-hand information, and to learn more about the organisation. In fact, it could be asserted that the position of leadership becomes a privileged one, enabling the leader to have a more holistic view of the campus, and also to project oneself and make oneself known [42]. This possibility is especially positive and beneficial in the case of female academics, as they often have serious difficulties in accessing informal networks of support and influence [75,102–104], and, in many cases, they have a smaller circle of contacts than their male counterparts [105]. These social networks become, in turn, a fundamental resource for sharing professional obligations and for the ability to advance strategically [106,107], which ends up benefiting and favouring the career trajectory of female leaders.

On the other hand, and with less incidence in their interviews, there is also the possibility of learning. The participants' testimonies show that the performance of the position allows them to acquire valuable skills and abilities in a field that is practically unknown and new to them. These findings are concomitant with the studies of Rodríguez and Aguiar [43] and Rodríguez et al. [42]. Indeed, most of them are multifaceted women, with multiple concerns and a broad desire for knowledge, but with few previous opportunities for training in this area, therefore leadership ends up becoming an appropriate space to discover new learning. Some even recognise that a large part of their identity and professional trajectory is due to their experience in areas of responsibility. Therefore, it could be affirmed that although leaders contribute with their effort and work to institutional improvement, they are also rewarded in multiple ways and forms [52,95]. In the face of this type of valuation, there are also some voices that admit to not having found any type of benefit in academic leadership. A possible explanation for this trend lies in the influence on them of meritocratic politics. As Peterson [102] rightly points out, women leaders are often accused of having betrayed the principles of academic meritocracy, by having gained access supposedly because of their status as women, and not because of their ability. In this sense, the results of our study show that holding the position represents an extraordinary opportunity for enrichment and professional growth for women leaders, as, in addition to feeling fully satisfied for contributing to the improvement of the organisation, they are also able to expand their network of contacts and acquire valuable knowledge that is useful to them, in that it informs them of how to manage in the institution.

Concerning the contributions they make with their work, a dominant tone in the narratives is the humility and modesty with which they allude to their contributions—a behaviour that may be a reflection of the traditional gender roles in which they have been socialised, as well as the exacerbated demand and perfectionism that women tend to apply to themselves [108]. Nevertheless, regardless of this and drawing on their personal qualities and values, the participants value their contributions to transformation and the progress of the institution [51]. Among other aspects, they highlight those skills of SL related to the improvement of the climate of coexistence in the organisation, such as their capacity for empathy, listening and dialogue, their skills for negotiation, mediation, and conflict resolution, or their competencies for emotional management. They also emphasise the principles and values with which they clothe their role, such as professional ethics [12], their deep sense of responsibility, their commitment and dedication to work, loyalty to the institution, and fairness and impartiality [1,15,109].

Other contributions of FSL are the construction of networks, both within the body itself and beyond the institution, as well as experience and knowledge in management; these results are consistent with the study by Fernández-Carvajal and Sequeira-Rovira [48]. One of the main characteristics traditionally linked to female leaders is their concern for people [45]; however, the participants are not yet fully aware of their contributions in this area.

Regarding the perception of the impact of gender on the satisfactions, opportunities, and contributions they make to the institution, the leaders do not express a clear or decisive position. On the contrary, both the neutral vision and the positive perception of gender show the same degree of iteration in their speech. Thus, while there are testimonies that reject that their feminine condition could have affected their positive experiences in any way, the same number of narratives consider it to be a determining element. In fact, those who adopt this positioning tend to clothe the female leadership style with a series of distinctive features which are opposed to male ways of doing things [52,110]. Among other characteristics, these include a more efficient use of time, a greater degree of task orientation, low interest in networks of power and influence, more noticeable mastery of multitasking, and a superior capacity for empathy and teamwork—qualities that, in some studies, have been associated with female leadership [111]. However, it cannot be ignored that these types of beliefs may be the result of socialisation in traditional gender roles, which lead to the attribution of a series of differentiated traits to men and women [3,108,112].

In summary, beyond the satisfactions of a personal nature that female leaders may find, the main reward derived from the performance of these positions of management lies in the changes and improvements they have achieved for the institution, thanks to female academic leaders' effort, work, and dedication. Access to positions of responsibility has allowed them, first and foremost, to leave their own habitat, and gain visibility, thus building new networks or expanding existing ones both on and off campus. Their main contribution to the organisation is at the axiological level, as they are capable of providing the institution with a series of values and attributes aimed at transforming the university.

The research shows a model of women's leadership centred on learning and personal and social values, as well as a clear overall picture of women's leadership strengths, weaknesses, and opportunities. Nevertheless, while women academics have opened the way towards empowerment under the SDG target 5c [113], they still face personal and contextual challenges, such as their own insecurity, the lack of political priorities [114] and reward structures, and ingrained prejudices in university organisational practices. Despite the small scope of our study, the findings offer implications for policymakers and managers who should push for the greater participation of women in university governance, as their input could be instrumental in advancing the sustainable development environment of the institution. The study can be useful for proposing practical leadership policies based on equal treatment and could be replicated in different contexts in order to contribute to a better understanding of the leadership of women academics in Higher Education.

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Article

How to Measure Inclusion in Higher Education: An Inclusive Rating

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Abstract: Nowadays, inclusion is a main concern whoever and wherever. Higher education and business schools have been criticized for their non-inclusion for many years. In this context, higher education has a model role to play concerning inclusion. However, there is a lack of tools to measure the inclusivity levels of institutions. Thus, it is difficult to really know if higher education is inclusive or not and in case it is needed, where they must be more inclusive. This paper proposes a new tool. This paper created an inclusivity index that provides an operational answer to assess inclusivity. This tool does not rank institutions as ranking was highly criticized. It rates the levels of inclusivity of all the stakeholders of higher education for different dimensions.

Keywords: inclusion; inclusivity; inclusion; measurement; rating; higher education

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1. Introduction

Inclusivity is quickly becoming one of the most challenging current issues of higher education because of changing demographics, growth of emerging countries, geopolitical issues, new laws, and policies. The United Nations made inclusion in education a human right with article 26 of the Universal Declaration of Human Right in 1948. Moreover, to reach the sustainable development goals, higher education must contribute to goals 3 "well-being", 5 "gender equality", and 10 "reducing inequalities", for example, which are linked to inclusivity. Inclusivity is also having an impact on how successful higher education is at preparing students for the society and work environment of today and tomorrow. Questions, such as: does inclusivity improve student learning [1] and does it promote excellence [2], are emerging in the field.

In addition, some higher education rankings consider inclusive elements, such as parity or internationalization, including the Financial Times (FT) or Economics (ECON) rankings. Accreditations are also looking at the subject. AACSB has published its commitment to diversity, equity, inclusion, and belonging (https://www.aacsb.edu/about-us/advocacy/diversity-and-inclusion (accessed on 30 June 2022)). EFMD has published its Global Focus magazine in partnership with GRLI in June 2022 on the theme of global responsibility (https://www.efmdglobal.org (accessed on 30 June 2022)).

In this context, to be able to track diversity and to evaluate its impact, it is necessary to measure diversity and its evolution. Based on existing work ([3]'s dashboard; [4] questionnaire), the goal is to develop an index to measure inclusivity. The development of the inclusivity index will enable higher education institutions to measure their progress on diversity; to stimulate a supportive and collaborative community of good practice; and to design, implement, and evaluate inclusive practices.

2. Literature Review

Research in this area fluctuates by year but has been increasing since 2014 (Figure 1). Professionals, such as academics, are looking at the measurement of inclusivity. They all use a questionnaire. It can be cited the footprint created by Mixity focused on employees and on different inclusive dimensions, and the barometer created by McKinsey focused on top management and some dimensions. Mozaïk, a recruitment firm, designed a diversity and inclusion barometer for recruitment purposes. None of these tools are adapted to higher education.

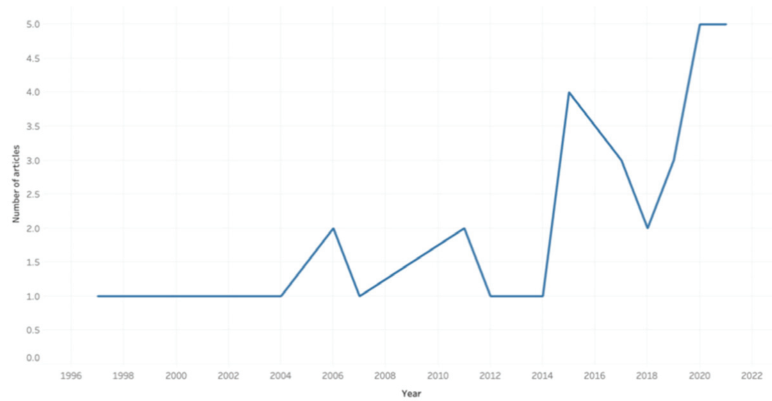

Figure 1. Number of articles.

Some academic works have analyzed the overall perception of sustainability in firms or schools [5–8]. Other researches define the concept of inclusivity, present the overall context [9], and study the impacts of an inclusive environment on performance [10–12]. These tools address schools for the entire sustainability.

Rezai [13] proposes a systematic literature review to analyze the situation of the research on workplace inclusion. A total of 27 studies were analyzed in depth. Ten were measure development studies. They measure ostracism, exclusion, and inclusion scales.

Inclusivity and practices are also explored. Mahlangu [14], for example, indicates that higher education can compensate economic but not cultural or social backgrounds. Moreover, the impacts of inclusive education are examined [15,16]. Jaiswal et al. [11] study the link between inclusivity perception and well-being; Lubiano [17] studies inclusivity perception and performance increasing. The medical sector is overstudied. The authors examine the attitude of medical students with their patients according to their cultural background [18], the medical students' perceptions of racial diversity and gender equality [19], and of diversity exposure [20].

Concerning the inclusive dimensions, other researchers have worked on identity. Churchill et al. [21] examine ethnic, linguistic, and religion diversity; Baker and Novak [22] examine race and ethnicity; and McLaughlin [23] examines race. Arman [24] analyzes the perception of minority groups. Wieczorek-Szyman [25] focuses on gender but gender and ethnic/racial discussions can be associated [26,27]. Disability is also studied in school systems or in firms [28–32]. UNESCO organized a conference on special needs education in Salamanca in 1994. All these studies focus on specific inclusive dimensions and do not cover all the dimensions.

The index of inclusion of [4] is the most advanced. It assesses culture, policies, and practices for the stakeholders, staff, parents, and children. It is a self-evaluation tool of learning and participation at school. However, no study assesses all the inclusive dimensions or all the stakeholders in the higher education. It is, therefore, proposed the creation of a tool to fill this gap. This tool is detailed in the following section.

3. A New Inclusive Rating

3.1. Methodology

Inclusivity is understood for all stakeholders of a higher education institution: students, employees, alumni, partners. The overall context is also considered.

The French legal framework defines 25 criteria of discrimination that can be grouped under 4 main dimensions: social openness, identity, gender, and disability.

In addition to considering these four stakeholders and these four dimensions, the notion of perimeter is added (Figure 2). The data used to quantify the index will come from a direct perimeter (the institution itself) and two indirect perimeters (the student associations and the foundation).

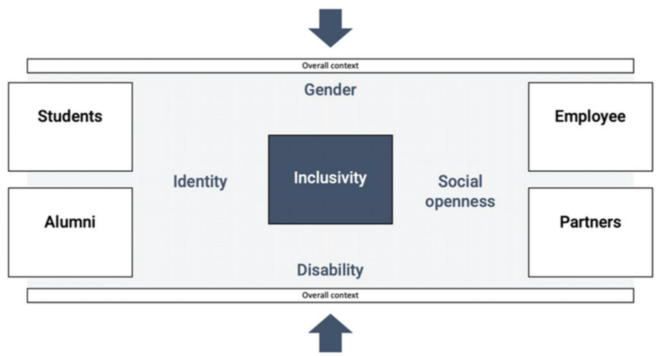

Figure 2. Inclusivity model.

Like the PIR [5], the levels of inclusivity are not intended to be a ranking but a rating. It is not about creating competition between institutions but rather about creating a supportive and collaborative community of good practices. This evaluation helps schools in their development and change towards more inclusive practices.

The choice of indicators follows the following approach according to Alkire et al. [33]:

- Defining the set of indicators that will be considered in the multidimensional measure (social openness, gender, identity, disability).
- Setting minimum and maximum target thresholds for each indicator. These thresholds will correspond to levels 1 and 5 of inclusivity. A sensitivity range between 5 and 10% will be applied to these limits in order not to create a threshold effect.
- Setting the scales for each indicator. The scales between these two levels will give the levels to be reached for levels 2, 3, and 4 of inclusivity.
- Selecting the weight for each indicator.
- Creation of the weighted sum of the indicators for an overall score.
- Possible breakdown of the score by dimension or stakeholder.

The indicators are detailed by stakeholder and then by dimension. Their scoring is explained. It is based on two main principles. The first is the resemblance to the local population. The second is the principle of diversity reached from a threshold of 30% [34,35]. Each indicator described below is weighted according to the breakdown below. The student–employee–alumni stakeholders each represent 30% of the overall index and the partners 8%. Each dimension has more than one indicator. According to each country and each institution, it could be difficult to find all the data. One dimension can be rated with at least one indicator. Indeed, partners are external stakeholders but do not represent the core stakeholders of the institution. They represent 10%. Each dimension is then weighted in a homogeneous manner, as are the different indicators for each dimension. The overall context corresponds to an overall inclusivity and represents 2%. All the process is synthetized in Figure 3.

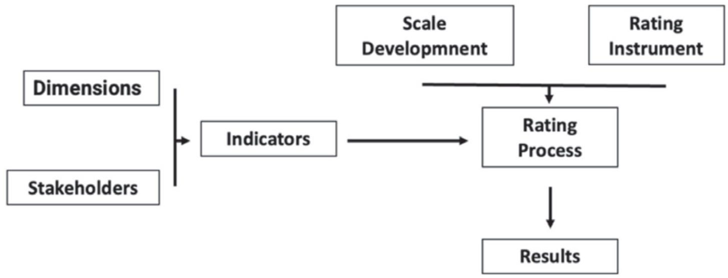

Figure 3. Process.

3.2. Indicators

3.2.1. Students

- Social openness

The social openness dimension is represented by two complementary indicators. In the case of a calculation for an organization outside France, the first indicator cannot necessarily be calculated. In this case, the second indicator will only be considered. The figures of these indicators must be adapted by country. The first one is the number of scholarship students. This figure is used as an indicator in many rankings. The rate of scholarship holders is adapted according to the country. The rate of high school is taken as reference for level 5. As this rate can vary, a range is applied. A minimum rate of 20% has been defined for level 1. The different levels of inclusivity were then defined linearly. The second one is the number of students according to their parents' socio-professional category. This information is, at least, known for the main program. This allows us to focus more broadly on the flagship program of a management school. This figure, which is larger than the number of scholarships, provides a better understanding of the student landscape in relation to the societal landscape. The CSP- are the opposite of the CSP+, which are heads of companies, craftsmen and shopkeepers, executives, higher intellectual professions, and intermediate professions. A minimum rate of 50% was defined for level 1 and level 5 is defined according to the country. The different levels were then defined linearly.

- Gender

The parity in the student population is important. This population is also very involved in student associations, which must carry the values of their school. Two indicators are therefore necessary: % male/female and % male/female association president. Parity corresponds to a percentage of 50% distribution between men and women. The target value of 50% is, therefore, expected regardless of the percentage of male or female. A minimum of 30%, corresponding to the gender mix threshold, was chosen for level 1. The other levels were calculated linearly.

- Identity

The schools must both represent their territories but also show an openness to the world. Geographical origin constitutes a discrimination in access to higher education. It is, therefore, important to measure the ratio of isolated territories, i.e., rural territories and isolated cities, to non-isolated territories, i.e., cities and peri-urban areas. The distribution of high schools reflects the distribution of the national population. A minimum rate of 10% was defined for level 1. Level 5 is adapted to the country. The different levels were then defined linearly. Secondly, the percentage of different nationalities is a measure of the international mix. As mentioned in the introduction, the minimum rate defined for a real mix is 30%, the target value. A minimum rate of 10% was defined for level 1. The different levels were then calculated linearly.

- Disability

Just like a company where the percentage of employees declared as having a disability is monitored, the percentage of students declared as having a disability must be monitored. In France, the law No. 2018-771 of 5 September 2018 "for the freedom to choose one's professional future" reforms the obligation to employ disabled workers (OETH) and sets a target of 6% for companies. This objective is chosen for level 1. The estimated percentage of the population that can be declared as having a disability is 18%, which represents the target value. The different levels are calculated linearly.

3.2.2. Employee

- Social openness

To measure this dimension without using personal and historical data of all staff, two indicators have been selected. Work–study students are students working in a company; by choice but also more often by necessity, as work–study contracts allow them to finance their studies. A total of 500,000 work–study contracts were signed in 2020 in France. France will have 24,892,000 salaried jobs in 2019 according to the French statistical Agency (INSEE). Work–study contracts, therefore, represent about 2% of salaried contracts. A total of 2% is, therefore, the target value with a sensitivity interval. The minimum value is 0. The different levels are calculated linearly. The second indicator is the % of nationalities not corresponding to one of the ten most advanced countries. The 10 most advanced countries are Switzerland, Australia, Belgium, Canada, France, United Kingdom, Spain, Italy, United States, and Germany. There are 197 countries in the world according to the UN. The population of these 10 countries represents about 10% of the world population. A total of 90% of the world's population lives in the 187 least developed countries. All the collaborators of the institutions must, therefore, follow this representation. To calculate this percentage, the nationality of the country of the institution is removed. This leaves a possible 196 countries, and the percentage is 91%. A minimum threshold of 30%, the threshold of diversity, has been chosen for level 1. The different levels are calculated linearly.

- Gender

The French "Index égalité professionnelle homme femme" allows many facets of parity to be considered. All companies with at least 50 employees must calculate and publish their gender equality index every year on 1 March. If the index is below 75 points, the company must implement corrective measures to reach at least 75 points within 3 years. The maximum index is 100. The level will, therefore, be defined by scores below 80; the level 5 by scores above 96. The different levels are calculated linearly. For the other countries, the wage gap between female and male is considered, which is one of the indicators of the French index. The difference between these two averages must be zero, with a sensitivity interval.

- Identity

Two criteria are highlighted here: geographical origin and age. The percentage of different nationalities is a measure of international diversity. As indicated in the introduction, the minimum rate defined for a real mix is 30%, the target value for level 5. A minimum rate of 10% is defined for level 1. The different levels were then calculated linearly. Moreover, the school must be representative of the active society. The gap between the age pyramid of the school and the country of the school is, therefore, measured. This gap will be compared to the distribution given by the statistics of the country. The target value for level 5 is a gap of 0 with a sensitivity interval. A deviation of more than 0.8 is considered a minimum for level 1. The different levels were then calculated linearly.

- Disability

Companies have a legal obligation to employ disabled employees. As in Section 3.2.1., the objective of 6% is chosen for level 1. The estimated percentage of the population that can be declared as having a disability is 18%, which is the target value. The different levels are calculated linearly.

3.2.3. Alumni

- Social openness

The social openness dimension is covered by the type of companies in which students will work after graduation. In the French system, an SME is a small or medium-sized company with fewer than 250 employees and annual sales of less than EUR 50 million or total assets of less than EUR 43 million. An ETI is an intermediate-sized company that does not belong to the category of SMEs and has fewer than 5000 employees and annual sales of up to EUR 1500 million or total assets of up to EUR 2000 million. A large company is a company that cannot be classified in the previous categories. The French statistical Agency (INSEE) indicates that the split between SMEs and GEs is 50–50. The target value for level 5 is, therefore, 50. The minimum retained for level 1 is 30. The different levels are calculated linearly.

- Gender

Wage gaps between male and female employees exist. The average wages of women and men after leaving school are compared. The difference between these two averages must be zero, with a sensitivity interval. This target value is defined for level 5. The French statistical Agency (INSEE) indicates an average gap of 18% for a minimum of 3 years of higher education without experience. A minimum of 20% for level 1 is, therefore, chosen. The different levels are calculated linearly.

- Identity

To measure international openness, the number of jobs by country is studied. The jobs of the outgoing student population are studied. A minimum of 10% working outside the country of study is expected for level 1. A target value of 30% is set for level 5. The different levels are calculated linearly.

- Disability

A total of 80% of disabilities occur during a lifetime. Former students at a school may have to retrain due to a life accident. They can train in their former school or in another institution. The school must, therefore, welcome students with disabilities for continuing education. It must also offer retraining assistance to its former students whose projects may also involve expertise not taught at the school. Moreover, like the number of students or employees who have declared a disability, the number of back-to-school students who have declared a disability follows the same logic. As in Section 3.2.1, the objective of 6% is chosen for level 1. The estimated percentage of the population that can be declared as having a disability is 18%. A range of 16–20% is defined for level 5. The different levels are calculated linearly. The institution does not offer all the possible training courses for retraining. Therefore, it cannot necessarily welcome all its alumni who have declared a handicap, but it can help them to retrain and to find the right training, whatever it may be, thanks to a retraining aid system.

3.2.4. Partners

The aim here is to consider each dimension as it relates to the school's partners.

In addition, the links with partners are measured via partnerships and student associations linked to the different dimensions:

- Social openness: partnerships aimed at social diversity, and professional order partnerships, associations aimed at social diversity.
- Gender: partnerships with a gender focus, and associations with an LGBT+ or gender focus.
- Identity: partnerships with diversity label, and association with diversity target,

- Disability: partnerships with companies targeting disability, and associations/projects targeting disability.

All these indicators are binary. The different levels are reached according to the following criteria:

- Level 1: The institution has no associations or partnerships.
- Level 2: The institution has associations or partnerships for at least one dimension.
- Level 3: The institution has associations or partnerships for at least two dimensions.
- Level 4: The institution has associations or partnerships for all dimensions.
- Level 5: The institution has associations and partnerships for all dimensions.

3.2.5. Overall Context

The general context is described by four indicators:

- % of employees aware of inclusivity.
- Internal communication on inclusive topics.
- External communication on inclusive topics.
- Reporting system.

The first indicator varies from 50% to 100% with a target of 100% of employees aware of level 5. The other three indicators are binary. Either the institution communicates and has a reporting mechanism in place, or it does not communicate and has no mechanism. To achieve level 2, the institution must at least communicate internally. To reach level 3, it must at least communicate externally. To reach levels 4 and 5, the institution must have a reporting system.

4. Mathematical Model

In formulating the model for the level of inclusivity, the general equation is determined. The overall level L depends on the level of the four stakeholders and the overall context: Students (*S*), Employee €, Alumni (*A*), Partners (*P*), Overall Context (*OC*).

$$L = f(S, E, A, P, OC) \tag{1}$$

The level of inclusivity of each stakeholder is related to the four dimensions: disability (*D*), gender (*G*), identity (*I*), social openness (*SO*).

$$S = f(D, G, J, SO) \tag{2}$$

$$E = f(D, G, J, SO) \tag{3}$$

$$A = f(D, G, J, SO) \tag{4}$$

$$P = f(D, G, J, SO) \tag{5}$$

The overall context is related with its own sub-factors:

$$OC = \sum_{i=1}^{4} f(x_{i)} \tag{6}$$

Variables

$x_{sd} = value\ of\ the\ indicator\ of\ the\ stakeholder\ s\ \in S\ for\ the\ dimension\ d\ \in D$
$y_{sd} = equal\ to\ the\ level\ l\ of\ inclusivity\ for\ the\ stakeholders\ s \in S\ for\ the\ dimension\ d \in D$
$x_c = value\ of\ the\ indicator\ of\ the\ overall\ context\ c\ \in C$
$y_c = equal\ to\ the\ level\ l\ of\ inclusivity\ for\ the\ the\ overall\ context\ c\ \in C$

Parameters

$m_{sdl} = minimum\ of\ the\ range\ for\ the\ level\ of\ inclusivity\ l \in L$
$M_{sdl} = maximum\ of\ of\ the\ range\ for\ the\ level\ of\ inclusivity\ l \in L$
$\alpha_s = weight\ of\ the\ stakeholders\ s\ \in D$

$\alpha_c = weight\ of\ the\ stakeholder\ \text{“}partner\text{”}$

$$L = \sum_{s=1}^{4} \alpha_s \sum_{d=1}^{4} y_{sd} + \sum_{c=1}^{4} \alpha_c \times y_c \tag{7}$$

With

$for\ s \in \{1,2,3\}, y_{sd} = l\ if\ m_{sdl} < x_{sd} < M_{sdl}$

$for\ s = 4, y_{sd} = l\ if\ \sum_{d=1}^{4} x_{sd} = l + 1$

$for\ c = 1, y_1 = l\ if\ m_1 < x_c < M_1$

$for\ c = \{1,2,3\}, y_c = l\ if\ \sum_{i=2}^{4} x_{c.} = l$

5. Discussion

Inclusivity has different dimensions. In the context of higher education, many stakeholders must be involved to ensure an inclusive environment. To measure the level of inclusiveness, the above mathematical model has 31 indicators with 5 levels of inclusiveness and, therefore, 5 associated ranges. These 31 indicators are aggregated by dimension and then by stakeholder to give an overall level of inclusivity. It is, therefore, important to test the sensitivity and robustness of the model to validate the calculated inclusivity levels.

Two tests are necessary to measure the robustness of the model (Figure 4). The first test examines the sensitivity of the inclusivity index compared to changes in the values of the indicators. The second test examines the variation in the level of sub-inclusivity to quote the inclusivity index.

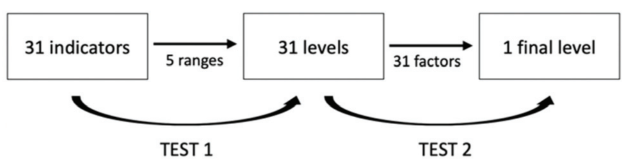

Figure 4. Tests.

In terms of sensitivity analysis, the binary data have a medium margin of error of 50% (Figure 5). For the quantitative data, the medium margin of error depends on the value and the range.

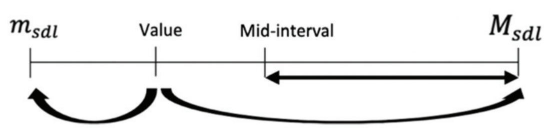

Figure 5. Margin of error.

Figure 5 illustrates the calculation of the average margin of error for a higher or lower level reached. On average, this margin of error is

$$\frac{M_{sd5} - m_{sd5}}{4 \times 2 \times 100} \tag{8}$$

Table 1 presents this margin of error for all the indicators. Different scenarios are designed to analyze the impact of the uncertainty of the data:

- Scenario 1: 1% margin of error in the indicator values.
- Scenario 2: 2% margin of error in the indicator values.
- Scenario 3: 5% margin of error in the indicator values.

Table 1. Margin of error.

Indicator	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
% Of error margin	3	5	3	3	3	3	2	0	1	2	3	0	2	3	2	3
Indicator	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
% Of error margin	2	50	50	50	50	50	50	50	50	50	50	1	50	50	50	

On average, to change the final level it takes a difference of 0.5. According to Table 2, this implies a percentage of error of 5% on all the indicators. A real error of 5% on all indicators implies that 17 of them change level on average. In the worst case, they change level in the same direction, and we obtain an impact of 0.83. To obtain 0.5, we only need 14 indicators that change level in the same direction. On the other hand, for less than 13 indicators changing level in the same direction, there is no impact. In conclusion, this sensitivity study shows that for the algorithm not to be robust, it is necessary to have a proven error of 5% on all the indicators and that 14 of them suffer the error in the same direction. The probability of this happening is 0.01%.

Table 2. Impact on the final level according to the percentage of margin of error.

% of Margin of Error	Number of Impacted Indicators	Impact on the Final Level
1	3	0.08
2	8	0.4175
3	17	0.83

To test the robustness of the inclusivity index, an outlier is integrated in a homogeneous scenario, which is the worst scenario in terms of robustness. This outlier is successively given to each stakeholder. The main stakeholders, student, employee, and alumni have the same weight so a random one was chosen. Fifteen scenarios are designed as explained below:

- Scenarios 1–3 have a homogeneous level of 1 and an outlier with a level of 5.
- Scenarios 4–6 have a homogeneous level of 2 and an outlier with a level of 5.
- Scenarios 7–9 have a homogeneous level of 3 and an outlier with a level of 5.
- Scenarios 10–12 have a homogeneous level of 3 and an outlier with a level of 1.
- Scenarios 13–15 have a homogeneous level of 4 and an outlier with a level of 1.

The results in Table 3 show that the index is robust wherever the location of the outlier and whatever the homogeneous level of the scenario. Scenario 3 is the only one which is sensitive. This scenario has a homogeneous level of one and an outlier with a level of five for one main stakeholder. This result could be discussed. First, the fact that the inclusivity level of one mail stakeholder influences the global result does not seem so unrealistic. Second, it is a highly improbable scenario in real life. Ten scenarios are designed and explained below:

- Scenarios 1–3 have a homogeneous level of 1. An outlier of 5 is integrated.
- Scenarios 4–6 have a homogeneous level of 2. An outlier of 5 is integrated.
- Scenarios 7–9 have a homogeneous level of 3. An outlier of 5 is integrated.
- Scenario 10 has a homogeneous level of 4. An outlier of 1 is integrated.

Table 4 shows the results. With 1 dimension with a level of 1, a final level of 5 is impossible to obtain. To obtain a level of 5, 3 dimensions on 4 with a level of 5 are needed with another level of 2 or 3 (scenarios 6 and 9); only 1 dimension on 4 with a level of 5 is needed if the other levels are 4 (scenario 10).

The analyses demonstrate that the model is robust enough to be used as a reliable measurement tool.

Table 3. Sensitivity results to an outlier integration.

Stakeholders/Scenar	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Employee	1	1	5	2	2	5	3	3	5	3	3	1	4	4	1
Student	1	1	1	2	2	2	3	3	3	3	3	3	4	4	4
Alumni	1	1	1	2	2	2	3	3	3	3	3	3	4	4	4
Partners	1	5	1	2	5	2	3	5	3	3	1	3	4	1	4
Overall context	5	1	1	5	2	2	5	3	3	1	3	3	1	4	4
Total	1.08	1.32	2.2	2.06	2.24	2.9	3.04	3.16	3.6	2.96	2.84	2.4	3.94	3.76	3.1
Inclusivity level	2	2	3	3	3	3	4	4	4	3	3	3	4	4	4

Table 4. Scenarios with level 5.

Dimension/Scenario	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Gender	1	1	1	2	2	2	3	3	3	4
Identity	1	1	5	2	2	5	3	3	5	4
Social openess	1	5	5	2	5	5	3	5	5	4
Disability	5	5	5	5	5	5	5	5	5	5
Total	2	3	4	2.75	3.5	4.3	3.5	4	4.5	4.25
Inclusivity level	2	3	4	3	4	5	4	4	5	5

6. Conclusions

This inclusivity index offers a broader view, both in terms of dimensions and stakeholders, than other searches [13]. The inclusion index [4], a questionnaire completed by some stakeholders, does not have the same focus. It is based on feelings, which is also very important, but this index aims at a quantified picture of the inclusivity in the broad sense of an institution of higher education. In that context, this inclusivity index must respond to the characteristics and legislations of different countries. It will appear incomplete for some countries where a lot of personal information is accessible and already very intrusive for other countries where access to personal data is very limited. It has been the subject of much back and forth between different stakeholders in international higher education. It is, therefore, the result of a compromise between creating a tool that can be used by all countries and creating a tool that measures inclusivity in higher education as widely as possible.

This inclusivity index has now to be shared with different higher education institutions to improve the global level of inclusion of higher education. The rating form is intended to allow collaboration and sharing of good practices between higher education actors. The participation of many institutions will create a community that is committed to the creation of a more inclusive society. The annual calculation of inclusivity levels will measure the overall improvement of higher education in terms of inclusivity.

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Sustainability and Conflict Management in the University Environment. Analysis of Students of the Degrees in Labour Relations and Human Resources, and Social Work at the University of Granada (Spain)

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Abstract: In 2015 the United Nations approved the 2030 Agenda which established 17 Sustainable Development Goals (SDGs). The importance of these SGDs to universities, and universities' commitment to them, requires not only involvement but also the development of research projects, instruments and practices that enable the SDGs to be carried out. Conflict is inherent within any social group and the need to perceive, analyse and manage it is crucial in order to move towards sustainable social development. This research paper analyses conflict existing within the university environment. It specifically relates to students studying for two degrees at the University of Granada (Spain): a degree in Social Work and a degree in Labour Relations and Human Resources. The main instrument used to gather information was a survey addressed to students of both degrees. As a quantitative research technique, it has allowed us to gather evidence about and analyse students' perceptions of conflict. The main results reveal the existence of conflict resulting from interactions between the students themselves, interactions between the students and teaching staff and interactions between the students and service and administrative staff (SAS). Central to perceptions of conflict existing within the university environment are the professional and educational interests of students, as well as issues relating to academic assessment and excessive bureaucracy.

Keywords: sustainability; human development; culture of peace; coexistence; university students; conflicts

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1. Introduction

When speaking about sustainability, or sustainable human development, we often automatically think of the relationship between individuals and the natural, physical or biological environments. In other words, we focus on the environment and planetary defence. However, sustainability is also connected, from an economic perspective, to rationalised modes of production which are in harmony with the environment and which limit growth in order to allow time for the regeneration of resources and prevent their depletion. It can be said to centre on the balance between nature and human action.

There is another way of thinking about the concept of sustainability. This relates to the structural framework in which social relationships develop between individuals or groups of individuals and other individuals or groups. An early awareness of conflicts and an ability to manage them forms the basis of human development and sustainability. Conflict management is key to achieving fairer and more egalitarian societies under the umbrella of collaboration, solidarity and the cessation of violence in all its forms. This is the focus of this research project.

When presenting the results of the Teaching Innovation Project 'Conflict Management in Universities as a Strategy for Improving Teaching Quality', the Dean of the University of Granada (UGR), Pilar Aranda, pointed out that those of us who are part of the university community are aware that:

> "In such a large and heterogeneous group it is natural that, at certain times and in certain circumstances, disparities of criteria may arise, culminating in conflicts which must be addressed, and resolved, by the best procedure which guarantees the reparation of the damage caused, if any. This should guarantee the independence and impartiality of the bodies in charge of addressing and resolving the conflict at hand" [1] (p. 13).

There are many authors [2–5] who understand conflict as something consubstantial with human nature itself, seeing it as part of everyday life and embedded within the different strands which make up the social fabric [6]. The way conflicts are dealt with determines their resolution as well as the future relationships between the different parties. For this reason, positive conflict management is advocated; in other words, we refer to a form of management which adopts a proactive and constructive attitude when dealing with conflict.

According to Zaccagnini [7], conflict can be presented as a solvable problem as long as there is a willingness to accept that it is normal and a natural part of our daily interaction with others. On the other hand, conflict has positive aspects, as it can help us to adopt different perspectives when understanding a given situation and because it can improve relationship skills and self-esteem by strengthening relationships with others. In this way, people strengthen those resources that allow them to be protagonists of their lives, to be *agents*, while taking responsibility for their actions [8].

It is necessary to be 'vigilant' when detecting and identifying conflicts. Failing to deal with them or dealing with them in the wrong way can lead to the entrenchment, and even escalation, of conflict which could lead to social exclusion [9].

This article analyses the main results of a research project, funded and carried out at the UGR within the Framework of the Teaching Innovation and Good Educational Practices Programme (2019–2020). The general objective of the study was to identify and analyse conflicts existing within the educational environment of university students studying for the degree in Social Work and the degree in Labour Relations and Human Resources at the UGR. The primary data collection technique used was a survey addressed to students of both degrees.

The theoretical framework of the study is presented below. It is based on the need to understand, analyse and adequately manage social conflicts with the aim of advancing sustainable social development. The university environment is not exempt from these problems. Therefore, student conflicts have been studied from three perspectives:

1. Conflicts within the student body itself;
2. Conflicts between the student body and the teaching staff;
3. Conflicts between the student body and the service and administrative staff.

The reason this work is in line with the objectives of sustainability and sustainable human development is that it is aimed at achieving a society based on cooperation, dialogue, solidarity and a culture of peace and therefore the advancement towards fairer and more egalitarian societies. Here we are talking about societies focused on sustainable lifestyles which allow for the integration of all human beings in harmony with the planet.

2. Literature Review

When approaching the study of conflict, there is a general guideline, which shows that conflict is part of daily life. Conflict tends to be present whenever there is interaction between two or more individuals or groups of individuals, whether in the public or private sphere (in the workplace, within education, in a community, a family, and so on).

According to Alzate [4], people tend to have a negative attitude towards conflict as a result of socialisation processes. These processes convey pessimistic messages about the pain, sadness, frustration or discomfort caused by having to deal with a conflict situation. These messages, arising from close socialisation environments (family, friends, teachers, etc.), as well as more universal ones (literature, cinema, media, etc.), 'help to construct attitudes and beliefs about conflict which affect the way we relate to others and how we respond to conflict situations' [4] (p. 108).

Marsal [10] holds that conflicts are neither good nor bad, but rather fruitful companions along the way, giving place to new situations and human relationships. In line with this, Becerril [11] points to the existence of a stream of sociological thought which embraces a positive concept of conflict. The following authors form part of this stream:

- Simmel [12], who sees conflict as a way of introducing a person to the norms, values or culture of a society and therefore as an integrating and necessary element in societies and human relationships;
- Coser [13] and his contribution to keeping groups cohesive in favour of social change, defining conflict as the struggle for scarce resources;
- Dahrendorf [14], who conceives of conflict and change as normal and general components of society.

By assuming, as a starting point, that conflict is inherent in human nature and in any area of our lives, the way in which it is approached will determine the way in which it is resolved and the outcome of the relationship between the different parties involved.

However, if conflicts are dealt with in the context of competition, denial, avoidance or accommodation, the effect is likely to be entrenchment and/or polarisation. On the other hand, we can assume a method of conflict resolution which is positive and constructive and based on agreement and collaboration. As Alzate [4] holds, this method can help us to learn appropriate ways of solving problems, build better and more lasting relationships and learn more about ourselves and others.

2.1. The 2030 Agenda for Sustainable Development and the University of Granada's Master Plan

In 2015 the UN adopted the 2030 Agenda for Sustainable Development as an opportunity for societies worldwide to improve the lives of all people. To this end, a total of 17 goals were established, ranging from the elimination of poverty to fighting climate change, improving education, promoting equality, protecting the environment and redesigning our cities.

These SDGs are intended to build on the Millennium Development Goals (MDGs). The idea is that all countries, regardless of their level of development or wealth, should promote prosperity and commit to protecting the environment, with each country taking responsibility for their achievements.

Of the 17 proposed SDGs, Goal 4 focuses on ensuring inclusive, equitable, quality education and the provision of lifelong learning opportunities. Goal 16 focuses on promoting just, peaceful and inclusive societies. These two goals are the focus of this paper. This is because quality education is the foundation necessary for achieving sustainable development. It works hand-in-hand with peace in order to achieve the other SDGs.

However, violence, in all its manifestations, continues to be a problem for people all over the world.

One of the aims of Goal 4 is that students should be in a position to acquire both theoretical and practical learning. As pointed out by Vila and Martín [15] (p. 103), 'they are (...) necessary to promote sustainable development, in particular through education for sustainable development and the adoption of sustainable lifestyles, human rights, gender equality, the promotion of a culture of peace and non-violence, global citizenship, and the valuing of cultural diversity and the contribution of culture to sustainable development '.

With regard to Goal 16, Díaz [16] (p. 262) highlights how '(...) the achievement of sustainable development, in all its forms and manifestations, requires the adoption by states of measures that promote peace (...)'.

The key lies in legislation so that rules are more effective and people's rights are protected. This is in addition to educating people in a culture of peace and non-violence. As Jares [17] (p. 22) states, it is a matter of promoting a pedagogy of coexistence with human rights as its regulatory framework, together with the essential elements of respect, dialogue and solidarity. In this sense, living together is a continuous exercise based on dialogue with one another.

The University of Granada sees its role as a vehicle for responding to the social transformations at the heart of its strategic objectives. Society needs to constantly adapt to the economic, social and political changes which shape it. In this sense, universities are key players in these transformative processes, as their role is to generate knowledge and learning.

Universities are active agents which play a leading role in meeting the challenge of seeking a more intelligent, fairer, more balanced, sustainable, socially responsible and egalitarian society.

All of this is set out in the Master Plan (Plan Director 2021. Vice-Rectorate for Institutional Policy and Planning, University of Granada. Available on line: Available online: https://institucional.ugr.es/areas/planificacion-estrategica/plan-director, accessed on 20 September 2021)—a plan which contains 11 main lines of action, 34 strategic lines, 111 objectives and 563 actions. This document includes, for each strategic line, links with the main objectives and lines of action of the Arqus Alliance of European Universities, as well as links with the SDGs adopted by the 2030 Agenda. This Master Plan has been coordinated by the UGR.

As two of its lines of action, we highlight Main Lines I and VII. Specifically, the first main line of action, *a university with a human dimension*, is one of the defining characteristics of the university to which we aspire. This is one in which university management is oriented towards and is for people. In fact, the objectives and management actions proposed in this first main line focus on the establishment of a framework of university life and working conditions which enable the stable and appropriate development of an individual's professional career, a balance between work and family life and a favourable environment for training and learning.

Regarding Main Line VII, *the socially committed university*, higher education is required to provide solid skills in order to achieve success in today's world. This is in addition to contributing to the training of citizens in ethical principles committed to peacebuilding, the defence of human rights and the values of democracy. A university's social responsibility involves contributing and integrating ethical principles, good governance and social commitment into its basic functions.

Likewise, this main line of action involves a firm commitment to sustainable development through training initiatives which allow the university community to continue raising awareness of the 2030 Agenda and thus commit to inclusion, diversity, equality and work-life balance. In short, this represents a commitment to society as a whole.

2.2. Towards a Culture of Peace

Peace can be defined generically as 'the set of conflict situations in which non-violence is chosen' [18] (p. 236).

One of the classic distinctions frequently made in peace studies is the distinction, established by Gatltung [19], between negative peace and positive peace. Negative peace is understood as the absence of direct violence. Positive peace refers to the absence of 'structural violence' and the existence of structures, policies and institutions that intervene proactively in human development. In other words, this is not only peace as absence of war but also peace without poverty, inequalities and the violation of human rights. Furthermore, it promotes initiatives that make it possible to tackle present conflict situations and anticipate future ones.

The 2030 Agenda, as a comprehensive, universal and transformative development agenda, is oriented towards positive peace. In this sense, Sanahuja [20] affirms that concepts of peace and development end up being almost indistinguishable. However, it is worth bearing in mind that the peace and security pillar of the 2030 Agenda should not be seen, in the SDGs, as the mere elimination of direct violence and consequently only in terms of negative peace. In fact, around half of the 169 targets that make up the 17 SDGs of the

2030 Agenda allude directly to 'positive peace'. In other words, this is about proactive intervention by institutions in order to promote policies that result in human development.

In this proactive sense, coexistence and the development of the Culture of Peace are challenges for universities at the present time as well as in the future. This is because they are related to the SDGs, which promote, justice, peace and inclusive societies, in addition to other values.

Bernal [21] holds that it is necessary to promote a 'culture of peace'. For this, it is essential to socialise the values, attitudes and behaviours which reject violence and guarantee mutual respect between individuals.

In this context, in which education emerges as essential and necessary, the importance of a positive, dynamic and participatory process, in which dialogue is promoted and conflicts are resolved in a spirit of mutual understanding and cooperation, is recognised [22]. A culture of peace is the product of long-term actions, under universally recognised moral and ethical principles, which seek to sow their message in the minds of individuals [23].

2.3. Management of Conflict in Spanish Universities

In universities, as in other organisations, different and often conflicting interests coexist. Social interaction in university communities creates fertile ground for the emergence of conflicts. For this reason, universities have established their own bodies to manage conflicts when they arise. These bodies include the University Ombudsman, the Services Inspectorate and the Equality and Reconciliation Unit.

The University Ombudsman was introduced in Spanish universities when the Organic Law of Universities 6/2001 was implemented (Organic Law 6/2001 of 21 December, on universities (LOU). Available online: https://www.boe.es/eli/es/lo/2001/12/21/6/con, accessed on 24 September 2021). This law was enacted with the aim of safeguarding the rights of members of the university community and was established as an instance of conflict management and resolution.

Normally there are three courses of action for conflict management: resolution of queries, dealing with complaints and implementing mediation procedures. 'Queries' involves giving and receiving advice on interpreting regulations (in this case, university regulations) and issuing information on the rights of the parties involved in a conflict. 'Complaints', on the other hand, can be made at the request of a party or ex officio. The aim is to investigate and clarify what is considered to be in violation of the rights of members of the university community. Finally, the Ombudsman's Office is also responsible for mediation and conciliation.

The intervention of the University Ombudsman usually concludes with the issuing of suggestions, recommendations and warnings. However, although the Ombudsman does not have the power to modify the resolutions of the University Administration, he/she can urge other bodies to exercise their powers of inspection and sanction (Regulations for the Organisation and Functioning of the University Ombudsman of the University of Granada, 23 February 2006. Available online: https://secretariageneral.ugr.es/bougr/pages/desarrollo/nuevas/defensoruniversitario230206/%21, accessed on 20 September 2021).

The second body is the Services Inspectorate, whose role is disciplinary. It initiates those disciplinary proceedings that are necessary to ensure the correct functioning of the university services. Its functions include ensuring compliance with current regulations, the fulfilment of the obligations of all members of the university community and the power to initiate disciplinary proceedings when necessary. The Services Inspectorate can intervene in an ordinary way when it acts ex officio or in an extraordinary way when a complaint or claim is presented.

The third body responsible for conflict management is the Equality and Reconciliation Unit. This body oversees the Harassment Prevention and Response Office (HPRO) and is responsible for dealing with cases of harassment. The HPRO focuses on two lines of action. The first is prevention, through awareness-raising, information, training, the detection of possible cases, responses to harassment, assisting victims and acting on the alleged harasser. The second establishes appropriate disciplinary measures.

Finally, it is worth mentioning the recent approval of Spain's Draft Bill on University Coexistence (Draft Bill on University Coexistence, approved by the Council of Ministers on 25 May 2021. Available online: https://www.universidades.gob.es/stfls/universidades/Servicios/articulos/transparencia_gobierno/participacion_publica/audiencia/ficheros/MAINLeyConvivenciaUniversitaria.pdf, accessed on 20 September 2021), which establishes the foundation for coexistence in the university environment. One of the cornerstones of this draft bill is the important role of mediation and constructive conflict management in promoting coexistence between university members. The use of more peaceful and collaborative methods in the resolution of disputes, which could prevent the normal development of the essential functions of teaching, research and knowledge transfer, presents a great challenge for all universities, as they must set themselves up as models for society when it comes to dealing with conflict.

Universities are required to create a specific commission (referred to as the Coexistence Commission) in order to promote the use of alternative conflict-management procedures, such as mediation, and channel proposals to improve coexistence and the 'implementation' of the provisions of this bill. Title II defines and develops the mediation mechanism and procedures.

The 'mediation mechanism' is specifically defined as a voluntary procedure that is external to a disciplinary procedure. It is one in which active, deliberative and respectful dialogue, assisted and managed by a mediator, enables the conflicting parties to find coexistence in the university environment and reach an agreement for the resolution of their conflict. Conversely, the 'mediation procedure' is understood as an alternative means of conflict resolution within the framework of a disciplinary procedure in accordance with the provisions of articles 20 and 23 of the present bill. This procedure does not apply in cases that may involve sexual harassment, harassment on grounds of sex or gender-based violence, or in cases that may involve academic fraud or damage to the university's assets.

In short, the approval of this bill will represent a decisive step towards the implementation of a culture of peace, which is so necessary in 21st century societies. In general and in particular, it is an essential component of those areas related to training the new generations who are and who will be responsible for building the present and the future.

3. Research Methodology

The research for this paper has been funded and carried out at the University of Granada (Spain) within both the Framework of the Teaching Innovation and Good Teaching Practices Programme and the Teaching Innovation Project 16/92: 'Conflict Management in University Centres as a Strategy for Improving Teaching Quality', developed during the years 2019 and 2020.

The general objective of the research focuses on establishing, and analysing, the levels of conflict perceived by students studying for two degrees at the University of Granada (Spain): Labour Relations and Human Resources and Social Work.

Regarding data production techniques, the survey was used as a primary source in addition to analysis of secondary documentary sources. This enabled us to obtain information on the students' opinions, attitudes and evaluations. The questionnaire, (which was pre-tested) was given to students in person in the classrooms in the Faculties of Social Work and Labour Relations and Human Resources. This was in order to subsequently process the data with the SPSS/PC statistical programme.

The total sample obtained consists of 355 surveys, which indicate a response rate of 16.5%, given that the total population under study (population universe) corresponds to all students enrolled in both degrees—2145 students. Therefore, assuming that the sampling had been random, for a confidence level of 95% (2 sigmas) and with P = Q, the estimated statistical margin of error is $\pm$4.5%.

As can be seen (Table 1), of the total number of responses, the majority were from female students (72.7%), with a much smaller percentage from male students (27.3%). The greater presence of women studying for both degrees, in addition to the high level of feminisation of these degrees, is the reason for their greater representation in the sample. Regarding age, there is a certain balance between the two groups, although the highest representation is held by the group aged 21 and over (55.3%). In terms of the year of study, the first and second years account for the majority of the students surveyed (71.7%), while the third and fourth years account for a smaller proportion (28.3%). With regard to faculty, the highest representation comes from Social Work students (63.8%), compared to students of Labour Relations and Human Resources students (36.2%).

Table 1. Sample characteristics.

	N	%
Gender		
Men	97	27.3
Women	258	72.7
Age group		
From 17 to 20 years old	156	44.7
21 and over	193	55.3
Academic year		
First–Second	252	71.7
Third–Fourth	99	28.3
Faculty		
Labour Relations and Human Resources	129	36.2
Social Work	227	63.8

Source: Own elaboration.

The type of analysis carried out was descriptive, using frequencies and contingency tables. All the crosses of variables used in this research paper were undertaken by taking gender, age group, academic year and faculty as independent variables. The analysis of these crosses of variables was carried out whenever there was a statistically significant level of association between variables, according to the chi-square statistical test, with a confidence level of 95% and a significance level of 0.05.

4. Findings and Discussion

In this section we present and analyse the conflicts cited by students of the Faculties of Labour Relations and Human Resources and Social Work at the University of Granada. For this, three dimensions of the students' social interactions were analysed:

1. Conflicts arising from students' daily coexistence in the faculty;
2. Conflicts arising from students' interaction with the teaching staff in the classroom;
3. Conflicts between students and the service and administration staff.

4.1. Regarding Conflicts between Students

Table 2 shows degrees of agreement with different statements which allowed us to ascertain to what extent students feel affected by different types of problems. In general, three out of four students (75.2%) say that they 'often' or 'always' have good relations with their classmates. Even the integration of new students does not, for the majority, normally represent a problem, as they 'often' or 'always' try to integrate them (57.2%). In the case of disagreements, seven out of ten (71.8%) usually solve conflicts through dialogue. Along the same lines, the majority say that there are 'rarely' or 'never' conflicts between peers which affect others (60.6%) or conflicts that are motivated by the use of social media (57.1%). Peer-to-peer criticism is uncommon, with only a minority (12.6%) stating that it happens 'often' or 'always'.

Table 2. Conflicts among students.

	Never	Rarely	Sometimes	Often	Always	TOTAL	N (356)
I have a good relationship with my classmates	_	4	20.8	48	27.2	100	(356)
Normally, if I have a problem with my classmates, we solve it through dialogue	1.4	5.9	20.9	41	30.8	100	(354)
All classmates get along well	25.2	22	23.2	24.1	5.5	100	(345)
There are small sub-groups within our class	0.9	0.9	8.8	27.6	61.8	100	(351)
When a new student arrives, we try to integrate them	3.4	14.4	25	36.5	20.7	100	(348)
There are conflicts between classmates which affect the rest of us	28	32.6	24.9	10.8	3.7	100	(350)
Conflicts arise through social media (WhatsApp, Twitter, Facebook, etc.)	32	25.1	23.6	14.1	5.2	100	(347)
I feel that my classmates criticise me behind my back	39.6	29.3	18.5	7.8	4.8	100	(351)

Source: Own elaboration.

However, conflict is part of coexistence within social groups and the university setting is not exempt from this. Proof of this is that one in four students (25.2%) believe that they 'never' get along well with their classmates and a significant proportion (45.2%) say that they get along with classmates 'rarely' or 'sometimes'. Creating small subgroups in class is a reality that occurs 'often' or 'always' (57.2%), with all that this entails in terms of social interaction and competition in order to obtain the best academic results.

In general terms, the analysis of conflict existing between the students does not show statistically significant differences according to gender, except in the perception of the degree to which conflicts between peers affect others. Table 3 shows that males (22.7%) consider, to a greater extent than females (11.5%), that conflicts between classmates affect others 'often' or 'always'. However, the general perception is that they do not usually affect others, as the majority of males (77.3%) and females (88.5%) consider that conflicts between peers do not usually ('sometimes', 'never' or 'rarely') affect others.

Table 3. Level of agreement according to gender.

		Gender	
		Men	Women
There are conflicts between classmates which affect the rest of us	Never	22.6	30.1
	Rarely	39.2	30.2
	Sometimes	15.5	28.2
	Often	17.5	8.3
	Always	5.2	3.2
	TOTAL	100	100
$p = 0.008$	N (349)	(97)	(252)

Source: Own elaboration.

The gender variable is not a major determinant of conflict between students. However, age group, academic year and faculty are major determinants.

Regarding age groups, as age increases (Table 4), students are more inclined to integrate with new classmates, see fewer conflicts between classmates that affect others, perceive fewer issues arising from the use of social media and less hidden criticism. The opposite is true of the younger age group. In particular, the older students (aged 21 and over) are more likely (57.6%) to 'always' or 'often' integrate a new classmate into the class group, whereas the younger students (aged 17–20) are much more reluctant to do so. This younger group, in the early academic years, also consider themselves less affected by conflicts between other classmates (72.4%, 'never' or 'rarely'), or by criticism behind their backs (77.4%, 'never' or 'rarely') or by conflicts arising from the use of social media (68.2%, 'never' or 'rarely').

In general, conflict increases as age increases. This is a factor that can be explained by the consolidation of groups within the class and a greater degree of competition between them.

Table 4. Level of agreement with different statements according to age group.

		Age Group	
		From 17 to 20	**21 and Over**
When a new classmate arrives, we try to integrate them	Never	2	4.8
	Rarely	13.2	12.4
	Sometimes	28.3	25.2
	Often	29.5	40.8
	Always	27	16.8
	TOTAL	100	100
$p = 0.012$	N (341)	(152)	(189)
There are conflicts between classmates which affect the rest of us	Never	41.7	18.1
	Rarely	30.7	35.8
	Sometimes	20.3	27.1
	Often	5.3	13.1
	Always	2	5.9
	TOTAL	100	100
$p = 0.000$	N (343)	(153)	(190)
Conflicts arise through social media (WhatsApp, Twitter, Facebook, etc.)	Never	44.8	24.3
	Rarely	23.4	25.6
	Sometimes	17.5	28
	Often	10.4	17.4
	Always	3.9	4.7
	TOTAL	100	100
$p = 0.002$	N (340)	(154)	(186)
I feel that my classmates criticise me behind my back	Never	42.6	39.9
	Rarely	34.8	24.5
	Sometimes	15.5	17.5
	Often	4.5	11
	Always	2.6	7.1
	TOTAL	100	100
$p = 0.054$	N (344)	(155)	(189)

Source: Own elaboration.

In a study carried out by Martínez et al. [24], based on finding out and analysing the opinions and evaluations of students of the degree in Labour Relations and Human Resources at the University of Granada, it was found that they are most likely to drop out of their courses in the third and fourth years. The main reason is due to a low fulfilment of their expectations regarding the professional opportunities created when they enrolled, as well as the fact that they suddenly take an interest in other degrees. On the other hand, those in the early years (first and second year) indicate that they are satisfied with their studies. In this sense, the greater perception of conflict by the older students who are in their final years could also be related to an increase in demotivation.

Age tends to be associated with students' academic year, so we found quite a few similarities in the analysis of conflict according to these variables. The analysis of conflict according to the academic year (Table 5) shows that, in the more advanced years (third year onwards), a higher percentage of students believe ('often' or 'always') that conflicts between classmates affect others, that conflicts arise through social media and that classmates criticise each other behind their backs. In addition, the integration of a new classmate into these years creates more difficulty than in the early academic years.

Table 5. Level of agreement with different statements according to the academic year of students.

		Academic Year	
		First and Second	**Third and Fourth**
When a new classmate arrives, we try to integrate them	Never	1.8	4.5
	Rarely	13.3	25.8
	Sometimes	25.3	17.3
	Often	34.4	25.6
	Always	25.2	26.8
	TOTAL	100	100
$p = 0.016$	N (344)	(246)	(98)
There are conflicts between classmates which affect the rest of us	Never	33.4	12.3
	Rarely	32.5	37.6
	Sometimes	22.7	17.8
	Often	8.4	27.6
	Always	3	4.7
	TOTAL	100	100
$p = 0.003$	N (349)	(249)	(100)
Conflicts arise through social media (WhatsApp, Twitter, Facebook, etc.)	Never	34.3	28.8
	Rarely	24.9	16.7
	Sometimes	22.4	18.5
	Often	14.2	13.8
	Always	4.2	22.2
	TOTAL	100	100
$p = 0.056$	N (346)	(249)	(97)
I feel that my classmates criticise me behind my back	Never	42	34.9
	Rarely	31.5	18.8
	Sometimes	16.5	24.4
	Often	5.6	15.5
	Always	4.4	6.4
	TOTAL	100	100
$p = 0.000$	N (350)	(250)	(100)

Source: Own elaboration.

Regarding the faculty in which they are studying, it was found (Table 6) that the Social Work students consider (more than the Labour Relations and Human Resources students) that conflicts between classmates 'never' or 'rarely' affect them. They also believe that conflicts arise through engagement with social media and that they are criticised by classmates behind their backs. The lower level of conflict between Social Work students is also corroborated by the fact that they are more inclusive. This is because a considerable majority (61.9%) state that they 'often' or 'always' integrate new classmates compared to the Labour Relations and Human Resources students who perceive this to be a lower proportion (49.2%).

Table 6. Level of agreement with different statements according to the faculty where they study.

		Faculty	
		Labour Relations and Human Resources	**Social Work**
When a new classmate arrives, we try to integrate them	Never	4.8	2.7
	Rarely	20.6	10.8
	Sometimes	25.4	24.8
	Often	42.1	33.3
	Always	7.1	28.4
	TOTAL	100	100
$p = 0.000$	N (348)	(126)	(222)
There are conflicts between classmates which affect the rest of us	Never	18.1	33.6
	Rarely	32.3	32.7
	Sometimes	31.5	21.1
	Often	11	10.8
	Always	7.1	1.8
	TOTAL	100	100
$p = 0.002$	N (350)	(127)	(223)
Conflicts arise through social media (WhatsApp, Twitter, Facebook, etc.)	Never	22.8	37.1
	Rarely	25.2	25
	Sometimes	29.3	20.5
	Often	17.9	12.1
	Always	4.8	5.3
	TOTAL	100	100
$p = 0.048$	N (347)	(123)	(224)
I feel that my classmates criticise me behind my back	Never	30.2	44.9
	Rarely	27	30.7
	Sometimes	22.2	16.4
	Often	13.5	4.4
	Always	7.1	3.6
	TOTAL	100	100
$p = 0.002$	N (351)	(126)	(225)

Source: Own elaboration.

These differences, which relate to faculties, can be explained by the low expectations regarding employment opportunities expressed by students of Labour Relations and Human Resources. In the study carried out by Martínez et al. [24], it was found that the vast majority of students studying for this degree (88.8%) consider it 'unlikely' or 'not at all likely' that they will find a job within 12 months of completing their studies. Furthermore, they show an enormous lack of knowledge when it comes to the job opportunities available to them (Ibidem). This is largely explained by the significant level of uncertainty regarding professional opportunities, which characterises students of this degree, compared to the excellent institutionalisation of Social Work graduates.

Conflict between students exists, although in general it is uncommon. However, in order to obtain a more concrete view of this issue, students were asked to name the three main areas of conflict perceived in their daily coexistence with their classmates. As can be seen (Figure 1), competitiveness appears as the source of conflict most frequently mentioned by the students (51%). This is a reality which relates to obtaining the best marks as well as the best academic credentials when obtaining collaboration grants and other types of financial aid. It should not be forgotten that the average mark obtained in the degree is fundamental when it comes to a graduate's first professional opportunities. In the case of Spanish university graduates, these tend to be through scholarships and internship contracts, where the average mark is a real filter [25]. The first credential for university graduates is usually an academic transcript. Its importance is crucial since, as the average mark increases, the chances of employability also increase considerably [25].

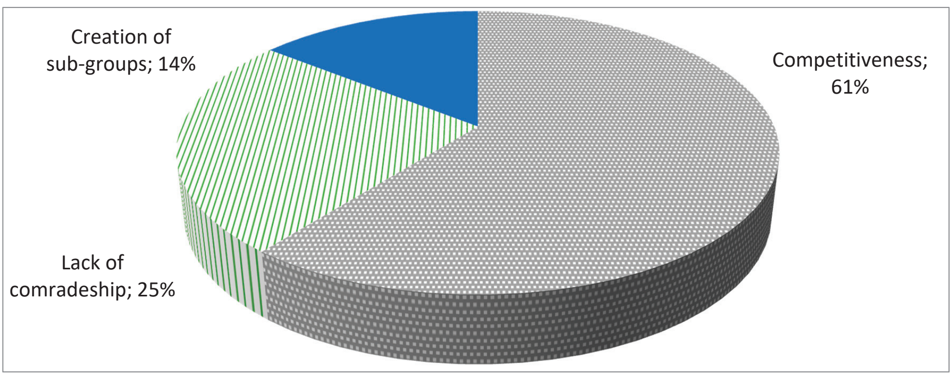

Figure 1. Three main conflicts perceived by students. Source: Own elaboration.

Students are no strangers to this reality, and competitiveness is often accompanied by a lack of comradeship (25%), which appears as the second most frequently mentioned conflict. Refraining from providing key information, refusing to lend class notes and being generally uncollaborative is reflected in group relations. The third most important perceived conflict is the creation of sub-groups (14%), which relates to greater personal affinity and/or shared interests. This is because the formation of groups, to collaborate on the theoretical and research work required for most of their subjects, is part of the competitive strategy. For this reason, and in many instances, these sub-groups are relatively closed, as they share not only informal relationships and friendships but also academic interests.

4.2. Students' Conflicts with Teaching Staff

The second specific objective of this research focuses on conflicts between students and teachers. As can be seen (Table 7), the level of conflict in this area is generally low. The majority of students feel that they 'often' or 'always' have a good relationship with teachers (71.6%) and that teachers respect them as individuals and as students (65.6%). Following this trend, a considerable majority report that teachers 'rarely' or 'never' clash with their students in class (59.6%) or that classmates have conflicts with teachers (69.9%). However, pejorative appraisals of teachers are evident. Seven out of ten students (74%) consider that they are 'often' or 'always' treated in a disrespectful manner by teachers. This can be related to the perceived arrogance attributed to teachers. Furthermore, the majority of students say that they are 'often' or 'sometimes' (56.5%) treated unequally by teachers.

Table 7. Student conflicts with teaching staff.

	Never	Rarely	Sometimes	Often	Always	TOTAL	N (348)
I have a good relationship with the teaching staff as a whole	_	2.8	25.6	54.1	17.5	100	(355)
I feel that teachers respect us as people and as students	2	4.2	28.2	43.8	21.8	100	(354)
There are teachers who treat students unequally	10.5	22.3	30.8	25.7	10.7	100	(354)
Teachers treat students in a contemptuous manner	0.9	3.4	21.7	48.9	25.1	100	(350)
There are teachers who clash with students in the classroom	22.1	37.5	27.9	10.8	1.7	100	(344)
My classmates have conflicts with our teachers	21.9	48	24.5	5	0.6	100	(342)

Source: Own elaboration.

Students explicitly highlight the problems caused by unequal relations between teachers and students in the classroom. The idea that there is unequal treatment or that students are treated in a disrespectful way is rooted in the different levels of authority and role attributed to teachers in the classroom.

According to the gender variable, there are no statistically significant differences between each of the statements, except when those questioned were asked about good relations with teachers. As can be seen (Table 8), most men and women consider that they ‘always’ or ‘often’ enjoy a good relationship with teachers. However, women show a higher degree of agreement, with slightly more than seven out of ten (74.3%) agreeing compared to slightly more than six out of ten (63.9%) men.

Table 8. Level of agreement according to gender.

		Gender	
		Men	Women
I have a good relationship with the teaching staff as a whole	Never	-	-
	Rarely	6.2	1.6
	Sometimes	29.9	24.1
	Often	47.4	56.8
	Always	16.5	17.5
	TOTAL	100	100
$p = 0.059$	N (354)	(97)	(257)

Source: Own elaboration.

With regard to the age group of the students (Table 9), a general trend can be seen in which the older group (21 and over) considers the level of conflict to be higher. The perception that teachers treat them in a disrespectful and unequal manner, the fact that there are confrontations in class and that their classmates have conflicts with teachers, places them a higher level of conflict than younger students. In particular, those in the younger group (17–20 years old) believe, to a great extent, that they are respected, as both people and students, by their teachers. Therefore, although the general pattern for the majority continues to indicate a low level of conflict, as students get older their perception of conflict appears to increase.

Table 9. Level of agreement with different statements according to age group.

		Age Group	
		From 17 to 20	**21 and Over**
I feel that teachers respect us as people and as students	Never	0.7	4.3
	Rarely	3.9	4.2
	Sometimes	23.2	31
	Often	43.2	44.1
	Always	29	16.4
	TOTAL	100	100
$p = 0.025$	N (347)	(155)	(192)
There are teachers who treat students unequally	Never	14.1	5.6
	Rarely	24.4	22.8
	Sometimes	30.7	30.7
	Often	24.4	24.2
	Always	6.4	16.7
	TOTAL	100	100
$p = 0.059$	N (347)	(156)	(191)
Teachers treat students in a disrespectful manner	Never	39.1	34.7
	Rarely	41.6	33.4
	Sometimes	13.5	25.7
	Often	5.8	4.9
	Always	-	1.3
	TOTAL	100	100
$p = 0.019$	N (346)	(156)	(190)
There are teachers who clash with students in the classroom	Never	29.3	17.3
	Rarely	41.2	33.9
	Sometimes	22.2	34.3
	Often	5.9	12.2
	Always	1.4	2.3
	TOTAL	100	100
$p = 0.014$	N (338)	(153)	(185)
My classmates have conflicts with our teachers	Never	31.2	16.9
	Rarely	47.4	47.8
	Sometimes	16.9	28.6
	Often	4.5	5.2
	Always	-	1.5
	TOTAL	100	100
$p = 0.001$	N (336)	(154)	(182)

Source: Own elaboration.

In line with age, the academic year that students are in also shows this general trend. As can be seen (Table 10), first and second year students are more likely to rate ('always' or 'often') that their relationship with the teaching staff is, in general, good and that teachers respect them both as people and students. Students in more advanced years (third and fourth) are more likely to state that they are 'often' or 'always' treated unequally and disrespectfully by teachers, that teachers clash with students in class and that their peers have issues with teachers. Again, in line with age group, students in more advanced years are those who show the highest levels of perception of conflict.

Table 10. Level of agreement with different statements according to the academic year.

		Academic Year	
		First and Second	**Third and Fourth**
I have a good relationship with the teaching staff as a whole	Never	-	-
	Rarely	2.2	2.8
	Sometimes	22.1	33.2
	Often	55.2	35.2
	Always	20.5	28.8
	TOTAL	100	100
$p = 0.014$	N (354)	(252)	(102)
I feel that teachers respect us as people and as students	Never	1.8	12.8
	Rarely	3.1	4.2
	Sometimes	25.9	20.8
	Often	40.5	46.9
	Always	28.7	15.3
	TOTAL	100	100
$p = 0.000$	N (353)	(251)	(102)
There are teachers who treat students unequally	Never	13.8	13.6
	Rarely	26.1	9
	Sometimes	31.4	31.3
	Often	22.6	22.3
	Always	6.1	23.8
	TOTAL	100	100
$p = 0.000$	N (353)	(251)	(102)
Teachers treat students in a disrespectful manner	Never	39.3	26.4
	Rarely	38.9	27.1
	Sometimes	16.4	29.1
	Often	4.8	16.5
	Always	0.6	0.9
	TOTAL	100	100
$p = 0.043$	N (352)	(251)	(101)
There are teachers who clash with students in the classroom	Never	28	17.4
	Rarely	41.9	17.9
	Sometimes	22.1	29.3
	Often	7.3	32.3
	Always	0.7	3.1
	TOTAL	100	100
$p = 0.000$	N (343)	(243)	(100)

Table 10. *Cont.*

		Academic Year	
		First and Second	**Third and Fourth**
My classmates have conflicts with our teachers	Never	27.2	18.2
	Rarely	50.3	31
	Sometimes	18.8	23.9
	Often	3	26.9
	Always	0.7	-
	TOTAL	100	100
$p = 0.000$	N (341)	(242)	(99)

Source: Own elaboration.

Statistically significant differences were also found with regard to faculty (Table 11). Students in the Faculty of Labour Relations and Human Resources indicate higher levels of conflict than those in the Faculty of Social Work. Specifically, future graduates in Labour Relations and Human Resources report, to a greater degree, ('sometimes', 'rarely' or 'never') that lecturers respect them both as people and students, and also to a greater extent ('often' or 'always') that there are teachers who treat them in a disrespectful and unequal manner, that teachers clash with students in class and that their classmates engage in conflicts ('often' or 'always').

Table 11. Level of agreement with different statements according to students' faculty.

		Faculty	
		Labour Relations and Human Resources	**Social Work**
I feel that teachers respect us as people and as students	Never	2.3	1.8
	Rarely	5.4	3.6
	Sometimes	36.4	23.6
	Often	41.1	45.3
	Always	14.8	25.7
	TOTAL	100	100
$p = 0.032$	N (354)	(129)	(225)
There are teachers who treat students unequally	Never	3.1	14.7
	Rarely	13.2	27.6
	Sometimes	38	26.7
	Often	29.5	23.6
	Always	16.2	7.4
	TOTAL	100	100
$p = 0.000$	N (354)	(129)	(225)
Teachers treat students in disrespectful manner	Never	23.4	41.8
	Rarely	38.3	37.3
	Sometimes	30.5	15.1
	Often	7.8	4.9
	Always	-	0.9
	TOTAL	100	100
$p = 0.001$	N (353)	(128)	(225)

Table 11. *Cont.*

		Faculty	
		Labour Relations and Human Resources	**Social Work**
There are teachers who clash with students in the classroom	Never	15.9	25.7
	Rarely	34.1	39.5
	Sometimes	35.7	23.4
	Often	12.7	9.6
	Always	1.6	1.8
	TOTAL	100	100
$p = 0.057$	N (344)	(126)	(218)
My classmates have conflicts with our teachers	Never	19	23.6
	Rarely	34.9	55.6
	Sometimes	37.3	17.1
	Often	7.2	3.7
	Always	1.6	-
	TOTAL	100	100
$p = 0.000$	N (342)	(126)	(216)

Source: Own elaboration.

Once again, students studying for the Degree in Labour Relations and Human Resources perceive higher levels of conflict than those studying for the Degree in Social Work.

As can be seen (Figure 2), when students are asked about the three main areas of conflict they have or have had with teachers, the majority (67%) point to academic marks. This is a traditional problem which is directly related to the interests of the students and which, to a large extent, triggers other types of perceptions and conflicts. As the second most significant source of conflict, a considerable percentage of students (22%) point to teacher superiority. Again, this stems from the need to impose discipline in the classroom, as well as to enforce assessment criteria, where teachers are responsible for these tasks. The third most important conflict arises from the use of technology in class (11%). This it is not due to a lack of competence in the use of technology but rather the misuse of it by students. The inappropriate use of mobile phones and laptops in class is seen to lead to clashes between teachers and students.

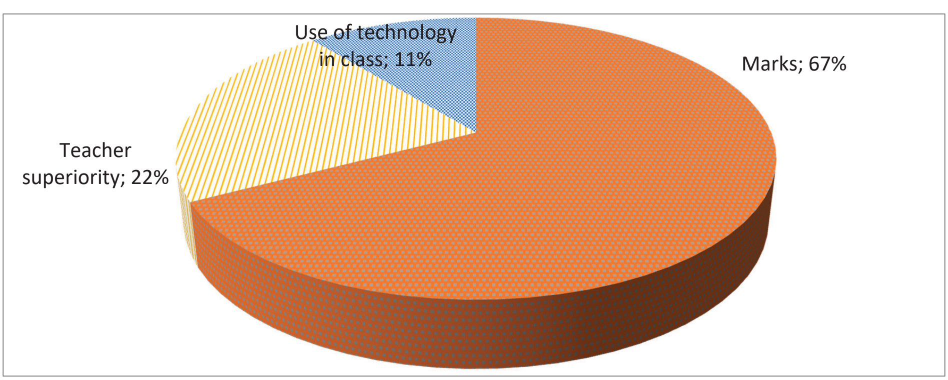

Figure 2. Three main conflicts between students and teaching staff. Source: Own elaboration.

4.3. Conflicts between Students and Service and Administration Staff

The third specific objective of this research focuses on identifying students' conflicts with the service and administrative staff. Table 12 shows the degree of student perception of a number of statements referring to the staff of the secretary's administrative offices and the caretaker's offices. The most marked pattern indicates that a considerable majority indicate a high degree ('always' or 'often') of agreement with the statements. In particular, students maintain that they are treated in a friendly and correct manner in the caretaker's offices. The caretakers are seen to be willing to help them and they receive satisfactory responses and answers. Similar conclusions are to be made with regard to the help given in the faculty secretary's offices. A majority of respondents believe that they are also 'always' or 'often' dealt with correctly, have their administrative matters resolved, are treated in a friendly way and listened to.

Table 12. Conflicts with the service and administrative staff.

	Never	Rarely	Sometimes	Often	Always	TOTAL	N (356)
Whenever I have gone to the secretary of the faculty, I have always been attended to in a correct manner	1.2	8.4	20.6	36.8	33	100	(345)
Whenever I have gone to the secretary of the faculty, I have always been able to resolve my administrative matters	1.7	7.5	21.4	34.6	34.8	100	(345)
The staff at the secretary of the faculty are friendly and willing to listen to you	2.3	9.3	25.2	36.5	26.7	100	(345)
The caretaker's office staff are friendly and helpful	0.9	3.2	20.6	37.5	37.8	100	(344)
Whenever I have been to the caretaker's office, I have always been treated correctly	0.3	2.9	15.4	39.4	42	100	(343)
Whenever I have gone to the caretaker's office, I have always got a satisfactory response	0.9	4.3	25.2	34.8	34.8	100	(345)

Source: Own elaboration.

This low perception of conflicts with the service and administrative staff does not show significant differences with respect to gender, age, academic year and faculty.

In general, the levels of conflict are low in this area, but the minority who subscribe to a certain degree of conflict indicate, in order of importance: lack of information, unfriendliness and excessive bureaucracy (Figure 3).

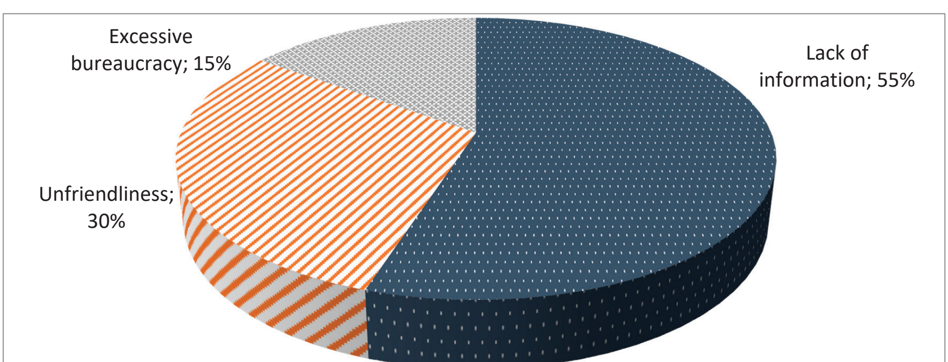

Figure 3. Three main areas of conflict between students and service and administration staff. Source: Own elaboration.

5. Conclusions

Universities have a responsibility to society, which can be translated into knowledge transfer. This is because they occupy a privileged place in the field of education, research and innovation. They are therefore central to global sustainable development. In line with this, Blasco, Brusca and Labrador [26] state that universities have embraced the SDGs in their research and from multiple perspectives. The transfer of knowledge and pedagogical development involves the inclusion of the SDGs in university curricula and in the teaching guides aimed at academic staff.

Sáez, Fernández and Castillo [27], in a similar study, and in their analysis of universities' desire to achieve the SDGs, consider universities to be fundamental in this respect, referring to their innovative and multidisciplinary nature. The responsibility entrusted to universities for training and research, has been translated in practice. This is known as 'transfer' and is an applied dimension of the United Nations 2030 Agenda which acts as an essential guide.

This research paper covers areas of study from the perspective of sustainable development, including the study and analysis of conflict and its subsequent management, in educational, social and professional contexts. On the subject of conflicts in higher education, the investigators Arias and Arias [28] highlight the importance of university as a formative and socializing entity and question where its limits are and what is teachable and what isn't. The role of the education system in society is still up for debate.

In every human group, and in all social relationships, conflict is present more or less explicitly. The way in which it is perceived constitutes a turning point for activating mediation procedures which allow it to be managed in a peaceful and equitable manner. In the face of confrontation and the consequent escalation of conflict, mediation as a solution technique together with the development of a culture based on dialogue, peace and equity, become essential instruments in the advance towards sustainable social development.

Room for dialogue about conflict as well as prevention and management of it should have a prominent place in the university environment. Peaceful conflict resolution, through accommodation and avoidance, form a part of the strategies adopted by young university students. In this sense, conflicts are produced in a context marked by the search for recognition, where academic interest is present [29].

The results of the investigation carried out by Arias and Arias [28] also corroborate peaceful confrontation within the same group. The authors point out the importance of analysing and managing conflict from a positive, transformative and dynamic viewpoint of social processes. In practice, more than constructive conflict management, what is unleashed/triggered are situations of avoidance with certain nuanced breakdowns expressed with/by silence and other types of verbal and symbolic violence.

The analysis of students' perceptions of conflict shows that, for a notable majority, there is a low level of conflict. In general, conflict is not very representative. However, it does exist. Only a minority of students say that they do not have good relations with their classmates. The creation of small, closed groups of friends/colleagues, the refusal to integrate new classmates and criticism among the students lead to conflicts which affect them, and which are not managed through dialogue. Gender is not a determining variable for the perceived degree of conflict. However, other factors are, such as age group, academic year and the faculty where students study. With regard to age, which is usually associated with academic year, a positive correlation is observed with respect to the perception of conflict: more conflict appears to arise in the older age group. With respect to faculty, the highest perception of conflict is seen in students of Labour Relations and Human Resources; among students of Social Work, there is a lower perception of conflict.

The three most negative areas of conflict perceived by students exist in relation to the context of their own dynamic as students. This is because they focus on competitiveness and the creation of sub-groups leading to lack of comradeship within the class. The desire to obtain the best marks leads them to compete. This gives rise to sub-groups which are often closed and thus weaken the bonds of companionship. The new assessment methodologies applied to grades encourage group work which results in the creation of cliques where formal and informal interests and relationships become part of a social dynamic.

In addition to formal and informal coexistence and relationships between students which generate conflict, another of the dimensions analysed is the perception of conflicts between students and teachers.

Intense and formal relations between teachers and students also give rise to problems. However, again, the level of perception of conflict is generally low. For a majority of students, relations with the teaching staff are good; they feel respected both as individuals and students, confrontations are very rare and their classmates do not usually engage in conflicts. This predominantly positive dynamic is altered by the majority perception that teachers treat them in a disrespectful and unequal manner. This is often linked to existing prejudice and arrogance on the part of teachers, who are seen as authority figures.

The perception of conflict hardly changes according to gender. However, it does change according to age, academic year and the faculty in which students are enrolled. As age increases, the perception of conflict increases. The older age group (21 and over) feels, to a great extent, that they are treated in a disrespectful and unequal manner by teachers, that their classmates clash with teachers and that clashes take place between teachers and students. However, the younger age group (17–20 years) perceives, to a great extent, that they are respected by their teachers, both as individuals and students. This trend is corroborated according to the academic year the students are in, with those in higher years having the greatest perception of conflict. By faculty, students studying for the degree in Social Work are those who perceive the least level of conflict, compared to those studying for the degree in Labour Relations and Human Resources, who are much more affected by conflict. This can be explained by the different professional expectations related to these two degrees, with those students studying for degrees in Social Work having much higher expectations.

In general, the level of conflict between students and teachers is very low, but it is still present for a minority. More specifically, the three main areas of conflict reported are related to assessment. In order of importance, they point to marks, teacher superiority and the misuse of technology in class.

Finally, conflicting relations between students and the service and administrative staff were analysed. Here the general absence of perceived conflict is noteworthy as the vast majority of students indicate that they are treated in a correct and friendly manner by these members of staff. They have their administrative matters resolved, obtain satisfactory answers and indicate that the staff show a willingness to help them. It is important to note that there are no statistically significant differences linked to gender, age group, academic year and faculty.

However, a minority of students perceive a certain level of conflict with service and administrative staff. In order of importance, the most significant issues are lack of information, unfriendliness and excessive bureaucracy. Here, bureaucracy occupies a central place due to its excessive complexity which sometimes triggers conflicts.

Although not for a significant majority, conflicts, of different degrees, do exist between students in the university environment and must be managed. To this end, prevention, diagnosis and management must form part of a university's strategy. Education for peace and in values based on conciliation and mediation are vital for successful conflict management and for consequent sustainable social development.

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Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

MDGs	Millennium Development Goals
SDGs	Sustainable Development Goals
UN	United Nations
HPRO	Harassment Prevention and Response Office
SAS	Service and Administration Staff
SPSS	Statistical Package for Social Sciences
UGR	University of Granada

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Section 3—SMART AND SUSTAINABLE CAMPUSES

sustainability

MDPI

Article

Sustainability Reports and Disclosure of the Sustainable Development Goals (SDGs): Evidence from Indonesian Listed Companies

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Abstract: This study investigates the factors that determine disclosure of the Sustainable Development Goals (SDGs) of companies listed on the Indonesian stock exchange in the period from 2017 to 2021. The research was conducted through an exploratory study using panel data (from each company's websites), parametric correlations, and regression models. The findings show a 60% increase in the disclosure of the SDGs in sustainability reports from 2017 to 2021, with the highest level of disclosure achieved for SDG 3 (Health and well-being) and SDG 4 (Quality education). The lowest disclosure was for SDG 14 (Life below water). The study demonstrates statistically that governance factors such as the presence of women on the board of directors and the number of board meetings positively affect SDG disclosure in listed companies in Indonesia. Factors related to companies' profitability, environmental sensitivity, and board size do not, however, influence SDG disclosure. These findings have implications for academics, stakeholders, practitioners, and governments who are strategically positioned to achieve the SDG agenda in 2030. This study has limitations in that the data were drawn only from companies in the SRI-KEHATI Index.

Keywords: sustainable development goals; sustainability reports; SDG reporting; SRI-KEHATI Index; governance level; company characteristics

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1. Introduction

The SDGs were established in 2015 by the United Nations General Assembly (UNGA). They consist of 17 goals and 169 targets and are intended to be achieved by 2030 to reduce inequality between nations [1–3]. Organizations, companies, and regulatory authorities are working on development and dissemination of non-financial information through publication of sustainability reports, sustainable investments, green banking, environmental issues, human rights, climate change, etc. All of these topics are also topics of study from both a theoretical and an academic perspective [4–9].

In general, a country's level of development and well-being depends on its internal factors and regional environment [10]. Government policies are thus a fundamental element for implementation of the SDG agenda, but achieving effective implementation requires the collaboration of companies and institutions [11,12]. Companies must ensure that they do not hinder achievement of the SDGs [13], since achievement of the SDGs also affects the organization's long-term sustainability [14,15].

The SDGs are a universal call to action to end poverty, protect the planet, and improve the lives and prospects of people worldwide. In 2017, Indonesia issued Regulation No. 59, which contained a commitment to support achievement of the SDGs by 2030. Article 1 details the parties other than the central government involved in this effort. In the same year, the Indonesian government also issued Financial Services Authority Regulation No.

51/POJK.03/2017, which regulates implementation of sustainable finance for financial services institutions, issuers, and listed companies. This regulation requires Indonesian companies to play an important role in corporate sustainability by publishing annual sustainability reports [16].

Also in 2017, at the Development Goals Summit (DGS), the Indonesian government declared that progress toward achieving the SDGs at regional level is scarce, given the high development gap. The government promised to reduce the development gap and strengthen implementation of the SDGs at the local level. In developing countries such as Indonesia, therefore, organizations must pay attention to the four pillars of sustainable development—economic, social, environmental, and institutional—to achieve the goals for SDG implementation by 2030.

Building on the above-mentioned premises, this study aims to fill an important research gap by analyzing the relationship between disclosure of SDGs and the factors that characterize companies listed on the Indonesian stock exchange in the years following the obligation to publish the sustainability report.

Stakeholder theory suggests that profitable companies work harder to preserve their positive reputation and need to continually address their stakeholders' expectations. Sustainability activities show the efforts companies make to satisfy stakeholders' demands [17,18]. Legitimacy theory also suggests that profitable companies undertake more sustainability activities to manifest their contribution to society's well-being and legitimize their existence [19]. Disclosure of progress toward SDGs is also very important to their stakeholders because it is an additional investment and shows legitimacy, bolstering a company's good reputation [20]. Companies that actively participate in achieving the SDGs experience obstacles, however, which are related to factors beyond their internal control and the value chain as a whole [21,22].

Previous research has found a relationship between some characteristics of companies—size, income, gender diversity on the board of directors (BOD), among others—and the dissemination of specific SDGs [2,23–25]. Marketing companies [26] and multinational companies are also promoting SDG disclosure [27].

Other studies have shown that SDG disclosure is still only symbolic and that corporate engagement in implementing them is still limited and more intentional than actual. These studies also reveal that the measurement of level of corporate engagement in the SDGs is associated with various methodological difficulties, related mainly to selection of indicators, data availability, and interpretation [22,28]. Lack of commitment to the SDGs can sometimes be explained by lack of knowledge, lack of understanding of SDG practices, and other sociological and economic factors in different regions [22,29]. The dissemination of the SDGs thus continues to raise intense academic debate about what factors explain or trigger their dissemination by companies and organizations [2,30].

Based on previous studies, and to achieve our study objective, which focuses on listed companies in a developing country, we pose the following research questions: RQ1. What level of SDG disclosure do companies listed on the Indonesian stock exchange report? RQ2. What SDGs are disclosed most often and prioritized by stock market companies in Indonesia? RQ3. What factors determine SDG disclosure among Indonesian companies?

We analyzed the factors that determine disclosure of the SDGs of companies listed on the Indonesian stock exchange in the period from 2017 to 2021. The research was performed through exploratory study using panel data (from each company's websites), parametric correlations, and regression models.

The dependent variable is the level of SDG disclosure, calculated from total SDG disclosure divided by the 17 SDG targets. The data were obtained from financial and sustainability reports published on the companies' websites. The independent variables analyzed were financial profitability (ROE), environmental sensitivity of the industry or sector, size of the administrative board, gender diversity on the board, and number of board meetings. In addition to addressing the specific research gap (level of disclosure of the SDGs and prioritization of each of the 17 SDGs), we examine the relationship of the

SDG level and the factors that determine SDG disclosure to the variables analyzed, using statistical correlations. Regression models constitute the research methodology.

To the best of our knowledge, this is one of the few studies to examine the level of SDG implementation, and its relationship to the factors that determine this achievement, behind Indonesian listed companies' obligation to submit sustainability reports.

This study makes several contributions to the literature on SDG development in Indonesia and the factors that determine companies' implementation, as each country must evaluate progress in its implementation of the United Nations 2030 Agenda, involving governments and stakeholders [31–33]. Our study specifically shows a 60% increase in disclosure of the SDGs in sustainability reports between 2017 and 2021. The highest disclosure levels are achieved for SDG 3 (Health and well-being) and SDG 4 (Quality Education). The lowest disclosure is for SDG 14 (Life below water). Statistically, governance factors such as presence of women on the BOD and number of board meetings have been shown to have a positive effect on SDG disclosure in listed companies in Indonesia. Factors related to profitability, companies' environmental sensitivity, and BOS do not, however, influence SDG disclosure.

The results of this study are also useful for monitoring companies' sustainability performance after issuance of the 2017 Regulation No. 51, and for determining what specific factors' influence can be useful for decision makers such as managers and investors [34,35]. This study examines specifically where Indonesian companies prioritize their SDG activities as a government strategy to support reporting, as well as a form of commitment to achieving the SDGs themselves [36].

This study is divided into the following sections: Section 1: Introduction; Section 2: Theoretical background, literature review, and hypothesis development; Section 3: Research methodology; Section 4: Results and discussion; and Section 5: Conclusions, implications, research limitations, and future research opportunities.

2. Theoretical Background and Literature Review

Some theories used to analyze companies that conduct sustainability activities are agency theory, interest group theory, and legitimacy theory. Jensen and Meckling [37] adopt agency theory when a difference of interests exists between managers (agents) and owners (directors). Whereas managers focus their goals on generating maximum profit to obtain bonuses or compensation for good performance, owners and shareholders want to obtain high profitability without incurring excessive managerial costs. Agency theory suggests that companies adopt more sustainable practices in periods of low profitability as a means of convincing financial actors that the current sustainable initiatives will result in long-term growth in results and competitive advantage for the company [38].

Freeman et al. [39] define stakeholder theory as the view that organizations are composed of a set of actors, which it calls interest groups (stakeholders), and that the purpose of a business is to create the greatest possible value so that the interest groups can be successful and sustainable over time. Both theories relate to SDG activities and encourage companies not only to focus on company profitability but also to protect, develop, and improve community welfare in the company's environment. This is the background against which the company should align its corporate activities with the SDG agenda.

The SDG framework can expand the way companies present their non-financial reporting [40]. Yet the impact of SDG reporting is difficult to assess, as creating value for shareholders is not always easy to quantify [41]. Some companies believe it is not important to report on their non-financial activities [42]. Integration of non-financial or sustainability and financial information has, however, become a new paradigm among researchers [43–45].

Aligning the SDG goals with value creation for shareholders becomes difficult on its own [30], and the absence of reporting standards makes it hard for companies to convey information on their achievement of SDGs. The United Nations and WBCSD Global Reporting Initiative, United Nations [46] have sought to solve this problem by introducing an SDG Compass to permit companies to measure and see their contribution while aligning corporate strategies to achieve SDGs.

The SDG Compass explains how SDGs affect a company's business by providing the tools and insights needed to put sustainability at the center of one's business strategy. According to PWC studies 2018 [40] and 2019 [47], companies have taken important steps in disclosing the SDGs from year to year. According to Emma and Jennifer [6], SDG disclosure influences companies' reputation, competitive advantage, and financial performance. Institutional investors also believe that SDG disclosure is the best way to evaluate environmental and social performance [23].

According to the Secretary General of the United Nations, global achievement of SDGs is only 15%. Further, some studies have revealed significant differences in SDG achievement between countries and regions. In Europe, for example, the analysis by Pizzi et al. [48] of European companies found that only 38.1% of companies in Europe included SDG achievement in their non-financial reports. Analyzing 48 sustainability reports from 20 companies in Greece, Tsalis et al. [49] found that SDG disclosure was low and focused only on reporting on SDG 7, Clean and affordable energy. Analyzing related SDG reports in Italy using 153 companies from eight different industries, Pizzi et al. [12] showed 34% disclosure of SDGs. Gutiérrez-Ponce [50] finds that, on average, listed companies in Spain present a 75% level of information on all SDGs and that significant analogies exist between level of disclosure of GRI-ESG sustainability information and level of performance on the SDGs/ESG.

In analyzing EU real estate companies during the period 2016–2018, Ionaşcu et al. [32] found a gap between planning and realization or achievement of the SDGs. They attributed this gap to the companies' inadequate strategies and knowledge of sustainable engagement. In 2017, Avrampou et al. [51] also analyzed performance on the SDGs in banking in European countries, taking the GRI report as a reference. Their results showed that banking in Europe generally made a low contribution to performance on the SDGs.

In other regions, development of SDGs has also been studied at the industry level. For example, Kumi et al. [11] conducted in-depth interviews with 85 mining and telecommunications companies in Ghana during 2015–2018 and found low levels of SDG achievement. Along the same lines, Erin and Bamigboye [52] found that SDG disclosure in 80 listed companies in Africa was at very low levels. This result was due to lack of management commitment, lack of regulatory compliance, and the potential implications of respondents' business costs. Analyzing the impact of achieving the SDGs on bank profitability in 28 countries, Ozili [44] finds that banks that achieve specific SDGs generally improve their profitability, but different impacts on bank profitability measures are experienced in different regions.

In Southeast Asia, Ike et al. [53] analyzed 16 companies operating in four countries: Vietnam, the Philippines, Thailand, and Indonesia. Their results show that companies prioritize SDGs 4, 8, 9, 11, and 12. In their study of the 100 largest companies in Malaysia, Hamad et al. [54] find an increase in SDG disclosure in Malaysia during 2016–2020, with priority disclosure focusing on SDGs 8, 12, and 13.

In Indonesia, Regulation No. 59 in 2017 became the government's commitment to achieving SDG goals. This regulation regulates how the Indonesian government achieves SDGs at the scale of both regional and central government. The Indonesian Development Plan is based on four pillars aligned with achievement of the SDGs: the economic pillar, the environmental pillar, the social pillar, and the legal certainty pillar [55]. In the same year, Indonesia regulated sustainability reporting for companies, in line with the SDGs.

Several studies specifically analyzed Indonesian companies' contribution to the SDGs. For example, Gunawan et al. [56] analyzed 585 companies in Indonesia using sustainability reporting from 2014 to 2016. Their results showed that Indonesian companies focused most on achieving SDGs 3, 4, 8, 11, and 12. Further, the analysis by Mutiarani and Siswantoro [57] of 34 provinces in Indonesia during 2015–2016 showed that local government's characteristics impacted SDG implementation in Indonesia. Hudaefi's [58] analysis of 198 fintech (financial technology) companies in Indonesia found that fintech companies have contributed to achievement of SDGs 1, 2, and 3 by contributing financial ideas and innovations to the small and microenterprise (SMEs) sector.

Regarding the Indonesian achievement of the SDGs, 2023 data from the Ministry of National Development Planning of the Republic of Indonesia show fulfillment of 63% of the total 216 indicators of the National Action Plan for SDGs 2021–2024. This figure does not, however, encourage progress in achieving the SDGs at the regional level. Given the high development gap in the current global crisis—especially after the pandemic and the war in Ukraine, which complicates efforts to achieve the SDGs—we lack research that addresses the problem of delineating which factors determine disclosure of the SDGs of companies listed on the Indonesian Stock Exchange, as these companies are obligated to report sustainability.

Development of Hypotheses

Many researchers [59–61] have explored the relationship between social responsibility and financial performance. Bonifácio, Neto, and Branco's [62] cross-sector and cross-country analysis obtained evidence of a relationship between corporate social responsibility (CSR) and financial performance. Companies with good financial performance tend to have good relationships with stakeholders through disclosure of non-financial information [12]. In contrast to Gutiérrez-Ponce and Wibowo [16], which shows that profitability has no effect on environmental activities in Indonesian companies, and based on prior theoretical and empirical research, we hypothesize that:

H1. *Company profitability is related to SDG disclosure*.

The business industry sensitivity is measured by its level of social, environmental, and ethical commitment. Companies in sectors such as mining, alcohol, or gambling (among others) are classified as not very sensitive [63,64]. Richardson and Welker [65] and Garcia et al. [66] classify companies that produce chemicals, gas, mining, oil, metallurgy, and forestry products as sensitive industries because they are more likely to cause social and environmental damage. Disclosure of sustainability information plays an important role in improving sensitive industries' image and legitimacy [6].

Other studies, such as that of Aqueveque et al. [67], show that controversial industries will further enhance their reputation through their CSR activities. Jo and Na [68] prove that controversial industries must perform more activities related to social and environmental ends to obtain many investors. Singh and Rahman [69] show that implementing SDGs also depends on the industry segment. Based on prior theoretical and empirical research, we pose the following hypothesis:

H2. *Companies' sensitivity in environmental matters affects SDG disclosure*.

The size of the board of directors (BOS) plays an important role in corporate governance mechanisms related to SDG disclosure, as does the ability of size to influence corporate strategy [46,70]. Several researchers have studied the impact of BOS on SDG disclosure—for example, Martínez-Ferrero and García-Meca [24] and Husted and Sousa-Filho [71]. They show an increase in positive relations relating the number of director members to CSR practices. Lagasio and Cucari [72] conducted a meta-analysis of 24 articles related to non-financial disclosure. BOS is negatively related to SDG disclosure, however, because it tends to slow decision making [73]. Said et al. [74], who tested quality of corporate governance in Malaysian companies, found that a large BOS results in ineffective communication and leadership and has a negative effect on CSR. Based on prior theoretical and empirical research, we pose the following hypothesis:

H3. *BOS is related to SDG disclosure*.

Women have different views from men, relative to personality, leadership style, values they profess, decision-making patterns, etc. [75]. The presence of women on the BOD brings new knowledge on climate change policies, alternative energy, and green building [76]. Gender diversity in the BOD drives environmentally friendly corporate strategies [77]. Isidro and Sobral [78] found that women directors tend to be more supportive of social activities than male directors. Rosati and Faria [23] found that the percentage of women's presence on the BOD had a positive influence on sustainability issues. Further, Zampone et al. [79] show that gender diversity on the BOD positively influences SDG disclosure and that there is a direct relationship between gender diversity on the BOD, SDG disclosure, and the mediating role of the sustainability committee.

Other research shows that female directors on the BOD do not influence sustainability performance [80]. Based on prior theoretical and empirical research, we pose the following hypothesis:

H4. *Gender diversity on the BOD is related to dissemination of SDGs*.

Board meetings are needed to develop effective corporate strategies for sustainability performance. Frequency of board meetings is expected to increase transparency and reduce problems of agency. Sekarlangit and Wardhani [80] analyzed performance on SDGs in Southeast Asian companies and found that the holding meetings more frequently increases SDG disclosure. Analyzing companies in Europe, Martínez-Ferrero and García-Meca [24] show that the presence of the board at meetings affects the company's commitment to sustainable development. In their meta-analysis of 24 empirical studies, Lagasio and Cucari [72] demonstrated that the number of meetings increased ESG disclosure. Based on prior theoretical and empirical research, we pose the following hypothesis:

H5. *The number of board meetings is related to SDG disclosure*.

3. Research Methodology

To achieve our research objectives and answer the questions raised, we conducted an exploratory, descriptive, inferential study. The methods include panel data analysis (using data from each company's website), statistical correlations, and regression models.

The methodology followed is content analysis, defined as follows: "Qualitative content analysis is a research method for the subjective interpretation of the content of text data through the process of systematic classification, coding, and identification of themes or patterns" [81]. This methodology has been widely adopted in studies of corporate disclosure [50,82–85] and is based on the framework for risk communication analysis developed by Beretta and Bozzolan [86]. Previous studies have also used content analysis to measure sustainability performance [6,12,22,76,80,87].

3.1. Sample and Data Collection

The study population is companies listed on the Indonesia Stock Exchange (SRI-KEHATI). The SRI-KEHATI Stock Index, first published by the KEHATI Foundation with the Indonesia Stock Exchange (IDX) on 8 June 2009, is a green index that measures the United Nations Principles for Responsible Investment (PRI). The KEHATI Index is currently the only source of investment guidelines that prioritize ESG issues in the Indonesian capital market, with company selection rules using ESG principles and Sustainable Responsible Investment (SRI). The current composition of the SRI-KEHATI Index, which is reviewed and updated twice a year in May and November, comprises 25 stocks of publicly traded companies listed on the IDX.

The study period is 2017–2021, due to ratification in 2017 of the requirements that listed companies present sustainability reports.

We obtained the data from the websites of each company. Firstly, we identified the 25 companies in the Indonesia Selective Index (listed in the SRI-KEHATI Index) in September 2023 by their company name and tax identification number (NIF). Secondly, we classified the companies by sector, following the criteria established by the selective index itself.

To build the database, we first downloaded the annual reports (financial and sustainability) of each of the 25 listed companies and captured the information from each sustainability report by filtering the phrases and words related to the 17 SDGs and their 169 goals. This classification was performed using "RapidMiner" software (https://rapidminer.com/get-started/, accessed on 13 December 2023). A coding procedure was also established to capture information on the SDGs by assigning a value of 1 if the report provided information and 0 otherwise. To measure SDG performance for each goal, this study uses the SDG Compass. Compiled by the UN Global Compact, GRI, and the World Business Council for Sustainable Development (WBCSD), the SDG Compass provides guidance on how companies strategize, manage, and measure the company's contribution to achieving the SDGs.

Additionally, following previous research [2,64–66], the sectors were classified by environmental impact. To collect information on the "environmental sensitivity of the industry", we used a dummy variable, assigning a score of 1 if the company had an impact on the environment and 0 otherwise. All data were transferred to an Excel spreadsheet for processing and study.

Table 1 shows the number and percentage of companies analyzed and classified by sector in the period 2017–2021. The total number of companies that presented sustainability reports in the 5 years analyzed is 110, of which the banking/financial sector represents 22%. This figure is followed by the real estate and construction sector, and then the infrastructure, public services, and transportation sector, each with 15%.

Table 1. Number of companies by sector (2017 and 2021).

Sector	N	%
Banking/Finance	24	22
Agriculture	8	7
Property and Construction	17	15
Trade and Investment Services	7	6
Various Industries	6	5
Infrastructure, Utilities, and Transport	16	15
Consumer Goods Industry	13	12
Basic and Chemical Industry	14	13
Mining	5	5
Total observation	110	100

3.2. Variable Measurement

This study uses company characteristics and level of governance as independent variables, as defined in Table 2. Financial profitability (ROE) is defined as a characteristic of companies, in line with previous research by [12,88–90]. Following [2,12], we use industry sensitivity as a variable to classify industries that have a greater impact on the environment relative to those that have less impact. To measure governance level, we use the BOS variable with the number of board members, in line with several previous studies [76,91–93]. The variable gender diversity in the BOD measures percentage of women in the BOD, again aligning with some previous research [76,94,95]. The number of BOD meetings is also used as an independent variable, in line with some previous research [24,72,93].

Table 2. Explanation of variables.

Variables	Labels	Formula
Independent Variables		
Profitability	PROFIT	Net income after taxes divided by average total assets at end of year
Environmental Sensitivity of the Industry	SENSITIV	Using dummy variables, the value 1 if includes industries that impact the environment and 0 otherwise
Board Size	BOS	Number of board members
Board Diversity	BOD	Percentage of women on board
Number of Meetings	MEETING	Number of board meetings held in a year
Dependent Variables		
SDG Disclosure	SDGs	Total disclosure of SDGs divided by Target 17 SDGs
Control variables		
Size	SIZE	Natural logarithm of total assets at end of year
Leverage	LEV	Total Leverage Formula = Total Debt/Shareholder's Equity at end of year

The dependent variable is the level of SDG disclosure, calculated as total SDG disclosure divided by the 17 SDG targets. Data were obtained from financial and sustainability reports published on the companies' websites.

We use two control variables: size (SZ) and leverage (LEV). SZ is measured using the natural logarithm of total assets and LEV using the company's total debt. These control variables have been used in previous studies, such as [16,24,88,89,96–99]. All financial data for this study are expressed in Indonesian currency, the Rupiah (Rp).

3.3. Empirical Model

This study uses panel data that combine time series and cross-sectional data. Before performing the regression test, we tested the classic assumptions to check for normality of the data. Before the regression test, we performed correlation tests between variables measured using Spearman's correlation coefficient. Next, we performed the corresponding tests for normality of the data. First, we tested normality of the data using the Kolmogorov–Smirnov test. Data are distributed normally if the significance value is >0.05. Secondly, we tested multicollinearity to determine whether the relationship between the independent variables was linear. Too high a VIF value is a sign of multicollinearity. Third, we tested for autocorrelation to determine whether a correlation exists between consecutive values in a time series or data series. The Durbin Watson test was used to analyze autocorrelation problems. Fourth, we tested heteroskedasticity using the Breusch–Pagan test. A significance value of >0.05 indicates no symptoms of heteroskedasticity.

This study used multiple regression tests to determine the influence and relationship of all variables on SDG disclosure. This approach coincides with that of several previous studies [54,66,92]. We tested whether the fixed effects model (FEM) or the random effects model was more suitable using the Hausman test. The FEM model is accepted when the probability value is <5%.

Based on the studies cited above, this analysis uses econometric equations with the following multiple regression model:

$$SDGPerf_{i,t} = \alpha + \beta 1 PROFIT_{i,t} + \beta 2\ SENSITIV_{i,t} + \beta 3 BOS_{i,t} + \beta 4 BOD_{i,t} + \beta 5 MEETING_{i,t} + \beta 6 SIZE_{i,t} + \beta 7 LEV_{i,t} + \varepsilon_{i,t} \quad (1)$$

where SDGPerf is SDGs disclosure, PROFIT is company profitability, SENSITIV is an industry that impacts the environment, BOS is number of board members in the company, BOD is proportion of women in the company's board of directors, MEETING is number of board meetings in a year, SIZE is the size of the company's assets, LEV is the company's total debt, "α" is a constant, "β1-7" is the independent variable and the company's control variable, "ε" is an error, "i" is a company, and "t" is a period.

4. Results and Discussion

4.1. Descriptive Statistics for All Variables

This section is used to answer RQ 1 and RQ 2, on the level of SDG disclosure in Indonesia and the most disclosure by Indonesian companies that contribute to achieving the SDGs.

Table 3 shows that the average ROE (profit) is 18% annually. The variable that measures companies' environmental sensitivity (SENSITIV) indicates that, on average, 79% of companies fall into the category of companies that positively impact the environment, have an average of seven members on their boards of directors, and have 11% women as board members. Furthermore, Indonesian companies hold an average of 42 meetings per year, their total assets average IDR 275,166,373 (in thousands) in an accounting period, and they have an average debt ratio of 75%.

Table 3. Descriptive statistics of the variables expressed in percentages (%).

Variables	Mean	Min	Max
PROFIT	18	−22.90	146.60
SENSITIV	79	0.00	100
BOS	7.65	4	12
BOD	11	0.00	60
MEETING	42.23	12	281
SIZE	275,166,373	3,529,557	1,725,611,128
LEV	75.87	−16.50	348.40

Figure 1 presents the level of SDG disclosure in the years analyzed. The results show that SDG disclosure in sustainability reports has been increasing each year. In 2017, 32% of Indonesian companies disclosed the SDGs in their sustainability reports. This level of information increased to 60% in 2021. The trend continues as stakeholders gain awareness and demand information. Sekarlangit and Wardhani [80] showed that companies in Southeast Asia experienced an increase in SDG disclosure each year, while Bose and Khan [100] show that developing countries (including Indonesia) have rapidly increased their SDG disclosure.

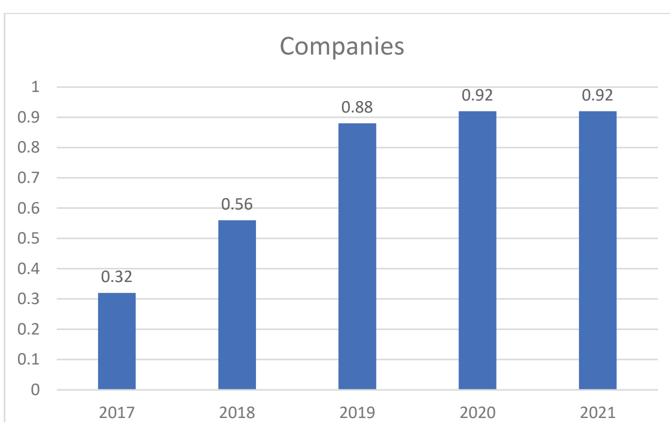

Figure 1. Companies that disclose SDGs every year.

To answer RQ2, Figure 2 shows the priority in disseminating the SDGs—that is, which SDGs are most widely disseminated in Indonesia.

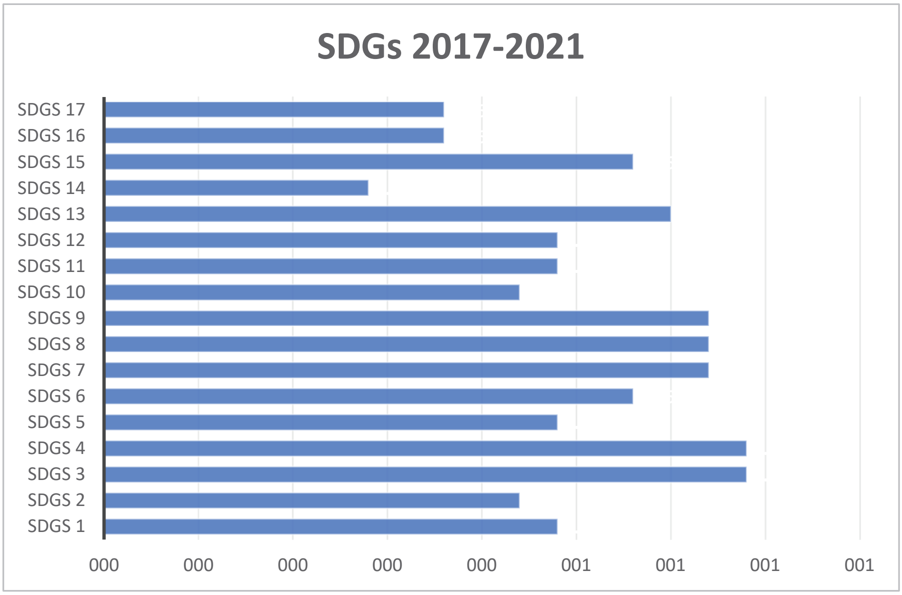

Figure 2. SDG disclosure priorities in Indonesia (2017–2021).

The highest levels of disclosure are in SDG 3 (Health and well-being) and SDG 4 (Quality of education), each with a value of 0.68. These results indicate that the government's development policies focus on qualification of its human resources through a commitment to education and health to impact social well-being and improve economic development.

Another interesting result is the commitment to preservation of the environment and prevention of climate damage. Several SDG targets that have a disclosure value greater than >0.50—for example, SDG 6 (Clean water and sanitation), SDG 7 (Affordable and clean energy), SDG 9 (Industry, innovation, and infrastructure), SDG 13 (Climate action), and SDG 15 (Life on land).

However, SDG 14 (Life below water) has among the lowest disclosure values in Indonesia. This result shows that Indonesian companies still have little concern for river and marine ecosystems. Fifty percent of the population lives in coastal areas, and a healthy and protected ocean is crucial to the country's development and prosperity. This finding is in accordance with research [32] showing that most companies determine their SDG priorities according to their company's strategy and activities.

Given this problem with SDG 14, an agreement was signed in November 2022 between the government and 28 organizations—eight government ministries, eight UN entities, and 12 partners to join forces within the framework of the National Agenda Action Associations Blue (National Blue Agenda Actions Partnership).

Our analysis of the dissemination of other SDGs related to the environment shows that only SDG 13 reaches prioritization levels over 50%. However, environmental onsite sewage disposal systems (OSDs) that aim to achieve more sustainable cities (SDG 11), and responsible consumption and production (SDG 12), as well as signing of alliances to achieve the objectives (SDG 17), obtain lower levels of disclosure or prioritization.

Social objectives—such as SDG 5 on gender equality, SDG 1 on ending poverty, and SDG 16 on promoting just, peaceful, and inclusive societies—also fail to reach 50% in the prioritization and dissemination levels.

4.2. Correlation Result

This test is used to determine the direction of the relationships between all variables. We use the Spearman correlation test to determine the direction of the relationship between the independent and dependent variable.

Table 4 shows the results of the correlation test between all variables. We observe that SDGs have a positive correlation with sensitive industries (0.359). This finding shows that industries that are highly sensitive to the environment (such as mining, oil, and gas) commit increasingly to environmental issues to improve the company's image [67].

Table 4. Correlation test for all variables.

	SDGs	**Profit**	**Ind Sens**	**BOS**	**BOD**	**Meeting**	**Size**	**Lev**
SDGs	1	−0.059 *	0.359 **	0.315 **	0.281 **	0.204 *	0.365 **	−0.047
Profit		1	0.089	0.158	0.565 **	−0.173	−0.091	−0.159
Sensitiv.			1	−0.754 **	−0.208 *	−0.474 **	−0.697 **	−0.086
BOS				1	0.449 **	0.195 *	0.603 **	−0.099
BOD					1	0.046	0.193 *	0.009
Meeting						1	0.238 *	0.503 *
Size							1	−0.024
Lev								1

Note: Correlation is significant at * 0.05 ** 0.01.

SDGs have a positive relationship to BOS (0.315). Thus, the number of members on the BOD aligns with the company's CSR performance [71]. SDGs also have a positive correlation to board diversity (0.281), showing that the presence of women on the BOD encourages companies to behave in an environmentally friendly manner [78]. Further, SDGs have a positive correlation with number of meetings (0.204), in line with Martínez-Ferrero and García-Meca [24], who found that the presence of the board at the meeting would increase the company's commitment to sustainable development.

Companies' financial profitability is, however, inversely related to SDG disclosure. This result may be due to the fact that sustainability activities use a large amount of financial and organizational resources in the short-term, reducing profits [45,89,101–103].

4.3. Regression Results to Determine Factors of SDG Disclosure

This section presents the results to answer RQ3 and contrasts the hypotheses related to the determining factors in listed companies' SDG disclosure. Table 5 shows the results of the normality tests (multicollinearity, autocorrelation, and heteroskedasticity). The normality test shows that the data are normally distributed, as seen from the Kolmogorov–Smirnov significance value of 0.138 > 0.05. The tolerance and VIF values for all variables are >0.1, and the VIF values <0.10 indicate no symptoms of multicollinearity. The heteroskedasticity test shows the significance values for all variables is >0.05, indicating no symptoms of heteroskedasticity. The Durbin Watson value of 1.875 is within the range of 1.8 and 2.17 [104], indicating no symptoms of autocorrelation.

Before regression testing, we tested which model, FEM or REM, was more suitable. Since the Hausman test results showed a probability value of 0.0030 < 5%, the FEM was accepted. Table 6 shows the results of the proposed regression model to determine which factors influence SDG diffusion in Indonesia. The hypothesis is accepted if the significance value is less than 5%.

Table 5. Normality tests for data quality.

Model	Heteroskedasticity Test	Collinearity Test	
		Tolerance	VIF
PROFIT	0.693	0.598	1.673
SENSITIV	0.085	0.120	8.325
BOS	0.809	0.249	4.013
BOD	0.522	0.521	1.920
MEETING	0.071	0.448	2.231
SIZE	0.062	0.121	8.282
LEV	0.837	0.685	1.460
Durbin Watson	1.875		
Kolmogorov–Smirnov Z	1.156		
Asymp. Sig (2-tailed)	0.138		

Table 6. Regression results.

Model	Coeff (Sig)
Independent Variables:	
PROFIT	0.000 (0.785)
SENSITIV	0.061 (0.778)
BOS	−0.030 (0.247)
WOMEN	0.788 (0.013) *
MEETING	0.002 (0.077) **
Control Variables:	
SIZE	3.706 (0.064)
LEV	−0.001 (0.103)
Adj. R Square	0.168
F Test (Sig.)	0.000
Hausman test (Prob.)	0.0030 *
Fixed Effect Model (FEM)	Yes

Note: significant at * 0.05 ** 0.10.

The regression test results show that H1 is rejected—that is, that profit has no effect on SDG disclosure, as seen from the significance value of 0.785 > 5%. This result does not agree with that of [12], which states that profitability influences SDG disclosure. Our results show that companies' sensitivity in environmental matters does not affect disclosure of SDGs. We thus reject H2 with a significance value of 0.778 < 5%, indicating that the sensitivity of the industry will not affect disclosure of the SDGs. SDG disclosure thus does not depend on the type of industry (sensitive or non-sensitive). In fact, the existence of SDG reporting may be an alternative means to address industry controversy to reduce stakeholder pressure and social supervision and to improve the company's image [6].

The results of this study show that the BOS is not related to SDG disclosure (H3), since the significance value of 0.247 > 5% for BOS does not affect that disclosure. This finding coincides with Giannarakis [92], who shows that the BOS does not play a significant role in CSR disclosure, possibly because the board only contributes at the policy level, not the implementation level.

H4 is accepted, as seen from the significance value of 0.0013 < 5%. The presence of women on the BOD is thus significantly positive for SDG disclosure. This finding aligns with the results of Rosati and Faria [23], who show that women provide a better perspective and support environmental activities. It also shows that the presence of women on the BOD will increase control over the board and be favored by investors, reducing agency costs [105].

The results for H5 indicate that number of board meetings is related to disclosure of SDGs, based on the significance value of 0.077 < 10%. This finding coincides with the findings of Sekarlangit and Wardhani [80], who show that the number of meetings provides good knowledge of how committed companies are to SDG disclosure.

5. Conclusions, Implications, and Research Limitations

This study assesses implementation of SDGs in Indonesia and the factors that influence this implementation. Using data on Indonesian companies published on the Indonesia Stock Exchange in the period 2017–2021, we tested whether company characteristics (profitability and industry sensitivity) and governance level (board of size, board diversity, and number of meetings) impacted SDG disclosure in Indonesia. We also used control variables such as company size and debt (debt-to-equity ratio).

The findings, first, prove that disclosure of SDGs in Indonesia has increased every year. Whereas in 2017 only 32% of companies disclosed SDGs, this figure increased to 92% in 2021. Indonesia is thus seriously committed to achieving the 2030 SDG target. Second, companies in Indonesia focus on disclosing SDGs in social and environmental areas such as SDGs 6 (Clean energy and sanitation), 7 (Affordable and clean energy), 8 (Decent work and economic growth), 9 (Industry innovation and infrastructure), 13 (Climate change), and 15 (Life on land). The highest disclosures are in SDG 3 (Good health and well-being) and 4 (Quality education). The lowest is in SDG 14 (Life below water).

These results can be explained by Indonesia's status as a developing country. Both the government and companies develop strategies to improve people's well-being through a commitment to education and health to impact social well-being and improve economic development.

Although many of the companies analyzed are aware that their activities affect the environment, the environmental SDGs are not among their disclosure priorities. This finding may indicate that the Indonesian companies analyzed are trying to comply with the 2017 regulatory obligation to submit an environmental report that gives them a green or ecological image but are not as concerned about actual sustainability performance. Furthermore, it has been observed that the social SDGs have much to improve in terms of dissemination and performance. It is true that it is important for developing countries to create an environmental organizational culture that considers the costs of ecological transformation and sustainability of long-term investments. Since this path is longer in developing countries, it is important that they advance along that path.

The previous conclusion is reinforced by the finding that the companies' financial profitability is inversely related to SDG disclosure. This inverse relationship can be explained by the fact that short-term sustainability activities use a large amount of financial and organizational resources, diminishing the benefits. We also find that ROE (profit) does not influence the SDG disclosure strategy in the Indonesian companies analyzed.

Although companies' sensitivity in environmental matters does not affect Indonesian companies' decision to report and disclose the SDGs, gender diversity (or the presence of women on the BOD) and the number of board meetings are positively related to SDG disclosure strategy.

This finding accords with several previous studies that argue that women have a more innovative perspective on environmental conditions and climate change policies [76]. The number of meetings also positively impacts the environment. It is likely that meetings conducted by the board lead to more pro-sustainability alignment and decision making.

In conclusion, we note that the companies analyzed perform some greenwashing, orienting their marketing image to ecological positioning, while their actions less clearly or specifically favor the environment. The reports presented on "green communication" thus do not always mean that companies are more respectful of the environment or that they have acquired a commitment to the environment. It is important, however, that progress continues in a commitment to report on SDGs and ESG issues by measuring them with GRI indicators or the European sustainability reporting standards (ESRS) indicators.

This study has significant implications for stakeholders, governance policy makers, and academia. For stakeholders, it clarifies the relationship between SDG disclosure and financial and governance factors of listed Indonesian companies. Implications for practitioners can provide input on what factors will improve SDG disclosure. For investors, the findings relate financial performance to the characteristics of companies' BOD. Further, the results help policy makers to understand how and why companies change their reporting and transparency practices, affecting the credibility and effectiveness of corporate and sustainability reporting. For decision makers such as the government, our study provides an overview of Indonesian companies' contribution to the achievement of SDGs to help the government develop the right SDG-related policies. For academics, the study contributes to an emerging body of literature aligned with sustainability reporting, corporate governance, and non-financial information in an understudied emerging markets context, and therefore addresses development and governance gaps that can explain the problems involving information on and development of the SDGs.

This study has several limitations. First, the sample is only companies in the SRI-KEHATI Index, namely 25 companies with good performance relative to the environment. For better results, one could use a larger sample, such as all companies listed on the Indonesia Stock Exchange.

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How Do Universities in Türkiye Integrate Sustainable Development Goals into Their Strategies?

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Abstract: The strategic plans of universities have an important role in enabling HEIs to contribute to sustainability transitions. To address the current lack of studies in HEIs in Türkiye, this paper aims to determine how universities in Türkiye integrate sustainable development goals (SDGs) into their strategic plans to indicate the extent to which these universities align with the 17 SDGs and to discuss the visibility of SDGs in strategies. The research has been designed as a qualitative study involving document analysis. QS World University Rankings or being a research university are the two criteria for the sampling. The scope of the study consists of 27 universities, representing 13.4% of the universities in Türkiye. The most striking result was that, apparently, none of the strategic plans mentioned Goals 1 (no poverty), 6 (clean water), and 13 (climate action). The sampled universities in Turkey have established a restricted set of strategic objectives linked to SD Goals 2, 5, 10, and 11. These remarkable findings prompt inquiries into the underlying reasons for this constrained scope, warranting further investigation. A potential factor contributing to the limited objectives regarding these goals could be traced to a lack of awareness and understanding of the intricate connections between these goals and the overarching mission of higher education institutions.

Keywords: sustainable development goals; strategic plans; higher education; quality education; Türkiye

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1. Introduction

Higher education institutions (HEIs) can be engines of societal transformations [1], and universities are important incubators for finance, talent, and innovations [2,3]. In addition to this wider significance, universities are being buffeted by many forces and forced to reconsider their missions and goals [4] as these institutions create, form, and shape the future leaders, decision-makers, and intellectuals of the social, political, economic, and academic sectors [5–10], contributing to the advancement of society [11].

Since the 1990s, universities worldwide have embraced the overarching sustainability movement and, in particular, the 2015 United Nations SDGS. Many academic institutions have committed themselves to implementing sustainability through curriculum, research, as well as sustainability initiatives [12–14]. Universities hold tremendous potential to contribute towards sustainability [15] and have a major influence on the social environment of a region; therefore, these institutions must assume responsibility for creating long-term, future-proof sustainable development [8]. Since universities are under increasing scrutiny, university leaders should ask themselves how to most effectively achieve sustainability in the higher education context. This mission of universities raises the question "how must universities ensure that sustainability becomes an integral part of the university culture?" This concern has been the driving force of the study in order to create a multiplier effect within higher education in the short and long term [16,17].

Sustainable development goals (SDGs) have been prepared as a continuation of the United Nations Millennium Development Goals implemented in 2000 and as an agenda that carries the 17 goals even further [18,19]. Under the framework of the 2030 Agenda, the objective is to engage all societies in global endeavors aimed at diminishing poverty, enhancing global well-being, safeguarding cultural and social values, and mitigating environmental harm. This novel global development strategy underscores concerns spanning social and environmental aspects, including gender equality, addressing the needs of marginalized groups, minimizing food waste, combating desertification and drought, safeguarding biodiversity, and addressing economic factors such as growth, technological advancement, employment, and industrialization, thus highlighting a comprehensive approach to sustainable development [20].

The new 2030 Agenda for Sustainable Development clearly reflects the importance of an appropriate educational response [20,21]. The importance of Education for Sustainable Development (ESD) has been duly recognized as a crucial element in the global agenda, and education is a key enabler for the achievement of all 17 sustainable development goals (SDGs). Quality education (SDG 4), considered to be a driver for the achievement of all 17 SDGs, is the most powerful transformative force in the world today to develop equality, promote human rights and dignity, help to eradicate poverty, foster sustainability, and build a better future for all [20,22].

Global issues impose a new agenda to redefine the strategies of higher education institutions (HEIs), implement the 2030 Agenda for Sustainable Development, and cope with the targets established in "Transforming our World: the 2030 Agenda for Sustainable Development." The 2030 Agenda for SDGs is characterized by the direct involvement of higher education institutions in addressing the 17 SDGs identified in Agenda 2030. Higher education institutions, then, are also strategic stakeholders in achieving SDGs through initiatives at universities. Higher education institutions that have become the center of the SDGs movement [1,23] play a pivotal role within society in contributing to the development of sustainable humanity [24], as well as a critical responsibility in integrating SDGs into institutional strategic plans [25]. These contributions make universities more essential in creating societies and a workforce that is more sensitive to sustainability agendas. Therefore, universities are uniquely positioned to address this enormous challenge in order to build a better, global, sustainable future. Universities are the places in which the next generation of professionals worldwide are being educated. These educated political and business leaders will make better economic decisions related to society and the environment in the future [26–29].

The contribution of universities at the level of SDGs could be very extensive as they serve in all these fields, such as teaching and learning, research, innovation, technology production, climate change, governance, social leadership, and public commitment [27]. Universities are the strategic stakeholders [30] to develop strategies, methods, and research to implement SDGs while simultaneously realizing the intended goals [23,31]. Strategies set by universities will encourage local and regional intervention and support local and regional participation for SDG implementation [24]. The implementation of sustainable principles requires common strategies and synergy with higher education institutions. Information on how the university community translates SDGs into concrete objectives, strategies, and actions is still patchy, with the number of universities engaged in this type of reporting still being a concern [32,33]. Therefore, the improvement of universities' reporting practices enhances the disclosure of organizational performance and increases dialogue with stakeholders [32].

Universities have largely ignored global, cross-sectoral, multi-stakeholder developments in accounting for sustainability [2]. Indeed, universities are expected to include global issues in their value-creation processes through a holistic approach [2,30,34,35]. Higher education institutions are also essential in the establishment of societal values and the culture of the society, raising the newer generations with an innovative perspective within the framework of these values. Universities are leaders in education, research, and innovation, all of which underline their key role in helping society address these challenges [35]. Furthermore, through their teaching, research, and strategizing, university institutions need to educate students with the necessary knowledge and skills to achieve the SDG targets [2,33,35]. Universities are also considered to be role models that emphasize global goals through innovative initiatives and active policies [2,33,36].

HEIs are playing their own role in achieving and amplifying value-creation processes. Universities play a key role in elaborating and disseminating the sustainability theme and demonstrating a strong commitment to putting these principles into practice. Regarding the first issue, universities can identify sustainability needs and adapt them not only to research topics and educational programs [37] but also through strategic planning activities. Within this scenario, many universities have focused on integrating sustainable principles in their strategic plans due to the increasing awareness of the social role represented by HEIs. Universities with the adopted strategies based on SDGs become visible and understandable by stakeholders while highlighting the commitment to a new balance between business, the environment, and the social sphere. HEIs having a strategic vision regarding SDGs can contribute to the main driver of the country's economic, social, and other critical development [31]. Universities have to design policies and strategies from a whole-institution perspective to holistically integrate SD within its global goals [33,38].

Global needs and sustainable development goals result in universities taking a vital role in building the future. Regarding this agenda, Türkiye put the concept of sustainable development on its agenda in 1996 after the conference "United Nations (UN) Environment and Development" held in Rio in 1992 and later on took this concept into its Development Plans and many policies in the following years. The concept of sustainability has been included in the Development Plans, and these policy texts that include the concept of sustainable development have been important components of Türkiye's sustainable development agenda. Türkiye aims to ensure effective coordination among all stakeholders in the implementation phase of the 2030 Agenda. The 2030 Agenda imposes a responsibility not only on governments but also on businesses, NGOs, and higher education institutions [39]. The Council for Higher Education in Türkiye (COHE) is the top institution responsible for strategic planning, coordination between universities, and quality assurance mechanisms in higher education. COHE agreed on the importance of Education for Sustainable Development after the proclamation of the Decade of Education for Sustainable Development and accepted it as a principle that Türkiye's new agenda should be included in the planning of universities. COHE encourages universities to act in a way that is related to sustainable development goals.

Deliberately and proactively concentrating on the SDGs can facilitate transformative change within the university, contributing to a more sustainable and inclusive future. Therefore, it is worth investigating to what extent and how these global issues and priorities accepted by CoHE are included in the agenda of universities in Türkiye. To the best of the authors' knowledge, this is the first study seeking to explore how universities in Türkiye integrate SDGs into their strategic plans and this description could be a starting point for assisting HEIs to integrate SDGs into their action plans. How sustainable universities are can be used as a communication tool to visualize the sustainable practices adopted by universities [40].

Higher Education Institutions in Türkiye

The transition of HEIs in Türkiye to the implementation of strategic planning dates back to 2006. All public institutions in Türkiye were required to prepare strategic plans and comply with these plans with the Public Financial Management Control Law No. 5018 in 2003 [41], and this law adopted the "strategic management" approach, including the basic principles of effectiveness, efficiency, as well as the concepts of participation, accountability, and transparency [42]. The obligation of preparing strategic plans for public institutions in accordance with Article 9 of Law 5018 was introduced after recognizing the lack of administrational planning in the 2000s [43]. For this reason, it has become an important task of all institutions in Türkiye to prepare strategic plans and to follow them in line with country policies and targets. In continuation, universities became responsible for preparing strategic plans in 2006 [44]. In addition to Law No. 5018, higher education institutions in Türkiye are subject to "Regulation on Procedures and Principles of Strategic Planning in Public Management" and "Strategic Planning Guide for Universities" in the implementation of strategic plans. In addition, "Regulation on Academic Evaluation and Quality Improvement in Higher Education Institutions" has also emphasized strategic planning in universities. The relevant regulation imposed an obligation on universities to define strengths, weaknesses, opportunities, and threats through internal and external evaluations in order to improve quality and transform these strategies into concrete goals while monitoring performance indicators [45]. Working in coordination with the Strategy Development Department, the Strategy Development Board directs the strategic plan preparation process. The is primarily responsible for approving the strategic plans and ensuring their follow-up [46].

International ranking is a significant evaluation criterion in higher education in Türkiye. HEIs have traditionally employed international rankings as a means to evaluate and compare their performance with that of other universities. Subsequently, they scrutinize the factors contributing to their success or shortcomings. Universities use international rankings as an indicator of success to enhance the reputations of their institutions and to increase their credibility in the business world, as well as a promotional tool to attract both researchers and students. Students also rely on rankings to make decisions about the choice of HEIs [47]. University rankings have become a significant component in forming an institutional identity and helping assess the prestige, value, and price of universities. Universities strategically leverage the status provided by rankings to shape and define their institutional identities [48]. Therefore, the Council of Higher Education aims to evaluate universities using national and international criteria and create a competitive environment. One criterion is international ranking indexes, and the other is research university status.

A national criterion for ranking is "research university", which was introduced by The Council of Higher Education in 2017 within the scope of the "Specialization and Mission Differentiation Project". The performance of the universities in Türkiye is evaluated according to the criteria determined by the "Monitoring and Evaluation Commission" established by COHE. The criteria to evaluate university performance include three headings, "research capacity, research quality and interaction and collaboration", and 32 indicators. A total of 10 universities were declared as research universities in 2017 [49], whereas, at present, 22 of the universities listed in Table 1 were evaluated as research universities in 2023 [50]. Being a research university sets a very clear and high criterion for acting as a pioneer [51], which entails the strengthening of potential universities with financial, administrative, and academic support in order to ensure world-class university standards [52]. Research universities are recognized as the institutions that have determined a strategic roadmap and carried out this working discipline in accordance with this plan. The strategies of the universities and the level of realization are considered important in the selection of research university status [51].

Higher education in Türkiye has grown into a system of mass higher education in the 2000s. There has been a great growth in the number of universities and students and access to higher education [42]. A total of 208 universities, including 129 state, 75 foundation, and 4 foundation vocational schools, accommodate around 7 million students and 184,566 faculty members [53]. However, the level of international competitiveness seems inadequate [54]. Only 7 universities in Türkiye are among the top 1000 universities worldwide, and 15 of the universities are listed among the top 1400+ according to QS Rankings.

Various studies investigating the strategic plans of the universities in Türkiye mainly focused on entrepreneurship [55], a comparison of the planning process [56,57], thematic analyses for the mostly focused targets [58], the effects of strategic management of the universities on performance [59], and internationalization [60]. The study conducted by Dağlar [58] evaluated 112 state and 67 foundation universities according to their strategic plans and concluded that universities mostly set plans related to education, scientific research, community services, institutionalization, infrastructure, and stakeholders in their strategic planning. In addition, foundation universities also mention targets for finance and recognition. The study by Vural Yılmaz [60] investigated the strategic plans of 90 universities in terms of internationalization and found that claiming to serve as a global university has not been a realistic goal as the universities were far away from internationalized perspectives. It is evident that studies investigating the strategic plans of universities in Türkiye lack a focus on sustainability and the understanding of SDGs. Therefore, this is the first study aiming to determine how universities in Türkiye integrate SDGs into their strategic plans and this study can serve as an initial point for better steps to adopt SDGs to universities' strategies.

With this research, the intention is to indicate how universities in Türkiye integrate SDGs into their strategic plans. The study allows us to identify how well universities meet 17 SDGs by responding to the following research questions:

1. Which university had strategic goals relating to the highest number of SDGs in the Strategic Plans?
2. How many objectives relating to SDGs are contained in the Strategic Plans?
3. How do universities in Türkiye define strategic objectives relating to SDGs?

Table 1. University ranking and validity years of the strategic plan.

2023 QS World University Ranking	2023 Ranking	Validity Years of the Strategic Plan
Koç University *	477=	2020–2024
Middle East Technical University *	501–510	2023–2027
Sabancı University *	531–540	2021–2025
İstanbul Technical University *	601–650	2022–2026
Boğaziçi University *	701–750	2020–2024
Hacettepe University *	801–1000	2023–2027
İstanbul University *	801–1000	2019–2023
Ankara University *	1001–1200	2019–2023
Gazi University *	1001–1200	2019–2023
İstanbul Aydın University	1001–1200	2018–2022
Yıldız Technical University *	1001–1200	2021–2025
Akdeniz University	1201–1400	2022–026
Anadolu University	1201–1400	2019–2023
Dokuz Eylül University *	1201–1400	2021–2025
Ege University *	1201–1400	2019–2023
Gebze High Technology Institute *	1201–1400	2022–2026
İstanbul Bilgi University	1201–1400	2021–2023
İzmir Institute of Technology *	1201–1400	2019–2023
Marmara University *	1201–1400	2021–2025
Atatürk University *	1401+	2019–2023
Çukurova University *	1401+	2019–2023
Erciyes University *	1401+	2022–2026
Sakarya University	1401+	2020–2024
İstanbul Cerrahpaşa University *	No Ranking	2021–2025
Bursa Uludağ University *	No Ranking	2022–2026
Fırat University *	No Ranking	2019–2023
Karadeniz Technical University *	No Ranking	2019–2023

* These universities are also named "Research University", according to COHE. Sourced from (https://www.yok.gov.tr/Sayfalar/Universiteler/arastirma-universiteleri.aspx (accessed on 8 November 2023)) and originally created by the authors.

2. Materials and Methods

The study was designed as a qualitative research method based on document analysis. Document analysis is considered a research design as it includes both data collection and analysis techniques together. This research design is based on the systematic analysis and evaluation of both written and electronic documents [61]. In this research, the universities to be analyzed were selected according to being a research university or being included in the top QS World University Rankings.

The QS World University Rankings, which is defined as the most comprehensive ranking of its kind, asses the universities with various criteria such as academic reputation, employer reputation, faculty/student ratio, citation per faculty, international faculty ratio, international student ratio, and international research network. However, the QS World University Rankings introduced three new criteria, which are international research collaboration, employability, and sustainability [62]. It is expected that the universities in QS World University Rankings include more goals related to SD and work to achieve world standards. International and national competitiveness is crucial for universities in Türkiye; therefore, the QS World University Rankings or the research university category was established as a criterion, and universities were determined according to one of these two criteria.

The number of universities at the time of this study was 208 in Türkiye, including 129 state, 75 foundation, and 4 foundation vocational schools (https://istatistik.yok.gov.tr/ (accessed on 8 November 2023)). The scope of the study consists of 27 universities, representing 13.4% of the universities in Türkiye. A total of 23 of these universities are funded by the state, and 4 are privately funded. Moreover, 22 of these universities are named "Research University". Additionally, 4 of them are not listed in QS World University Rankings. The current strategic plans announced on the selected universities' websites were included in the review. The validity years of these Strategic Plans are given in Table 1.

All strategic objectives of the universities included in the research are provided in Supplementary Table S1. After the selection of universities, the official web pages of the universities included in the sample were scanned, and their announced strategic plans were reviewed. At the beginning of the study, 28 universities, which met the criteria for the study, were selected, but one of the universities was excluded as its strategic plan was not announced on its website. Strategic plans of 27 universities were downloaded and archived by researchers. The strategic plans were thoroughly scanned. The main objectives in the current strategic plans of the sample universities were manually coded and analyzed in relation to the SDGs, and data were coded under the 17 SDGs given in Table 2. To answer the research questions, keywords were underlined for each of the sustainable Development Plans, and strategic plans were analyzed through these keywords and associated with the goals.

Table 2. SDGs and abbreviations.

Sustainable Development Goals	
SDG-1 No poverty	SDG-10 Reduced inequalities
SDG-2 Zero hunger	SDG-11 Sustainable cities and communities
SDG-3 Good health and well-being	SDG-12 Responsible consumption and production
SDG-4 Quality education	SDG-13 Climate action
SDG-5 Gender equality	SDG-14 Life below water
SDG-6 Clean water and sanitation	SDG-15 Life on land
SDG-7 Affordable and clean energy	SDG-16 Peace, justice and strong institutions
SDG-8 Decent work and economic growth	SDG-17 Partnership for the goals
SDG-9 Industry, innovation, and infrastructure	

Originally created by the authors.

All strategic plans of the universities contained the sections of preparation process, situation analyses, future outlook, differentiation strategy, strategy development, monitoring–evaluation, updating the strategic plan, and presenting the strategic plan. Among these sections, the strategic development section, which constituted the data source of the study, included goals, targets, performance indicators, and strategies. While each university had a total of 4–6 strategic objectives, various targets and indicators were defined under these objectives. The Krippendorff's Alpha value has been calculated to measure the agreement between two coders. The calculated Krippendorff's Alpha is 0.9892. This high value indicates strong agreement among the coders, reinforcing the reliability of the coding process and interpretation of the data [63]. The strategic plans of all universities were examined under the heading of main objectives and targets. Throughout the analysis, the strategic objectives declared on the universities' websites and the targets under these aims were scrutinized. Objectives associated with SDGs were identified, and the number of keywords used in these objectives was examined. Tables were then created to present these findings.

3. Results

3.1. Which University Had Strategic Goals Relating to the Highest Number of SDGs in the Strategic Plans?

Which universities are more focused on SDGs in their strategic plans was a concern of the researchers, and to answer this question, the plans were analyzed in order to define the distribution of SDGs in the universities' strategic plans and the number of objectives relating to these SDGs. The number of objectives for each SDG is indicated by one dot in each colored field. Results are presented in Figure 1.

The distribution of SDGs in the universities' strategic plans is presented in Figure 1. All the selected universities except Fırat University have set at least a few objectives addressing SDGs. Within all these selected universities, it is surprising that Fırat University has set no SDG-related objectives. Middle East Technical University set the most strategic objectives related to SDGs, and each of these 12 objectives covers different goals mentioned in SDGs. This suggests that Middle East Technical University is more dedicated to achieving SDGs. According to the number of strategic objectives regarding SDGs, Koç University and Sakarya University are in second place by stating nine different objectives addressing SDGs. Koç University, which is a foundation university, has set objectives for Goals 4, 5, 12, 14, 15, 16, and 17. Sakarya University has also set objectives related to SDGs 3, 4, 7, 8, 9, and 11. After the first three universities, İstanbul Technical University has eight strategic objectives, and İstanbul University and Ankara University each address seven strategic objectives. Boğaziçi, Hacettepe, Ege, and Erciyes Universities have set six different objectives regarding SDGs. İstanbul Cerrahpaşa University has three strategic objectives related to Goals 3 and 4, and Karadeniz Technical University also has three strategic objectives, including SDG 3, 4, and 9. İstanbul Aydın University and Anadolu University have only set two strategic objectives addressing Goal 4 "Quality Education". It is a remarkable result that Goal 4, "Quality Education", is not directly addressed in the objectives of Sabancı University.

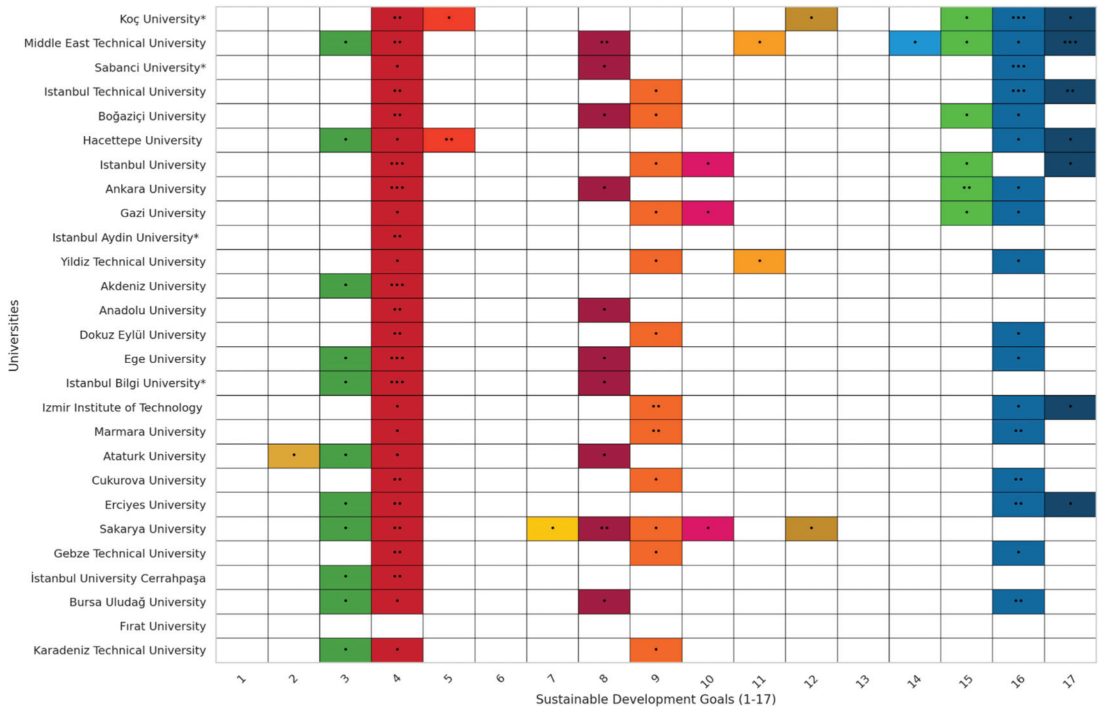
Of all the strategic plans of the universities, Goal 4 (quality education) and Goal 16 (peace, justice, and strong institutions) receive the most attention. G 4 appears in all but one of the plans in our sample, while Goal 16 is found in 17 strategic plans. Goal 3 (health), Goal 8 (decent work and economic growth), and Goal 9 (industry, infrastructure, and innovation) appear in 10–12 of the plans, while Goal 15 (life on land) and Goal 17 (partnerships) are found in 6 and 7 plans, respectively. The remaining Goals 2, 5, 7, 10, 11, 12, and 14 are only included in one to three of the universities' strategic plans. The remarkable finding is that climate action is not mentioned in any of the strategic plans of the sample universities. The most striking result was that, apparently, none of the strategic plans mentioned Goals 1 (no poverty), 6 (clean water), and 13 (climate action).

3.2. How Many Objectives Relating to SDGs Contained in the Strategic Plans?

The strategic plans of the 27 universities were investigated to analyze how frequently SDGs were mentioned. We also aimed to find out which goals were addressed the most and which goals were emphasized more in strategies. The number of objectives contained in the strategic plans of the universities in Türkiye is presented in Figure 2. The objectives of the universities matched with SDGs are provided in the Supplementary Table S2.

Goal 4, "Quality Education", was mostly emphasized, ranking first with 47 different objectives in all strategic plans of the universities. Goals 16, "Peace, Justice and Strong Institutions", ranked second as it was repeatedly addressed in 27 different objectives. After the first two goals, Goal 9, "Industry, Innovation and Infrastructure", appeared in 14 different objectives, and Goal 8, "Decent Growth and Economic Growth", appeared in 12 different objectives. We also came across Goal 3, "Good Health and Well-Being", in

11 objectives and Goal 17, "Partnership for the Goals", in 10 objectives. The fact that there was only one objective for three goals (Goal 2, 7, 14) is an important finding. These goals are Zero Hunger, Affordable Clean Energy, and Life Below Water.



* These universities are privately funded.

Figure 1. The distribution of SDGs in the universities' strategic plans. Originally created by the authors.

3.3. *How Do Universities in Türkiye Define Strategic Objectives Relating to SDGs?*

How universities in Türkiye define strategic objectives related to SDGs and which words were frequently used to set these objectives are also vital to visualize the understanding of SDGs. Results are presented in Figure 3. It is not a surprise but an expected result that "education" (f30), "research" (f27), and "quality" (f25) were the most frequently expressed keywords in all the strategic objectives of the selected universities. After these first three keywords, "social" (f19), "strengthen" (f18), "develop" (f16), "international" (f16), "capacity" (f16), "qualified" (f14), and "development" (f14) follow. "Institutional" (f 11), "entrepreneurship" (f11), "education and training" (f10), "innovation" (f9), "improvement" (f 9), "improve" (f9), "social contribution" (f8), "corporate" (f7), and "value" (f7) were the words repeated many times in the strategic objectives. The words "energy", "accreditation", "digital", "health", and "sustainable" were used only twice. The words "sustainable development goal", "industry", and "consumption" were repeated only once.

Various keywords were used to define SDG-related objectives; "entrepreneurship" was used by Boğaziçi, Hacettepe, İstanbul, Gazi, Akdeniz, Anadolu, İzmir Institute of Technology, Atatürk, Çukurova, and İstanbul Cerrahpaşa Universities; "innovation" was used by Boğaziçi, Atatürk, and Çukurova Universities; "institutional capacity" and "infrastructure" was used by Hacettepe, Gazi, Akdeniz, Ankara, Dokuz Eylül, İzmir Institute of Technology, Marmara, Çukurova, and İstanbul Cerrahpaşa Universities; "university-industry cooperation" was used by Ankara, and Sakarya Universities; "internationalization" was used by İstanbul Aydın, Anadolu, Ege, Erciyes, and Sakarya Universities.

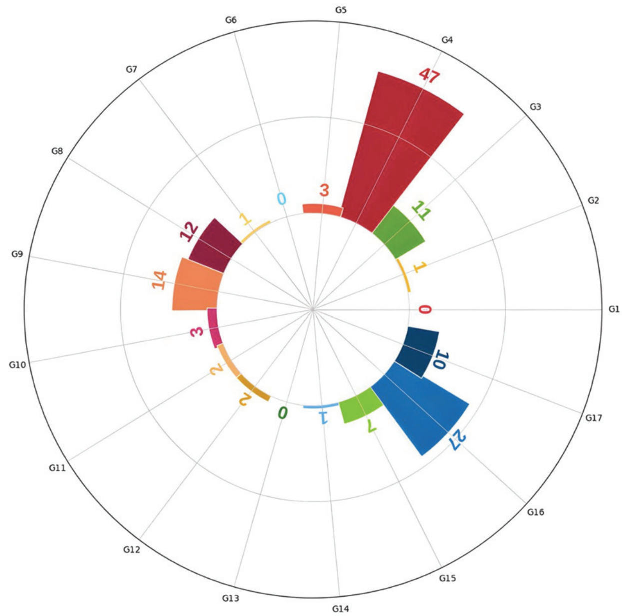


Figure 2. The number of objectives contained in the strategic plans. Originally created by the authors.

Figure 3. Word cloud for the frequency of the keywords to define strategies related to SDGs. Originally created by the authors.

Universities set remarkable objectives related to sustainability in their strategic plans. Koç University, İstanbul Bilgi University, and İzmir Institute of Technology set objectives using "research", "education", "management", and "social contribution" themes. The other universities generally used sentences to set objectives and targets. Middle East Technical University, having a high awareness of sustainability among other sample universities, set completely direct objectives as "*to sustainably increase the quality of education for national and international students*" and "*to develop sustainable, innovative research studies that can adapt to changes and needs at national and international scales*", and all its objectives match with sustainability. Sabancı University defines a clear objective as "*increasing impact on focused* *global issues and SDGs*", and other objectives also match with sustainable issues. İstanbul Technical University mainly defined objectives by phrases such as "*strengthening education and training with an innovative and dynamic approach*", "*raising awareness of society*", and "*international active role*". Boğaziçi, Hacettepe, İstanbul, and Gebze Technical University set objectives on education using "*strengthening the quality of education*"; Marmara, Anadolu, Gazi, Ankara, Erciyes, İstanbul Cerrahpaşa, and Karadeniz Technical Universities used "*increase/improve quality education*"; Çukurova, Dokuz Eylül, and Akdeniz Universities used "*develop quality of education*" to define objectives for education.

Sakarya University also set a direct objective related to sustainability: "*to be a leading university in the national and international arena in the realization of sustainable development goals*". It also defined a detailed objective addressing approximately all themes emphasized in SDGs: "*To carry out sensitive practices in the fields of education, health, social and environment, taking into account the principles of sanitary conditions, renewable energy, human development, social development, reduction of inequalities, responsible consumption and production, environmental protection in order to realize the responsible university*". Bursa Uludağ University also stated that it wished to "*enable social contribution through social responsibility and sustainability awareness*".

4. Discussion

This paper provides an overview of the Strategic Plans of the universities in Türkiye related to SDGs. A total of 27 universities from Türkiye, either in the top 1000+ according to QS World University Rankings or in the category of research university, were included and investigated to indicate how these universities integrate SDGs into their planning, imply how well these universities meet 17 SDGs, and infer how dedicated they are to SDGs. To explore this, a four-stage review was carried out; strategic objectives were listed, targets under these objectives were reviewed, objectives defining sustainability were analyzed, keywords were used to set objectives were counted, and results were presented.

That the sample universities set various objectives regarding SDGs, except Fırat University, is a significant result. Universities in the top 1000+ according to QS World University Rankings or placed in the category of Research Universities in Türkiye offer many strategic objectives regarding SDGs, including quality education, strong institutions, industry, innovation and infrastructure, economic growth, good health and well-being, partnership for cooperation, and life on land.

Quality education is the most emphasized goal among these strategic objectives of the universities. This is an expected result since education is one of the three pillars of the HEIs [64]. This result is consistent with the study conducted by Nauta et al. [37], which found that education and learning are the most represented planning for sustainable development. In addition, universities consolidate the process of teaching quality enhancement, expanding and requalifying the range of education with a view to sustainability [37]. However, it is a remarkable result that Sabancı University and Fırat University did not set a direct objective regarding "Quality Education". This means that these two universities ignore not only their key role but also Education for Sustainable Development [65,66].

Goal 16, "Peace, Justice and Strong Institutions", is the second goal emphasized mostly in the strategies of the sample universities. This result indicates that higher education institutions will be a pioneer in every field and set an example with their strong institutional culture. This goal is vital in promoting inclusive societies with integrity at multiple scales [67], and this goal addresses the issue of promoting inclusive societies based on strong institutions and the rule of law [68]. Strategies related to Goal 16 imply a lot and apply to all goals related to education, health, economic growth, and climate change [69].

Goal 9, "Industry, Innovation and Infrastructure", and Goal 8, "Decent Growth and Economic Growth", come after the first two emphasized goals after Goal 9. According to Fei et al. [70], industry is a key factor in the global efforts to achieve SDGs, and the results of the study imply that 10 out of the 17 SDGs were impacted by the construction industry. Saieed et al. [71] calculated the SDG 9 index for 124 countries and indicated that 58 countries progressed towards the SDG 9 target. In comparison, the remaining 66 countries regressed away from these targets, and in this study, Türkiye was located among the 15 countries which showed greater progress on SGD 9 targets.

The most significant finding is that the universities that set the most SDG-related objectives are both at the forefront of the QS World University Rankings and are in the category of "Research Universities". This result emphasizes that success is not accidental. This result also reveals that the leading universities mostly meet expectations regarding SDGs. This is consistent with previous studies, and the study concluded that the top 20 universities were also leaders in achieving sustainability [72]. Gedikkaya et al. [73] concluded, in their study, that universities in Türkiye had an increasing awareness and interest in sustainable development, and every year, more universities were included in indexes, such as STARS, UI, GreenMetric, and Times Higher Education Impact Rankings. However, our study showed that not all Turkish universities tend to include all SDGs in their strategies. For instance, some universities, including İstanbul Cerrahpaşa University, Karadeniz Technical University, İstanbul Aydın University, and Anadolu University, set very few strategic objectives matching SDG perspectives. The fact that Sabancı and Fırat University have not set any objectives for quality education is a remarkable result.

The fact that universities in Türkiye set no direct strategic objectives for climate action was an extremely striking result. This result is contrary not only to national policies but also to international emphasis. As in the national context, the Climate Change National Action Plan 2011–2023 designed a framework and formulated policies in order to mitigate and prevent climate change in Türkiye by creating awareness in society [74]. Climate change has an impact on almost all aspects of sustainable development, and this impact on SDGs gives rise to a pressing need to understand how action to address climate change can be reinforced [74]. The Times Higher Education Impact Ranking used climate action metrics to measure the climate action performance of the universities, and the latest list for 2020 indicates that the top five universities are in New Zealand, Australia, and the United States [75]. The world needs future leaders to be forward-thinking and innovative in industry, which requires them to feel confident to challenge the stereotypes on climate action and provide alternative solutions [76].

SDGs are a global framework for addressing pressing socio-economic and environmental challenges. Despite the universality of these goals, there appears to be a notable gap in the explicit incorporation of certain SDGs within the strategic plans of Turkish universities. This investigation delves into the academic discourse surrounding this phenomenon, aiming to uncover the underlying factors. The fact that sample universities in Türkiye have set a limited number of strategic objectives related to SD Goals 2, 5, 10, and 11 is noteworthy. This finding raises questions about the reasons behind this limited scope, and further investigation is needed. One contributing factor to the limited objectives of these goals may stem from a lack of awareness and understanding of the interconnectedness between these goals and the broader mission of higher education institutions. Tosun and Leininger [77] reported the Turkish context in their study and informed that the approach of Türkiye was interpreted as being consistent with previous initiatives aimed at ensuring sustainable development through SDGs, and the study also suggested a continuity in the government's policy approaches adopted in the past. Studies have shown that limited knowledge about the objectives associated with SDGs can impede their integration into institutional strategies [78,79]. There is a need to synchronize the policies implemented in one objective with the others [77]. Caiado et al. [80] supported this vision, stating that it was evident that SDGs should serve as a guiding framework for development policies. The challenges posed by the SDGs are interconnected and should be addressed collectively in a holistic manner rather than tackling them individually.

It is essential to note that all these analyses of the strategic plans and the objectives on sustainability should not be assessed as a guarantee of effective implementation practices on campus [81]. It is worth highlighting that universities have not been able to internalize and institutionalize an SDG insight [32,82]; that is, universities have not served to achieve institutionalization, which means all planning and innovation actions are part of the culture of the whole university. İlhan [83] indicated that the limitations of legal regulations in Turkey, the lack of competitiveness among public institutions, the rigidity and slowness of planning processes, the disregard for planning, and the difficulty of long-term planning are considered challenges in preparing strategic plans. All these reasons can be obstacles to internalizing and determining the correct strategy. Moreover, the study conducted by İlhan [83] highlighted that state universities in Türkiye prepare strategic plans in accordance with the strategic planning guide; however, these strategic plans do not guarantee the achievement of the objectives. Hence, the stages of implementation in the continuation of strategic planning should be monitored and evaluated. We believe that the best strategy to engage SDG within universities is to bring a top-down approach, and this requires a reversed viewpoint and looking through the biggest lens first [84]. It is also important to adopt an understanding of how the perspective related to sustainability should be harmoniously implemented with each goal. Additionally, the alignment between each goal should be considered, and they should be included in strategic planning accordingly. Therefore, it is anticipated that wider sustainable engagement will be catalyzed as an institutional strategy rolls out.

5. Conclusions

The paper reveals that the exclusion of key SDGs from the strategic plans of Turkish universities is a multifaceted issue involving factors such as limited awareness, resource constraints, institutional culture, and the broader policy environment. Addressing this gap requires a comprehensive approach that considers both internal and external dynamics shaping university priorities. Future research should delve deeper into the specific contextual nuances within Turkish higher education institutions to inform targeted strategies for the integration of essential SDGs into their strategic frameworks. Universities should be engaged more in SDGs and make SDGs explicit in their academic policies, institutional mission, strategy, and planning. Universities should develop and utilize SDG strategies to create a multiplier effect instead of an abstract concept. Strategies need to be well-planned and organized in such a way as to meet all goals [85].

The failure to incorporate the understanding of sustainability into strategic plans also poses a threat to international rankings. Although the QS World University Ranking criteria include the criterion of sustainable development goals, it is observed that universities in Türkiye do not fully comprehend these criteria and do not reflect them in their strategic plans. This may lead to the non-fulfillment of QS World University Ranking criteria and jeopardize these rankings.

The research just defined the most emphasized goals regarding SDGs included in the strategic plans of the universities in Türkiye. How these universities understand these SDGs in detail and put them into practice is still unknown. With this perspective, how universities will implement these strategies will be essential. Nevertheless, the difference between policy and implementation will be decisive, and in future research, the level of realization and effectiveness of the strategic objectives of the universities can be investigated. Research can be further advanced in the strategic plans of the universities by revealing the effectiveness of these strategies. Future research with a larger sample across Türkiye would be beneficial. The fact that there is no mention of HEIs in Türkiye promoting SDGs at the level of students and their learning can also be considered for future studies.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su152416799/s1, Supplementary Table S1. Strategic Goals of the Universities in Turkey. Supplementary Table S2. How many objectives relating to SDGs contained in the Strategic Plans?

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Article

Benchmarking Sustainable Mobility in Higher Education

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Abstract: Sustainable mobility is an increasingly significant issue that both public and private organizations consider in order to reduce emissions by their members. In this paper, the Life Cycle Assessment (LCA) approach was used to evaluate sustainable mobility. Data coming from a study carried out at the University of Foggia were processed by Gabi LCA software to estimate the environmental performance of the community members according to the methodology of the Product Environmental Footprint (PEF) guidelines 3.0. Results of the LCA were organized in different classes, creating an eco-indicator of sustainable mobility that can be applied to both the institution and individual members (called the Sustainable Mobility Indicator, SMI). The SMI, computed to assess the environmental impact of the University of Foggia, was also used to evaluate the best mobility scenario, which can be considered a benchmark. The creation of the performance classes and benchmark analysis represents an easier way to communicate sustainability based on the recommendations for achieving the sustainable development goals from the 2030 Agenda adopted by all United Nations Member States. Indeed, any organization can carry out this approach to assess its environmental impact (in terms of mobility) and shape transport policies accordingly, leading to the adoption of sustainable solutions.

Keywords: Sustainable Mobility; SDG 11; Life Cycle Assessment; Sustainable Eco-Indicator University

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1. Introduction

Sustainable mobility is a crucial issue for determining transport policy [1,2]. This is a global problem that concerns urban planning, all economic sectors, and higher education as well [3–6]. To assess sustainability in transport plans, many efforts have been carried out to determine metrics and indicators to face the problem in its three dimensions: economic (as for Moghaddam et al. [7], who compare inequality in transportation), social, and environmental [8–10]. Previous studies focused on the calculation of indexes based on the evaluation of various characteristics of sustainable mobility. Haghshenas and Vaziri [11] compared sustainable mobility indicators calculated on a global scale. On the other hand, Shiau and Liu [12] determined an indicator system for measuring and monitoring transport sustainability at the city level. In the same way, Jain and Tiwari [13] proposed a systematic approach to selecting sustainable mobility indicators for Indian cities. Mirzahossein et al. [14] investigate the traffic capacity under environmental constraints, calculating the maximum number of vehicles based on acceptable emission levels. Furthermore, adopting standardized methodologies to analyze transport modes and mobility plans from a life cycle perspective could help in defining an overall picture of sustainability and assessing the implications of choices and policies. Indeed, Life Cycle Assessment (LCA) has usually been adopted to evaluate the sustainability of mobility [15–20]. Starting from these premises, this paper proposes a way to calculate an indicator for assessing sustainable mobility in higher education. The paper analyses the results of a survey carried out in the academic community of the University of Foggia with the engagement of students, professors, and technical staff [21,22]. Among the data collected, this paper focuses on the various kinds of transport modes and the kilometers traveled with each one. These data were used as life cycle inventory for calculating the environmental performance of each transport choice according to LCA methodology and PEF guidelines 3.0. The research objective was to individuate a metric for calculating an indicator based on the environmental impact associated with the choice of transport mode, while the expected results were to determine performance classes as an easier way to communicate sustainability based on the recommendations for achieving the sustainable development goals from the 2030 Agenda adopted by all United Nations Member States. This approach appears to be in line with other experiments in which sustainable mobility was assessed according to a scoring process calculated for several elements of the mobility plan [23]. Then, a further effort was made to elaborate a procedure for benchmarking the environmental performances calculated according to the sustainable mobility indicator. This represents an innovative aspect based on the concept of continual improvement indicated in the standards for quality management systems [24]. This approach forces the organization to compare its real situation with the best available solution from an environmental perspective and helps it manage sustainable mobility. Miranda and Rodrigues da Silva [25] used the same approach for benchmarking sustainable mobility in Curitiba (Brazil). Thus, the model proposed in this paper could be replicable in other academic communities or applicable to other organizations.

2. Materials and Methods

Life Cycle Assessment of the Mobility of University of Foggia

The LCA is a standardized methodology that aims to assess the environmental burdens of a product, service, or organization by considering the overall system in terms of material and energy resources consumption (input) and emissions (output) [26–33]. The LCA was applied to the two scenarios of the University of Foggia (UNIFG) mobility habits, distinguished between hot and cold seasons. This distinction was important because, according to the survey results, conditions could highly affect the choices of transport modes.

The modeling phase was carried out by using the LCA software Gabi by Sphera Solutions, and its data sets included Ecoinvent v3.5 [34,35]. Table 1 shows the processes and data sets considered in the system, distinguishing between Sphera and Ecoinvent. For each transportation mode, as indicated in Table 1, the impacts of fuel production and use, as well as use of vehicles, were included. According to LCA methodology, as for proxy data on processes of petrol, diesel, LPG, methane, and electric cars, deriving from Ecoinvent and Sphera data sets, the functional unit was the kilometer. The same was true about scooters. On the other hand, as far as trains, buses, and aircraft, all impacts are referred to by the unit “passenger kilometers” (pkm) [36]. This choice is based on the need to consider that the impacts of public transport must be divided per the average capacity of the vehicles in terms of carried persons. As for sharing mobility, a multiplying factor of 0.25 was applied to the impact of passenger cars, whereas for hybrid vehicles, 80% of petrol cars and 20% of electric cars were considered. As far as the life cycle impact assessment, all the impact categories indicated in the Product Environmental Footprint (PEF) guidelines 3.0 were considered [37,38]. The results in absolute value were normalized and weighted according to Table 2 in order to obtain an aggregate indicator named “EF 3.0 eco indicator”.

Table 1. Processes and data sets considered in the LCA.

Process	Dataset
Car diesel, small size Euro 0	EU-28: Diesel mix at refinery Sphera
	GLO: Car diesel, 1986–88, engine size up to 1.4l Sphera
Car diesel, small size Euro 1	EU-28: Diesel mix at refinery Sphera
	GLO: Car diesel, Euro 1, engine size up to 1.4l Sphera
Car diesel, small size Euro 2	EU-28: Diesel mix at refinery Sphera
	GLO: Car diesel, Euro 2, engine size up to 1.4l Sphera
Car diesel, small size Euro 3	EU-28: Diesel mix at refinery Sphera
	GLO: Car diesel, Euro 3, engine size up to 1.4l Sphera
Car diesel, small size Euro 4	EU-28: Diesel mix at refinery Sphera
	GLO: Car diesel, Euro 4, engine size up to 1.4l Sphera
Car diesel, small size Euro 5	EU-28: Diesel mix at refinery Sphera
	GLO: Car diesel, Euro 5, engine size up to 1.4l Sphera
Car diesel, small size Euro 6	EU-28: Diesel mix at refinery Sphera
	GLO: Car diesel, Euro 6, engine size up to 1.4l Sphera
Car diesel, small size Euro 6b	EU-28: Diesel mix at refinery Sphera
	GLO: Car diesel, Euro 6 (from Sept 2019), engine size up to 1.4l Sphera
Car diesel, small size Euro 6c	EU-28: Diesel mix at refinery Sphera
	GLO: Car diesel, Euro 6 (from January 2021), engine size up to 1.4l Sphera
Car diesel, medium size Euro 0	EU-28: Diesel mix at refinery Sphera
	GLO: Car diesel, 1986–88, engine size 1.4–2l Sphera
Car diesel, medium size Euro 1	EU-28: Diesel mix at refinery Sphera
	GLO: Car diesel, Euro 1, engine size 1.4–2l Sphera
Car diesel, medium size Euro 2	EU-28: Diesel mix at refinery Sphera
	GLO: Car diesel, Euro 2, engine size 1.4–2l Sphera
Car diesel, medium size Euro 3	EU-28: Diesel mix at refinery Sphera
	GLO: Car diesel, Euro 3, engine size 1.4–2l Sphera
Car diesel, medium size Euro 4	EU-28: Diesel mix at refinery Sphera
	GLO: Car diesel, Euro 4, engine size 1.4–2l Sphera
Car diesel, medium size Euro 5	EU-28: Diesel mix at refinery Sphera
	GLO: Car diesel, Euro 5, engine size 1.4–2l Sphera
Car diesel, medium size Euro 6	EU-28: Diesel mix at refinery Sphera
	GLO: Car diesel, Euro 6, engine size 1.4–2l Sphera
Car diesel, medium size Euro 6b	EU-28: Diesel mix at refinery Sphera
	GLO: Car diesel, Euro 6 (from September 2019), engine size 1.4–2l Sphera
Car diesel, medium size Euro 6c	EU-28: Diesel mix at refinery Sphera
	GLO: Car diesel, Euro 6 (from January 2021), engine size 1.4–2l Sphera
Car diesel, large size Euro 0	EU-28: Diesel mix at refinery Sphera
	GLO: Car diesel, 1986-88, engine size more than 2l Sphera
Car diesel, large size Euro 1	EU-28: Diesel mix at refinery Sphera
	GLO: Car diesel, Euro 1, engine size more than 2l Sphera

Table 1. *Cont.*

Process	Dataset
Car diesel, large size Euro 2	EU-28: Diesel mix at refinery Sphera
	GLO: Car diesel, Euro 2, engine size more than 2l Sphera
Car diesel, large size Euro 3	EU-28: Diesel mix at refinery Sphera
	GLO: Car diesel, Euro 3, engine size more than 2l Sphera
Car diesel, large size Euro 4	EU-28: Diesel mix at refinery Sphera
	GLO: Car diesel, Euro 4, engine size more than 2l Sphera
Car diesel, large size Euro 5	EU-28: Diesel mix at refinery Sphera
	GLO: Car diesel, Euro 5, engine size more than 2l Sphera
Car diesel, large size Euro 6	EU-28: Diesel mix at refinery Sphera
	GLO: Car diesel, Euro 6, engine size more than 2l Sphera
Car diesel, large size Euro 6b	EU-28: Diesel mix at refinery Sphera
	GLO: Car diesel, Euro 6 (from September 2019), engine size more than 2l Sphera
Car diesel, large size Euro 6c	EU-28: Diesel mix at refinery Sphera
	GLO: Car diesel, Euro 6 (from January 2021), engine size more than 2l Sphera
Car petrol, small size Euro 0	EU-28: Gasoline mix (regular) at refinery Sphera
	GLO: Car petrol, controlled catalytic converter 87–90, engine size up to 1.4l Sphera
Car petrol, small size Euro 1	EU-28: Gasoline mix (regular) at refinery Sphera
	GLO: Car petrol, Euro 1, engine size up to 1.4l Sphera
Car petrol, small size Euro 2	EU-28: Gasoline mix (regular) at refinery Sphera
	GLO: Car petrol, Euro 2, engine size up to 1.4l Sphera
Car petrol, small size Euro 3	EU-28: Gasoline mix (regular) at refinery Sphera
	GLO: Car petrol, Euro 3, engine size up to 1.4l Sphera
Car petrol, small size Euro 4	EU-28: Gasoline mix (regular) at refinery Sphera
	GLO: Car petrol, Euro 4, engine size up to 1.4l Sphera
Car petrol, small size Euro 5	EU-28: Gasoline mix (regular) at refinery Sphera
	GLO: Car petrol, Euro 5, engine size up to 1.4l Sphera
Car petrol, small size Euro 6	EU-28: Gasoline mix (regular) at refinery Sphera
	GLO: Car petrol, Euro 6, engine size up to 1.4l Sphera
Car petrol, medium size Euro 0	EU-28: Gasoline mix (regular) at refinery Sphera
	GLO: Car petrol, controlled catalytic converter 87–90, engine size 1.4-2l Sphera
Car petrol, medium size Euro 1	EU-28: Gasoline mix (regular) at refinery Sphera
	GLO: Car petrol, Euro 1, engine size 1.4–2l Sphera
Car petrol, medium size Euro 2	EU-28: Gasoline mix (regular) at refinery Sphera
	GLO: Car petrol, Euro 2, engine size 1.4–2l Sphera
Car petrol, medium size Euro 3	EU-28: Gasoline mix (regular) at refinery Sphera
	GLO: Car petrol, Euro 3, engine size 1.4-2l Sphera
Car petrol, medium size Euro 4	EU-28: Gasoline mix (regular) at refinery Sphera
	GLO: Car petrol, Euro 4, engine size 1.4-2l Sphera
Car petrol, medium size Euro 5	EU-28: Gasoline mix (regular) at refinery Sphera
	GLO: Car petrol, Euro 5, engine size 1.4-2l Sphera

Table 1. *Cont.*

Process	Dataset
Car petrol, medium size Euro 6	EU-28: Gasoline mix (regular) at refinery Sphera
	GLO: Car petrol, Euro 6, engine size 1.4-2l Sphera
Car petrol, large size Euro 0	EU-28: Gasoline mix (regular) at refinery Sphera
	GLO: Car petrol, controlled catalytic converter 87–90, engine size more than 2l Sphera
Car petrol, large size Euro 1	EU-28: Gasoline mix (regular) at refinery Sphera
	GLO: Car petrol, Euro 1, engine size more than 2l Sphera
Car petrol, large size Euro 2	EU-28: Gasoline mix (regular) at refinery Sphera
	GLO: Car petrol, Euro 2, engine size more than 2l Sphera
Car petrol, large size Euro 3	EU-28: Gasoline mix (regular) at refinery Sphera
	GLO: Car petrol, Euro 3, engine size more than 2l Sphera
Car petrol, large size Euro 4	EU-28: Gasoline mix (regular) at refinery Sphera
	GLO: Car petrol, Euro 4, engine size more than 2l Sphera
Car petrol, large size Euro 5	EU-28: Gasoline mix (regular) at refinery Sphera
	GLO: Car petrol, Euro 5, engine size more than 2l Sphera
Car petrol, large size Euro 6	EU-28: Gasoline mix (regular) at refinery Sphera
	GLO: Car petrol, Euro 6, engine size more than 2l Sphera
Car Methane	DE: Methane Sphera
	GLO: Car CNG, Euro 3 Sphera
Car LPG	GLO: Car LPG, Euro 3 Sphera
Car Electric	GLO: market for transport, passenger car, electric Ecoinvent 3.5
Car Hybrid	GLO: market for transport, passenger car, electric Ecoinvent 3.5
	GLO: Passenger car, average, Euro 3-5, engine size from 1.4l up to >2l Sphera
Scooter	GLO: market for transport, passenger, motor scooter Ecoinvent 3.5
BUS	GLO: market for transport, regular bus Ecoinvent 3.5
Train	IT: transport, passenger train Ecoinvent 3.5
Sharing Mobility	GLO: Passenger car, average, Euro 3-5, engine size from 1.4l up to >2l Sphera
Aircraft	GLO: market for transport, passenger, aircraft Ecoinvent 3.5

Table 2. EF 3.0 normalization factors (person equivalents) and weighting factors.

Impact Category	Unit	Normalization Factors (Person Equivalents)	Weighting Factors
EF 3.0 Acidification	Mole of H+ Equation	0.017986	6.2
EF 3.0 Climate change—total	kg CO2 Equation	0.000124	21.06
EF 3.0 Ecotoxicity, freshwater–total	CTUe	2.34×10^{-5}	1.92
EF 3.0 Eutrophication, freshwater	kg P Equation	0.621118	2.8
EF 3.0 Eutrophication, marine	kg N Equation	0.051282	2.96
EF 3.0 Eutrophication, terrestrial	Mole of N Equation	0.00565	3.71
EF 3.0 Human toxicity, cancer—total	CTUh	53763.44	2.13
EF 3.0 Human toxicity, non-cancer—total	CTUh	4347.826	1.84
EF 3.0 Ionising radiation, human health	kBq U235 Equation	0.007246	5.01

Table 2. *Cont.*

Impact Category	Unit	Normalization Factors (Person Equivalents)	Weighting Factors
EF 3.0 Land use	Pt	4.48×10^{-7}	7.94
EF 3.0 Ozone depletion	kg CFC-11 Equation	20.66116	6.31
EF 3.0 Particulate matter	Disease Incidences	1680.672	8.96
EF 3.0 Photochemical ozone formation, human health	kg NMVOC Equation	0.02457	4.78
EF 3.0 Resource use, fossils	MJ	1.54×10^{-5}	8.32
EF 3.0 Resource use, mineral and metals	kg Sb Equation	15.72327	7.55
EF 3.0 Water use	m^3 World Equiv.	8.70×10^{-5}	8.51

3. Results

3.1. Analysis of the EF 3.0 eco-Indicator for Transport Modes

In Table 3, for each transport mode, and distinguishing between hot and cold seasons, kilometers are compared with the EF 3.0 eco-indicator calculated, multiplying the former by the relative impact per kilometer. It is essential to point out that the contribution of fuel production is about 15% in the case of diesel cars and over 20% for petrol cars; the rest of the impacts refer to the other phases of the life cycle. At the same time, it is worth noting that a large-sized Euro 5 diesel car presents a value a little higher than that of the same Euro 4 vehicles (around 5% more).

Table 3. Kilometers vs. EF 3.0 eco-indicator for both the hot and cold seasons.

	km		EF 3.0 Eco-Indicator		
	Hot Season	Cold Season	per km	Hot Season	Cold Season
Car diesel, small size Euro 0	0	1320	1.29×10^{-3}	0.00	1.71
Car diesel, small size Euro 1	0	66	1.31×10^{-3}	0.00	0.09
Car diesel, small size Euro 2	752	1328	1.14×10^{-3}	0.85	1.51
Car diesel, small size Euro 3	44,658	67,670	1.03×10^{-3}	46.13	69.90
Car diesel, small size Euro 4	58,984	105,345	9.39×10^{-4}	55.39	98.92
Car diesel, small size Euro 5	5500	18,827	1.02×10^{-3}	5.59	19.15
Car diesel, small size Euro 6	15,937	12,891	8.20×10^{-4}	13.07	10.58
Car diesel, small size Euro 6b	2240	4662	6.69×10^{-4}	1.50	3.12
Car diesel, small size Euro 6c	12,888	22,758	6.44×10^{-4}	8.31	14.67
Car diesel, medium size Euro 0	0	0	1.71×10^{-3}	0.00	0.00
Car diesel, medium size Euro 1	4260	0	1.71×10^{-3}	7.27	0.00
Car diesel, medium size Euro 2	15,698	34,581	1.50×10^{-3}	23.60	51.98
Car diesel, medium size Euro 3	131,916	239,685	1.31×10^{-3}	172.51	313.44
Car diesel, medium size Euro 4	199,252	372,083	1.13×10^{-3}	225.97	421.98
Car diesel, medium size Euro 5	154,650	283,778	1.20×10^{-3}	186.34	341.93
Car diesel, medium size Euro 6	121,688	234,502	9.99×10^{-4}	121.52	234.17
Car diesel, medium size Euro 6b	50,696	84,202	8.47×10^{-4}	42.93	71.31

Table 3. *Cont.*

	km		EF 3.0 Eco-Indicator		
	Hot Season	**Cold Season**	**per km**	**Hot Season**	**Cold Season**
Car diesel, medium size Euro 6c	90,631	161,111	8.23×10^{-4}	74.55	132.53
Car diesel, large size Euro 0	0	0	2.07×10^{-3}	0.00	0.00
Car diesel, large size Euro 1	0	0	2.06×10^{-3}	0.00	0.00
Car diesel, large size Euro 2	0	0	1.82×10^{-3}	0.00	0.00
Car diesel, large size Euro 3	7596	14,564	1.58×10^{-3}	12.00	23.00
Car diesel, large size Euro 4	14,787	30,571	1.44×10^{-3}	21.26	43.94
Car diesel, large size Euro 5	13,992	18,568	1.47×10^{-3}	20.53	27.25
Car diesel, large size Euro 6	2728	6208	1.23×10^{-3}	3.36	7.65
Car diesel, large size Euro 6b	6240	10,920	1.08×10^{-3}	6.74	11.79
Car diesel, large size Euro 6c	1710	3867	1.06×10^{-3}	1.81	4.08
Car petrol, small size Euro 0	0	83	1.46×10^{-3}	0.00	0.12
Car petrol, small size Euro 1	2971	13,674	1.43×10^{-3}	4.24	19.52
Car petrol, small size Euro 2	5968	12,974	1.28×10^{-3}	7.65	16.64
Car petrol, small size Euro 3	28,050	55,630	1.06×10^{-3}	29.73	58.97
Car petrol, small size Euro 4	70,413	142,469	1.00×10^{-3}	70.71	143.07
Car petrol, small size Euro 5	21,117	38,547	9.51×10^{-4}	20.08	36.66
Car petrol, small size Euro 6	26,970	59,364	9.15×10^{-4}	24.69	54.34
Car petrol, small size Euro 6b	7227	11,670	9.15×10^{-4}	6.62	10.68
Car petrol, small size Euro 6c	9389	22,584	9.15×10^{-4}	8.60	20.67
Car petrol, medium size Euro 0	0	0	1.79×10^{-3}	0.00	0.00
Car petrol, medium size Euro 1	0	0	1.71×10^{-3}	0.00	0.00
Car petrol, medium size Euro 2	3784	6718	1.55×10^{-3}	5.85	10.39
Car petrol, medium size Euro 3	6696	18,953	1.30×10^{-3}	8.67	24.55
Car petrol, medium size Euro 4	24,232	35,049	1.19×10^{-3}	28.93	41.84
Car petrol, medium size Euro 5	12,502	27,028	1.13×10^{-3}	14.15	30.59
Car petrol, medium size Euro 6	7830	10,880	1.08×10^{-3}	8.45	11.74
Car petrol, medium size Euro 6b	19,983	48,143	1.08×10^{-3}	21.56	51.95
Car petrol, medium size Euro 6c	7261	15,131	1.08×10^{-3}	7.84	16.33
Car petrol, large size Euro 0	0	0	2.21×10^{-3}	0.00	0.00
Car petrol, large size Euro 1	0	0	2.15×10^{-3}	0.00	0.00
Car petrol, large size Euro 2	0	0	1.97×10^{-3}	0.00	0.00
Car petrol, large size Euro 3	0	0	1.71×10^{-3}	0.00	0.00
Car petrol, large size Euro 4	636	1254	1.65×10^{-3}	1.05	2.06
Car petrol, large size Euro 5	0	0	1.58×10^{-3}	0.00	0.00
Car petrol, large size Euro 6	57	99	1.53×10^{-3}	0.09	0.15
Car petrol, large size Euro 6b	0	0	1.53×10^{-3}	0.00	0.00

Table 3. *Cont.*

	km		EF 3.0 Eco-Indicator		
	Hot Season	Cold Season	per km	Hot Season	Cold Season
Car petrol, large size Euro 6c	0	0	1.53×10^{-3}	0.00	0.00
Car Methane	91,705	179,936	1.13×10^{-3}	103.23	202.56
Car LPG	136,954	259,970	1.19×10^{-3}	162.81	309.06
Car Electric	0	0	4.36×10^{-3}	0.00	0.00
Car Hybrid	13,901	36,493	1.84×10^{-3}	25.57	67.11
Scooter	1087	6091	1.54×10^{-3}	1.68	9.39
BUS	1,640,107	3,723,199	1.42×10^{-3}	2334.35	5299.19
Train	2,796,495	5,928,588	7.44×10^{-4}	2080.27	4410.18
Sharing Mobility	329	828	3.02×10^{-4}	0.10	0.25
Aircraft	27,000	80,700	1.22×10^{-3}	33.04	98.75

The same situation is highlighted for medium-sized diesel cars, Euro 5 to Euro 4 cars, and for small-size diesel cars, Euro 4 to Euro 5. Furthermore, Table 3 shows, concerning electric or hybrid vehicles and methane cars, how their performances are not so sustainable, which is in line with other previous studies. This is principally due to the technological aspects linked to production and disposal, especially for batteries, and also the prevalence of fossil fuels in the power mix [35,38–46]. The accuracy of these results derives from the use of proxy data of the Sphera and Ecoinvent data sets used in the analysis, so we can assert that according to the results shown in Table 3, sharing mobility and public transport remain the most sustainable choices from a life cycle perspective.

3.2. The Environmental Performances of Mobility at the University of Foggia

The results in Table 3 are summarized in Figures 1 and 2, in which relative contributions of the primary transport mode are compared with the relative kilometers for the hot and cold seasons, respectively. The train appears attractive because while it represents over 47% of the total kilometers, its contribution in terms of impact is only almost 35%. On the other hand, as for the bus, its contribution of nearly 30% to the total kilometers becomes over 38% if its relative contribution is translated in terms of emissions. In the same way, the contribution of diesel cars changes from almost 14% in kilometers to over 17% concerning the eco-indicator. Regarding petrol cars and other transport modes, the percentage of the total impact does not change significantly concerning kilometers. As in the hot season, the train and bus covered around 75% of the total kilometers traveled in the cold season, and their advantages in terms of environmental performance, especially regarding the use of trains, are highlighted in Figure 2. The relationship between impact and kilometers of diesel and petrol cars appears slightly lower than that of the hot season due to the increase in the use of small cars. This is not true for the other transport modes, for which the same relationship highlighted for the hot season is detected.

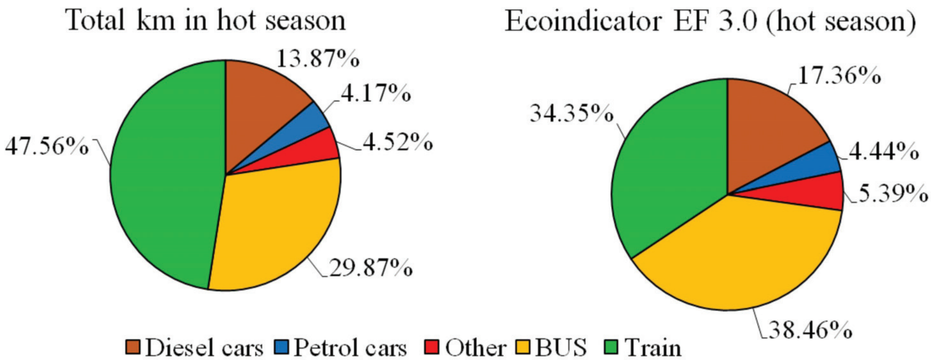

Figure 1. Contribution of the main transport mode in the hot season.

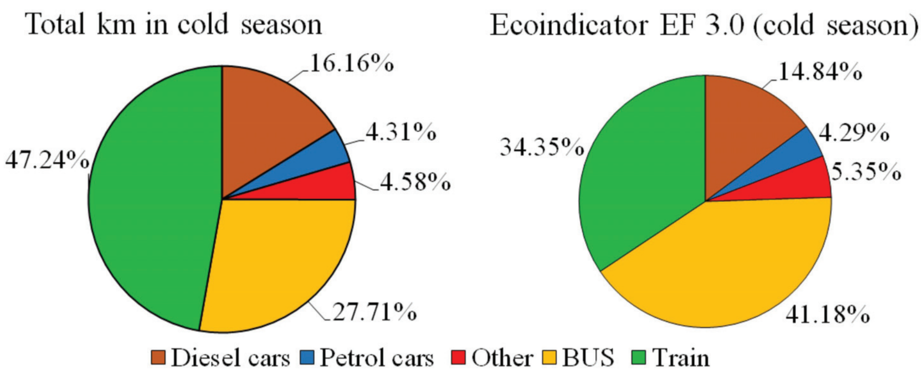

Figure 2. Contribution of the main transport mode in the cold season.

3.3. Benchmarking Sustainable Mobility in Higher Education

Starting from this analysis and considering the elaboration of the information collected through the survey at the University of Foggia, it is possible to formulate a simple indicator that is easy for all stakeholders in higher education to understand. The Sustainable Mobility Indicator (*SMI*) aims to express by a non-dimensional number the environmental performance class of the overall community. The value is calculated according to Equation (1).

$$SMI = \frac{\sum_{i=1}^{n}(kmi \times Ei)}{\sum_{i=1}^{n} kmi} \tag{1}$$

where:

- *kmi* represents the number of kilometers traveled using each transport mode, respectively, and for a certain period (year, season, week, etc.);
- *Ei* is the eco-indicator (in our case the EF 3.0 eco-indicator) calculated for the relative transport mode.

The SMI calculated according to Equation (1) could be compared with the best environmental performance deriving from the adoption of the best transport solution for all kilometers traveled. This latter is, in fact, the benchmark, and as the SMI negatively deviates from it, the performance class becomes worse. Table 4 shows the hypothesis of five performance classes calculated by multiplying the benchmark per 2, 4, 6, and 8, respectively. In the case of the University of Foggia, the situation is described in Figure 3. The performance class appears good. Indeed, the SMI is located in the first range.

Table 4. Hypothesis of performance classes.

Performance Classes	Range	SMI	SMI UNIFG (Hot Season)	SMI UNIFG (Cold Season)
A	From Benchmark to Benchmark $\times 2$	From 7.44×10^{-4} to 1.49×10^{-3}	1.02×10^{-3}	1.03×10^{-3}
B	From Benchmark $\times 2$ to Benchmark $\times 4$	From 1.50×10^{-3} to 2.98×10^{-3}		
C	From Benchmark $\times 4$ to Benchmark $\times 6$	From 2.99×10^{-3} to 4.46×10^{-3}		
D	From Benchmark $\times 6$ to Benchmark $\times 8$	From 4.47×10^{-3} to 5.95×10^{-3}		
E	From Benchmark $\times 8$ to Benchmark $\times 10$	Over 5.95×10^{-3}		

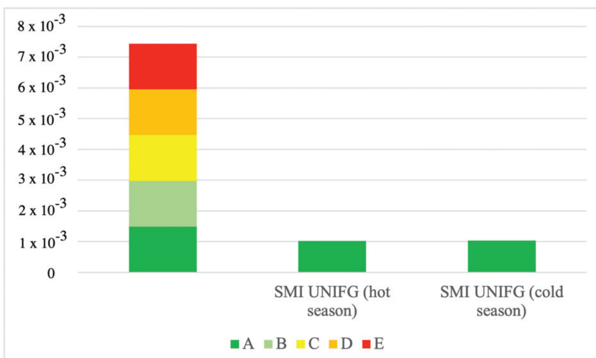

Figure 3. Comparison of the SMI between different performance classes.

4. Conclusions

The approach proposed in this paper for benchmarking sustainable mobility in higher education is based on the information collected by the use of a survey, as well as the environmental impact associated with the choice of transport mobility. It aims to elaborate performance classes based on a standardized methodology and communicate in an easier way the sustainability of transport modes by using the SMI. To enhance the model, it could be useful to stratify the sample and direct further analysis toward the attribution of an environmental profile for each component of the academic community. Despite limits and constraints linked to a large amount of data and information needed, this could play a crucial role in assessing the effects of mobility choices and evaluating their environmental implications.

This information could be very useful in managing mobility policies and addressing the sustainable habits of all community members. Further interesting analysis could be, for example, focused on the consequences of distance learning from a life cycle perspective. The advantages deriving from the lack of travel should be compared with the increasing use of energy (used for servers, computers, and electronic devices). In this way, the environmental profile determined by the SMI could be enriched with additional elements calculated according to LCA. Furthermore, the benchmarking phase in this paper is represented by the best situation for the particular organization, which could be referred to as an average performance identified by considering some specific parameters (e.g., geographical context, level of public investments in sustainable mobility of infrastructures). In the future, a certification system could be considered, and guidelines based on the approach proposed in this paper could represent a milestone in assessing sustainability in higher education and encourage sustainable choice in transport mode.

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sustainability

Article

An Exploratory Study Examining the Key Aspects and Actions for Universities to Achieve High Sustainability Rankings

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Abstract: Understanding the concept of sustainability and its implementation in specific actions is necessary for today's societies, and part of this responsibility falls on Higher Education Institutions. How these institutions have tried to address this issue has been diverse. To standardize, homogenize, and validate these sustainable practices, a few years ago, the University of Indonesia Green Metric positioned itself as the internationally accepted ranking; however, other rankings have begun to emerge, such as the Times Higher Education Impact Ranking, which also addresses the search for compliance of the SDGs. For a novel or incipient university to establish the politics and actions to fulfill sustainability and SDGs or stay on track may represent a disorienting and challenging task, particularly when these rankings have different origins or criteria. So, this research aimed to review the top ten universities and their actions in the University of Indonesia Green Metric and Times Higher Education Impact Ranking, along with the organizational initiatives in education, to clarify the key measures and actions adopted by universities toward sustainability and their participation in the rankings, to pursue the SDGs related to social and environmental impacts in universities. Additionally, as a case study, we analyzed in detail the actions performed by the Tecnologico de Monterrey (located at the 274th and 100–200th places of the University of Indonesia Green Metric and the Times Higher Education Impact Ranking, respectively) and compared them with those of Top Ten Higher Education Institutions in both rankings. As a result, a summary guide of the actions is suggested to guide higher education institutions in adopting the required level of sustainability development indicated in the rankings.

Keywords: sustainability; sustainable development goals (SDGs); university rankings; higher education; environmental education; educational innovation

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1. Introduction

Although its original use was in forestry, the term sustainability quickly spread into the academic lexicon. It was defined in 1987 as "*development activity that meets the needs of the present without compromising the ability of future generations to meet their own needs*" in the Brundtland Report of the World Commission on Environment and Development [1,2]. Initially restricted to purely environmental aspects, this concept was strengthened with other elements to become an integrated approach with three dimensions: ecological, economic, and social [3]. In 2015, the United Nations General Assembly, at its 70th session, established 17 Sustainable Development Goals (SDGs) [4–6].

On the other hand, to assess the impact, quality, and reputation of Higher Education Institutions (HEIs) in the Global University Rankings (GURs), the Quacquarelli Symonds (QS) World University Ranking® is probably the most accepted methodology [7]. This metric considers only six indicators: academic reputation, employer reputation, faculty citations, faculty–student ratio, international-student ratio, and international-faculty ratio. By 2023, the *QS Ranking* will assess the contribution of academic institutions to sustainable development through two new categories: social and environmental impacts. Some SDGs will guide efforts in two new categories that will be included in the 2023 Ranking Metric to measure the contribution of academic institutions to sustainable development. Considering the definitions of the SDGs and in terms of Social and Environmental Impacts, the category will be defined as shown in Table 1.

Table 1. SDGs included in the *2023 QS Ranking Metric*. (Source: own elaboration).

Social Impacts			
SDG5	Gender Equality	**SDG10**	Reduced Inequalities
Environmental Impacts			
SDG7	Affordable and Clean Energy	**SDG13**	Climate Action
SDG11	Sustainable Cities	**SDG14**	Life Below Water
SDG12	Responsible Consumption and Production	**SDG15**	Life on Land

Another GUR is the *Times Higher Education World University Rankings* (THE-WUR), which focus on research activity, measuring teaching, research, citations, industry revenue, and international outlook as indicators [8]. It should be noted that none of these indicators are related to sustainability, even though many educational institutions have begun to incorporate some "sustainability level" measures for years, mainly due to a growing concern about the environmental crisis and the consequences of climate change [9]. From the point of view of future students and considering that they usually make decisions based on the GRUs, it is striking that the GRUs still do not incorporate any sustainability considerations into their indicators [10].

From 2010–2018, the National Union of Students of the United Kingdom (NUS-UK) survey was carried out among students worldwide. They were asked about their expectations regarding sustainable development in their universities: 70% of this population indicated that they would like to see sustainability promoted through all their courses, and only 17% stated that their universities had good actions to limit their negative impact on the environment and society [11]. This survey showed university students' interest and global commitment to sustainability issues and the undeniable impact that universities have as social agents of change, and their ability to influence environmental policies and strategies [9].

Until now, the most ambitious project to measure the direct impact generated by sustainability strategies in universities has been the *UI GreenMetric*, created in 2010 by the University of Indonesia (UI). This sustainability ranking has been consolidating and spreading worldwide for a decade. In 2019, Puertas and Martí proposed the Data Envelopment Analysis (DEA)-Green Metric, a complement to the *UI GreenMetric*, to analyze the contribution of each university, categorizing universities into four groups depending on their level of sustainability: high, medium–high, medium–low, and low [12]. In 2020, Peirchinunno and Cazzolle re-evaluated and validated the *UI GreenMetric* with university campuses, defining it as an attractive and officially valid global sustainability ranking [13]. The *UI GreenMetric* allows for the identification of the areas of focus and opportunity of the efforts of each university and can also be used regionally to analyze sustainability in neighboring countries or globally to compare strategies of universities on different continents. The weight of the criteria in *UI GreenMetric* [14] is shown in Figure 1.

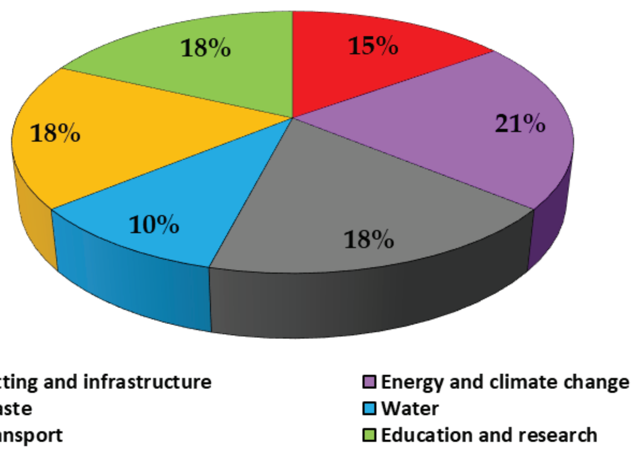

Figure 1. Weight of criteria in *UI GreenMetric*. (Source: own elaboration).

A recently developed but less known scale is the Times Higher Education (*THE Impact Ranking)*, founded in 2019, that assesses universities under the UN SDGs with calibrated indicators that provide comparisons across four areas: research, administration, outreach, and teaching [8]. A university's final score is calculated by combining its score on SDG17 (weight 22%) with its three highest scores of the remaining 16 SDGs (weight 26%). Under this aspect, the universities are qualified by different SDGs according to their approach [15].

At the European level, universities and other educational and training institutions work toward campus sustainability and a sustainable skills framework. Regarding the sustainability of the campus, the initiatives have been based on using internal policies such as *New European Bauhaus* [16] or *Level(s)* [17]. The first aims to educate and train architects and engineers with examples and prize competition. The second is aimed at successful buildings in terms of sustainable performance to act as data providers. Other initiatives related with the sustainable mobility policies and university governance strategies are the studies by Cappelletti et al. [18] and Sisto et al. [19]. In the 2020 study, Cappelletti et al. explain the details of the application of Machine Learning techniques to analyze aspects of sustainable mobility on the campus of the University of Foggia, Italy. In the 2022 study, Sisto et al. present a retrospective focus on the contribution of universities to the challenge of sustainability and a discussion of the most effective actions to improve sustainability within the strategic plan of the 2030 Agenda.

Regarding the sustainable competency framework, the leading development has been the *GreenComp* framework of graduate sustainability competencies [20]. This framework targets the organizational and individual levels of knowledge, skills, and attitudes necessary for sustainable performance. Several European schools and projects have adopted *GreenComp* as the primary guide for updating the curriculum. A recent example is the CALOHEE project [21], which has included *GreenComp* requirements in proposed quality frameworks in various areas of higher education, such as computer science, nursing, civil engineering, history, physics, and teacher education.

Since 2017, few studies have been reported on the general work of HEIs evaluating cases in sustainability. In 2018, Albareda-Tiana et al. evaluated education for sustainable development through the SDGs in teaching practices at the International University of Catalonia (IUC), Spain, with a mixed methodology (qualitative and quantitative) in data collection using university curricula and interviews with staff [22]. These authors revealed the future challenges and opportunities in the training of IUC graduates. However, they did not offer specific information on the actions or activities carried out for that university; they also only considered the contributions in the teaching aspect. In 2019, Mawonde and Togo presented as a case study the incorporation of the SDGs in the operation of the Johannesburg campus at the University of South Africa [23]. They found that the practices with the SDGs in teaching, research, and the community are aligned with the campus management, with student participation being the only limitation because this is a distance education institution, so the highlight of this study was that online education also plays an active role in the implementation of sustainability.

In addition to the studies related to university sustainable development initiatives, it is essential to highlight the numerous publications related to initiatives, projects, and activities aimed at strengthening the 17 SDGs by international associations for professional development. In particular, the contributions of recent years by the *International Association for Continuing Engineering Education* (IACEE, https://www.iacee.org/ (accessed on 1 February 2023)) and the *European Society for Engineering Education* (SEFI, https://www.sefi.be (accessed on 1 February 2023)) can be mentioned. These organizations have exerted a profound influence on global initiatives for sustainability since the active members of their Council and Executive Boards are researchers at prestigious universities.

This study aims to discuss the actions of the top ten universities (in the *UI GreenMetric* and the *THE Impact Ranking*) regarding sustainability. It also analyses the organizational initiatives in education that have arisen internationally. The study also includes the case of the Tecnológico de Monterrey, in Mexico, because of its privileged position in both rankings and its sustainability plan with measured results to participate in sustainability and SDG implementation through five dimensions (culture, mitigation, adaptation, education, research, and outreach). The Results and Discussion section also includes an analysis of the purposes and actions of the Tecnológico de Monterrey to discover and understand how these have contributed to the Tecnologico's positioning. Additionally, some examples will be presented on the role played by international associations to promote sustainability initiatives with member universities. Finally, a discussion guide and recommendations for universities on the path to sustainability will be developed.

2. Materials and Methods

This exploratory study uses a phenomenological methodology to determine the instances, examples, and scenarios that would allow for examining the phenomenon of the positioning of universities in the ecosystem of innovation and sustainability [24]. For this, the case parameters were defined, and the limits of what is included and what is excluded were established, considering the approaches used to collect and analyze the data.

Regarding the approaches explored in the literature review, the alternative index built from the variables used in the *UI GreenMetric*, developed through data envelopment analysis (DEA) [12], stands out. This methodology was the one that allowed for classifying all the universities according to their contribution to sustainability, to identify the possible critical factors for the sustainability of HEIs, and to guide their institutional policies toward the elements that require immediate attention. The purpose of the research was to provide descriptive information, suggest theoretical relevance, and allow a deeper understanding of the phenomenon of sustainability rankings for HEIs. In addition, we analyzed the actions and programs that the Tecnologico de Monterrey has carried out in its development in the sustainability rankings. For this, the "2025 Sustainability and Climate Change Plan" [25] document and the results one year after implementation were consulted.

3. Results and Discussion

3.1. Sustainability and Universities

According to the 2021 *UI GreenMetric* ranking, the top ten universities in sustainability are the Wageningen University & Research (WUR), University of Nottingham (UN), University of Groningen (UG), Nottingham Trent University (NTU), University of California, Davis (UCD), Umwelt-Campus Birkenfeld (Trier University of Applied Sciences) (U-CB (TUAS)), Leiden University (LU), University College Cork (UCC), University of Connecticut (UC), and University of São Paulo (USP) [26]. From this list, three institutions belong to the Netherlands, two to the United Kingdom, and two to the USA. In Figure 2, the universities in the first positions stand out for their scores in the energy criteria and climate change, comprehensive waste management, and education and research in sustainability.

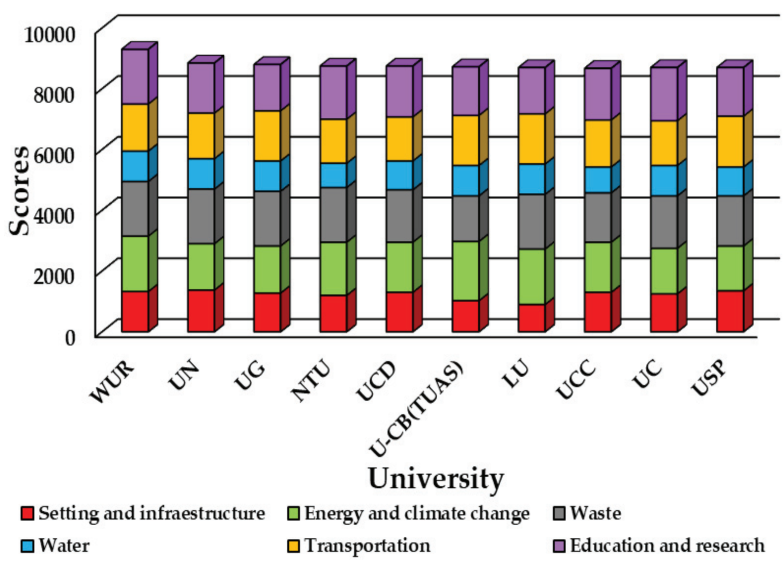

Figure 2. Scores of top ten universities in *UI GreenMetric* for sustainability. The bars' colors indicate the extent of the score of the corresponding element. The Wageningen University & Research (WUR), University of Nottingham (UN), University of Groningen (UG), Nottingham Trent University (NTU), University of California, Davis (UCD), Umwelt-Campus Birkenfeld (Trier University of Applied Sciences) (U-CB (TUAS)), Leiden University (LU), University College Cork (UCC), University of Connecticut (UC), and University of São Paulo (USP). (Source: own elaboration).

The 2020 data of the *UI GreenMetric* allow us to observe that the universities in the first positions present high values in the categories of integrated waste management, water and education, and research in sustainability; the institutions located at medium–high levels are strong in waste, education, and research; and the universities with low scores have a particular deficiency in water treatment [26].

Once, the *UI GreenMetric* online site (https://greenmetric.ui.ac.id/ (accessed on 1 February 2023)) was consulted for the top ten sustainable universities, and the associated scores and positions were organized to be displayed graphically. Subsequently, specific actions/activities were searched on the web pages of these institutions in terms of sustainability, and a comparative table was prepared, inquiring about the activities implemented in terms of sustainability by the top universities of the *UI GreenMetric*. Various actions were found in their sustainability reports as shown in Table 2. Reducing carbon emissions, recharging points for electric cars and e-bikes, waste separation, sustainable buildings, sustainable restoration, mowing for biodiversity, renewable energy generation, green startups, natural gardens, and a green and healthy campus are sustainable actions carried out by the universities.

Table 2. Sustainability actions reported by top ten universities of the *UI GreenMetric.* (Source: own elaboration).

University	Actions and Activities	References
Wageningen University & Research	Decreasing carbon emissions, charging points for electric cars and e-bikes, waste separation (>15 waste flows), sustainable buildings, sustainable catering, mowing for biodiversity, generating renewable energy, green startups, natural gardens, and a green and healthy campus.	[27]
University of Nottingham	Between 2010 and 2020, the university succeeded in reducing its carbon emissions by nearly 40%. The university sets out the pathway to achieve net zero carbon emissions by 2040 or earlier. They have the Green Rewards initiative, an interactive program for all staff and students at the university. It rewards the everyday behaviors and actions that improve sustainability and well-being in monthly prizes.	[28]
University of Groningen	In its roadmap to sustainability, the university's goal is to reach a 30% CO_2 reduction in 2026 (compared to 2019) and be CO_2 neutral in 2035. They expect more involvement in sustainability from students, staff, and external parties while applying a sustainable human resources policy for a dynamic and vital organization encouraging sustainable behavior among staff and students integrally.	[29]
Nottingham Trent University	The university is focusing not only on energy use (which is responsible for 14% of NTU's emissions outputs) but also on supply chain, travel, and working-from-home outputs, among others. They have set interim milestones of a 24% reduction in carbon emissions by 2025 and a 50% reduction by 2030. They have established a net zero carbon governance structure that implements projects to deliver the necessary carbon reductions in particular areas.	[30]
University of California, Davis	UC Davis offers a wide range of sustainability coursework, with over 60 percent of academic departments offering sustainability-related courses. Thirty-five percent of employees who conduct research are engaged in sustainability-related research. Through its Climate Action Plan, the campus has reduced greenhouse gas emissions below the year 2000 levels and is working to reach carbon neutrality by 2025.	[31]
Umwelt-Campus Birkenfeld Trier University	The university has a photovoltaic installation on the rooftops that generates approx. 520 MWh annually, which covers approx. 52% of the total amount of energy required if it were fed directly into the campus grid. Additionally worthy of note is the fact that approx. 372 tons of CO_2 emissions are annually saved due to the PV installation. The university also cools with CO_2-neutral heat.	[32]
Leiden University	In its vision toward 2030, this university outlines four actions: sustainability in teaching, sustainability in research, sustainable campus, and awareness and involvement. The students are trained to become academic professionals with the knowledge and skills needed to contribute to the transition to sustainability. Research is used to gain more insight into global sustainability issues and to develop knowledge for correct and proportional solutions. A green, circular campus with a significant energy reduction by 2050 as its goal is specified in the Energy Transition Roadmap for University Buildings.	[33]

Table 2. *Cont.*

University	Actions and Activities	References
University College Cork	In 2019, UCC Green Campus established the Living Laboratory Seed Fund to research and address real-life problems using the UCC campus as a testbed. From here, they have reached a 56% decline in waste between 2019 and 2020. The amount of general waste, mixed dry recyclables, and food waste declined in 2020.	[34]
University of Connecticut	Total campus greenhouse gas emissions declined despite increasing the campus building square footage and student enrollment. It reached 19.5% annual greenhouse gas emissions reduction, compared to a 2007 baseline, and 3860 tons of greenhouse gas emissions reduced from campus-wide LED projects since 2015. Additionally, 355,530 ft^2 of land is disconnected from storm drainage, protecting surface water quality and natural hydrology through low-impact development.	[35]
Universidade de São Paulo	The university created the Environmental Management Superintendence (EMS) in 2012 to plan, implement, maintain, and promote environmental sustainability on the campuses. It seeks to incorporate the environmental dimension of sustainability into all university policies, plans, and activities, whether in teaching, research, extension, or management.	[36]

Considering the *THE Impact Ranking*, the top ten universities are [37]: Western Sidney University (WSU), Arizona State University (ASU), Western University (WU), King Abdul Aziz University (KAU), University Sains Malaysia (USM), University of Auckland (UA), Queen's University (QU), Newcastle University (NU), University of Manchester (UM), and Hokkaido University (HU). The top SDGs developed were SDG17 (association of goals), followed by SDG9 (industry, innovation, and infrastructure) and SDG11 (sustainable cities and communities).

Thus, as observed, to maintain or improve their current positions, the universities must seriously adopt sustainability as their purpose. The concept of sustainability requires universities to simultaneously address all dimensions, including sustainability principles in their curricula, not with isolated efforts but as a joint strategy of several departments—managerial, administrative, and academic—of the institution. Therefore, it is essential to investigate and analyze which are the leading universities in the *UI GreenMetric*, what strategies have been implemented to reach these positions, and how they have interacted with government and societal actors. Although it was believed that the existence of robust and sustainable development policies in HEIs was a precondition for successful sustainability, this was proven wrong according to the results of research published in 2018 that involved 35 universities from seven countries (Brazil, Germany, Greece, Portugal, South Africa, United Kingdom, and the USA) [38].

3.2. Case Study of Tecnologico de Monterrey, in Mexico

According to the *UI GreenMetric* in 2021, the Tecnologico de Monterrey (TEC MTY), in Mexico, was ranked in the 274th position with a total score of 6825 points, with the highest score in education and research on sustainability (1575 points) and the lowest in water management (750 points). At the regional level, TEC MTY occupies the 29th place in Latin America. Meanwhile, it ranks 11th in Mexico [14]. When historical data (scores and rankings) are analyzed, TEC MTY has been in different places since its inclusion in 2016 in the *UI Green Metric* (Figure 3). In the beginning, TEC MTY reached the 184th position when only 515 universities participated in the ranking. This evolved with the incorporation of more universities, rendering a lower ranking, achieving 584th place. Still, in 2020, the institution improved its position despite adding new universities to the study (956) in 2021 [26].

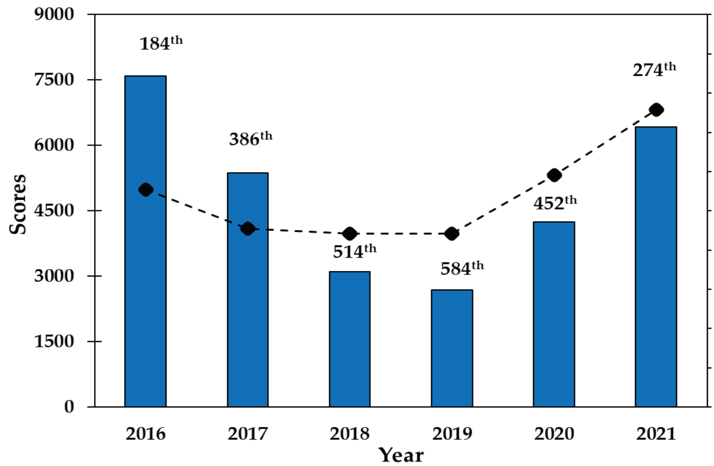

Figure 3. Historical ranking and scores of TEC MTY in *UI GreenMetric* for sustainability evaluation. (Source: own elaboration).

Considering the *THE Impact Ranking 2022*, the TEC MTY is between the 100 and 200th place with the participation of 1410 universities; this position has been preserved for the last three years (Figure 4). The universities have gradually been incorporated into this ranking; for the first time, 467 universities participated, and the TEC MTY ranked 90th. In the following years, there were up to 1117 in 2021 [37], and TEC MTY kept a similar place. The SDGs that have been best evaluated for TEC MTY are SDG5 (gender equality), SDG6 (clean water and sanitation), SDG11 (sustainable cities and communities), and SDG12 (responsible production and consumption).

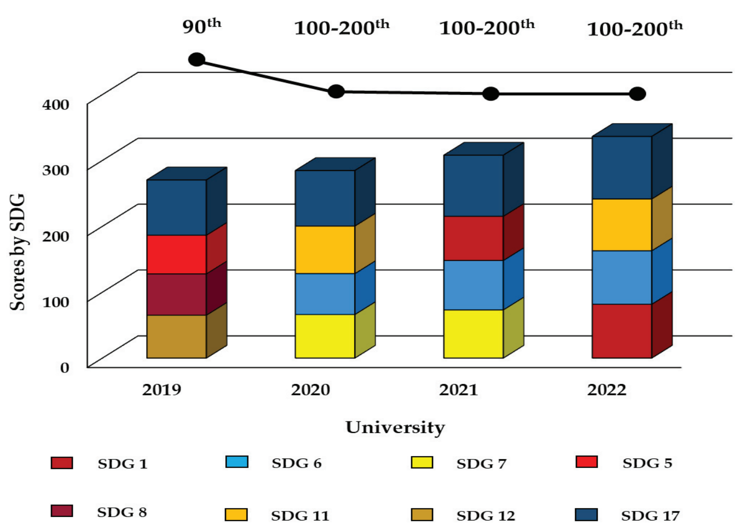

Figure 4. Historical ranking and scores by SDGs of TEC MTY in *THE Impact Ranking*. (Source: Own elaboration).

An investigation was carried out to know the particular actions of TEC MTY in terms of sustainability, finding that TEC MTY has a Sustainability Plan with clear objectives and actions to be carried out, which is public to the entire TEC MTY school community [25].

In April 2021, the TEC MTY presented its "2025 Sustainability and Climate Change Plan" to help reduce the impact of climate change and strengthen the internal culture of sustainability [25,39]. A year later, the Vice Presidency of Inclusion, Social Impact, and Sustainability generated a report with progress. Its impact will not be observed in the *UI GreenMetric* until the publication of the 2022 ranking. However, it can be inferred that some of the actions carried out so far can be closely related to the scores achieved in this metric in 2021 and the *THE Impact Ranking* in 2022. The plan comprises six dimensions: culture, mitigation, adaptation, education, research, and dissemination. The 28% reduction in greenhouse gas emissions compared to 2019 and reaching 100% renewable energy consumption in the institution's hospitals were the most relevant innovations in sustainability. The objectives and progress by 2022 are briefly mentioned in Table 3.

Table 3. Objectives, actions, and advances reported as part of the 2025 Sustainability and Climate Change Plan from TEC MTY. (Source: own elaboration).

Dimension	Objectives	Actions and Advances Reported in 2022
Culture	Implement an institution-wide culture of sustainability in each operating, leadership, and educational process.	Creation of a guide for sustainable events (recommendation for institutional events). The generation of 115.84 kg of CO_2 was avoided.
Mitigation	Reduce the institution's environmental impact by lessening our carbon footprint and driving circular water and integrated waste management.	Implementation of the first sustainability auto-evaluation per campus in energy, fuels, water, waste generation, and vehicles. A 63% of energies from clean sources was reached (increment of 9% annually).
Adaptation	Reduce the vulnerability to the present and future impacts of climate change and grow our capacity for resilience and adaptation to conditions generated by the environmental crisis.	Inventory of trees for promoting actions for their future care and maintenance.
Education	Prepare the Tecnologico de Monterrey students and faculty on climate change topics through education for sustainable development in curricular and co-curricular activities.	Implementation and mapping of SDGs in curricula.
Research	Drive interdisciplinary research to provide systemic solutions that will fully address the complexity of climate change and support sustainable development.	Mapping of research projects about climate change and sustainability for the future design of Research Interdisciplinary Funding.
Outreach	Be active in local, national, and global partnerships for sustainability and climate change, ensuring our academic, scientific, and technological capacities are available to society and fomenting the acceleration of processes toward sustainability.	Presentation of the Sustainability and Climate Change 2025 plan at the United Nations Climate Change Conference (COP26) in Glasgow in October 2021. Consolidation of the Lifelong Learning Green Academy, which is project oriented to form leaders from the private sector in sustainability and climate change.

Some goals and actions under the TEC MTY Sustainability plan [25] are summarized in Table 4. Additionally, as part of the commitments signed by the TEC MTY in 2019 under *the Global Climate Charter for Universities and Colleges on education* and in the education dimension, the institution has established a general goal "*to train students and teachers on climate change issues through education in sustainable development in the curricular and co-curricular activities of the institution, with the purpose that everyone has knowledge about climate change and sustainable development*". TEC MTY has undertaken a comprehensive academic vision of implementing actions to comply with the SDGs inside and outside the institution.

Table 4. Goals and actions in culture, mitigation, and adaptation of TEC MTY for achieving sustainability. (Source: own elaboration).

Aspect	Culture	Mitigation	Adaptation
Goals	Respect and nature care. Saving and moderation in all our daily actions. Empowerment and co-responsibility toward sustainability. The vision of global change, recognizing the vulnerability of human beings, and promoting better planning. The alignment of policies and procedures toward sustainability.	Provide 80% of the energy consumed from renewable sources. Reduce by 20% energy consumption per m^2. Reduce up to 50% of campus greenhouse gas emissions. Savings of 20% in water consumption. Design a comprehensive waste management strategy and implement it.	Generate vulnerability diagnoses of climate change on 100% of the Tec's facilities. Preparation of adaptation plans for each campus with three approaches: disaster risk reduction, an adaptation based on ecosystems (reforestation), and community-based adaptation (boost adaptability in vulnerable communities). Design a strategy for implementing and following the adaptation measures for the facilities with the highest risks.
Actions	Ensure awareness of environmental sustainability of all the community. Create communication and awareness campaigns in the community. Offer activities and programs to experience sustainability in the different internal areas. Establish drinking fountains with thermos fillers. Measure the behavior change index (consumption of office materials, waste generation, and food waste in cafeterias).	Supply of solar and wind energy through contracts and self-generation infrastructure. Reduce energy consumption. Replacement of lights and air conditioning equipment, centralization of services, installation of sensors, and measurement/control systems. Reduce institutional air travel. Reduce fuel consumption. Circular management of water (treatment, use, and reuse systems). Reduce water consumption (installing low flow, saving equipment, and using gray water).	Diagnose risks in the campuses and their ecosystems, analyzing the current economic impacts of climate change and future scenarios. Design and installation of monitoring and evaluation systems based on relevant indicators for adaptation to climate change. Design of master plans considering the factors studied and modeled for adaptation to climate change. Strengthening adaptation capacities through workshops for Operations, Physical Plant, Infrastructure, Security, Energy and Environment, Master Plans, and Urban planning.

Inner vision:

- Creation of Study Programs that include subjects with solid conceptual content on sustainability (for example, Biomimicry and Sustainable Development, Biology and Sustainability, Climate Change and Energy Use, Circular Economy, Bio Business, etc.).
- Creation of professional careers with a sustainable orientation (Sustainable Development Engineering).
- Evaluation of Sustainable competencies.

Vision outside the academic institution: Inner vision:

- Creation of the Vice Presidency of Inclusion and Sustainability that represents the University Institution in international events and forums.
- Creation of the Directorate for Sustainable Development Goals initiatives, which implements programs and establishes relations with governmental and non-governmental organizations to correctly fulfill the SDGs outside of the school.

Events such as the COVID-19 pandemic modify the schedule for meeting goals. In this regard, 19% of the courses have already included SDG topics [40]. Additionally, the TEC MTY has established an Institute for the Future of Education with a research group in charge of studying the teaching–learning process, considering sustainability as a transversal competence that can be evaluated for compliance [41]. In the research dimension, an analysis in the SCOPUS database of the sustainability research products published by the TEC MTY in 2016–2022 shows that 52.3% of the products were published in 2021 and 2022 (Figure 5).

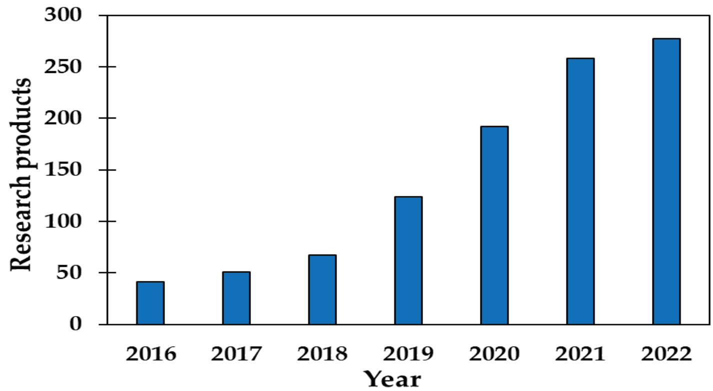

Figure 5. Published sustainability research products by TEC MTY in the period 2016–2022. (Source: Own elaboration).

Notably, the institution has six Strategic Focus Groups working directly with Sustainability: Energy and Climate Change, Economic and Environment Development, Sustainable Territorial Development, Science and Technology of Water, Social Innovation and Ethics, and Human Flourishing [25]. However, not only these Focus Groups are incorporating the sustainability vision in their research lines, but other groups are also focusing on it, as shown in Table 5. TEC MTY has begun to establish collaborations to foster sustainability. One of these is the establishment of the Energy Business Model Challenge with the power generator company Iberdrola [42], a competence for encouraging young entrepreneurs to propose sustainable solutions to the challenges in the energetic sector since 2017; the best project has been funded to be carried out under the advisory of Iberdrola and TEC MTY experts.

Table 5. Defined research lines related to sustainability at Tecnologico de Monterrey in 2022. (Source: own elaboration).

School	Strategic Research Group	Research Lines
School of Engineering and Sciences	Advanced manufacturing	Circular economies and eco-design
School of Engineering and Sciences	Bioprocesses	Bioprocess design; Innovative bioseparation technologies
Business School	Consumer Behaviour and Conscious Marketing	Responsible consumer behavior and social welfare
School of Social Sciences and Government	Economic and Environmental Development	Economic development; Social policy; Industrial economics
School of Engineering and Sciences	Energy and Climate Change	Energy efficiency: thermal and electrical; Clean energies: renewable and alternate; Climate change: mitigation, adaptation, and environmental benefits
School of Humanities and Education	Ethics and Human Flowering	Sustainability and the Anthropocene
School of Social Sciences and Government	Government and Public Entrepreneurship	Regional and City Development
Business School	Social Innovation and Sustainability	Ethics and social responsibility; Innovation of responsible and sustainable business models; Social entrepreneurship and high-value start-ups; Social impact evaluation; Sustainable clusters; Social innovation

Table 5. *Cont.*

School	Strategic Research Group	Research Lines
School of Architecture, Art, and Design	Sustainable Territorial Development	Resilience and adaptation to climate change; Analysis of territorial dynamics; Equitable cities
School of Engineering and Sciences	Translational Omics	Development of microbial technologies based on omics studies; Plant–microorganism interactions for solutions focused on agroecosystems
School of Engineering and Sciences	Water Science and Technology	Hydrological processes focused on water resources management in catchments; Advanced Treatment Processes and Reuse of Wastewater of domestic and industrial; Environmental geo-processes focused on the study of environmental impacts of human activities in the subsoil origin; Water Chemistry and Environmental Nanotechnology focused on the development of new and advanced materials

3.3. The Role of International Associations for Professional Development to Enhance Sustainability Initiatives with Universities

The formation of "a new type of university graduate" who is fully aware of sustainable development and capable of a holistic approach when facing challenges is required to meet society's problems and provide solutions through innovation and technology. Higher education programs and curricula must be revised to include these issues for the new type of professionals who can also inform, encourage, and guide society on the solutions to these new challenges. Likewise, HEIs have the responsibility to continue training graduates who have achieved the ethical–moral vision and the technical knowledge necessary to ensure the quality of life of future generations. For a sustainable world, qualified professionals with sustainability skills must continue learning to adapt to today's unsystematic, indeterminate, and dynamic risks.

The professionals of the 21st century have the responsibility to collaborate with critical thinking and systemic thinking, the ability to work in inter- and transdisciplinary frameworks, and have values consistent with the sustainability paradigm. Sustainability professionals highlight sustainability's technological and innovative role as a solution to vital environmental problems such as the climate crisis. Therefore, there is a need for continuing professional education in sustainability. There is clear leadership in continuing education in engineering for sustainable development that will apply multi-method experiential, active learning education for a resilient world and a sustainable future for all.

At the 2016 IACEE Global Conference in Porto, Portugal, IACEE members and representatives from various universities signed the Porto Declaration [43]. This statement is intended to continue IACEE's founding goals and lead members to foster sustainability in lifelong engineering learning and practice.

> *"Porto Declaration, 20 May 2016: Whereas the International Association for Continuing Engineering Education (IACEE) was founded in 1989 to foster a global network of organizations promoting lifelong engineering education.*
>
> *The IACEE recognizes the scale and complexity of the gap between existing solutions and our planet's needs. The IACEE is uniquely placed to act on this opportunity.*
>
> *The IACEE seeks to pivot the organization to connect individuals, universities, industry, government, and NGO organizations to meet humanity's grand challenges.*
>
> *Therefore, in keeping with its dedication to leading lifelong learning, the IACEE will develop global initiatives to address those 21st-century challenges threatening the survival of humankind through collaboration, design, creative thinking, and engineering.*

> *We, the undersigned, do hereby declare this at the IACEE 2016 Global Conference in Porto, Portugal, and pledge our commitment in actioning this call to service." (http://www.iacee.org/docs/PORTO_DECLARATION1.pdf (accessed on 1 February 2023))*

The role of associations such as IACEE and SEFI is to disseminate reports and reflections that contribute to achieving the global objectives of the UN's SDGs, promoting inclusive and sustainable development in universities, and fostering innovation. Some of the topics of interest included in the IACEE and SEFI agendas are:

- Identifying and understanding sustainability and education trends, approaches, programs, and other influential factors.
- Emerging trends in continuing education and adapting programs/approaches to meet these needs.
- Faculty development, support, and research.
- Identifying trends and adapting programs in universities.
- Academic–industry partnerships and impact on sustainability.
- New models in sustainability education and experience.
- Innovations in sustainability and continuing education.

Among the most critical IACEE projects related to sustainable development in universities, *SERinA* can be highlighted. The *SERinA* project was launched at the IACEE World Conference organized by the Tecnológico de Monterrey, Monterrey, Mexico, in May 2018 as an online portal dedicated to the support and promotion of engineering education and research linked to the concept of the 17 UN SDGs [6]. The SERinA project reported on May 2021 at the IACEE conference [44] intended to create a database of "Education, Research and Active Practices" highlighting initiatives for university students to be hopeful of the future and to develop a mindset of SDG practice within their intended projects of the future [45].

Among the most critical SEFI projects related to sustainable development in universities, *Erasmus+ A-STEP 2030* can be highlighted. The SEFI Special Interest Group on Continuing Education and Lifelong Learning undertook the *Erasmus+ A-STEP 2030* (Attracting diverse Talent to the Engineering Profession 2030) project for university students on sustainability and the future of engineering education. TU Dublin, Aalborg University, Metropolia University of Applied Science, BEST, Universum Global, SEFI, and nine other related partners are participating in the project, which was launched in September 2018 with the primary objective of developing an innovative curriculum to teach the appropriate skills and competencies for a sustainable future [46].

3.4. Discussion and Recommendation Guide for Universities on the Way to Sustainability

A qualitative analysis of content considering information from the initiatives and actions of the top ten best universities of the *UI GreenMetric* was performed. After reorganizing and summarizing the data, words were selected according to their relevance and frequency, which were recorded in an Excel file. Then, in a second Excel file, connections between words were established, and both files were fed to the *VOSviewer 1.6.18*® platform (https://www.vosviewer.com/ (accessed on 1 February 2023)) to create a word network (Figure 6). As observed, education and infrastructure are the main categories displaying more abundant actions. The high frequency of categories such as energy, water, and education show the most worked aspect in these universities located in the first places of the *UI GreenMetric* ranking. The actions about sustainable-related skills, courses, sustainability research, sustainable buildings, use of renewable energy sources, and reduction in carbon emissions were common in these universities. In the same way, less common but highlighted actions such as rainwater use and reduced green gas emissions are interesting since they create a difference in certain universities. Still, it needs to be worked on by other institutions yet.

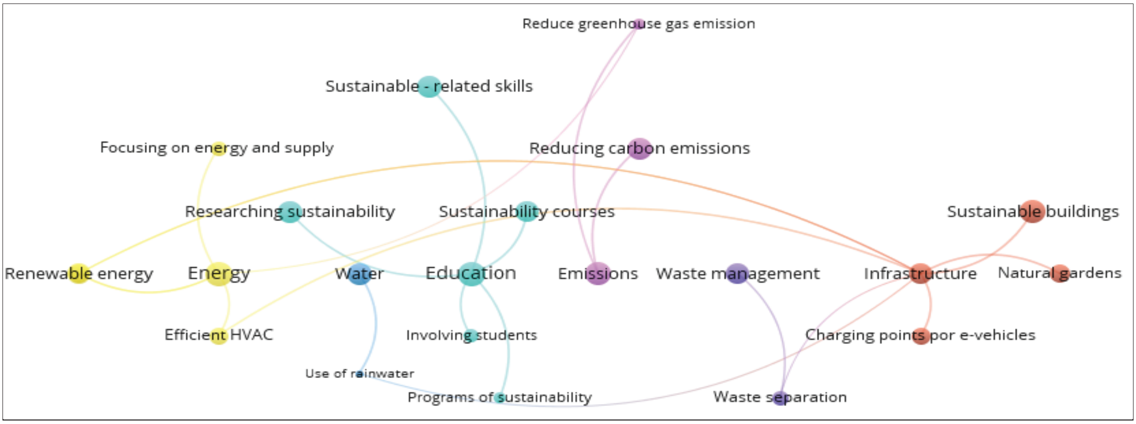

Figure 6. Word network of actions/activities implemented by top ten universities of the *UI GreenMetric.* (Source: own elaboration).

It has been evident that the reference ranking for measuring sustainability in HEIs is *UI GreenMetric*; however, more alternative scales are appearing, such as the *THE Impact Ranking* and the coming advertisements of SDG inclusion in the *QS Ranking*. In addition, the promotion of sustainable education comes not only from universities but also from multiple initiatives performed by independent education organizations such as IACEE in CEE through projects such as SERinA [43,45].

Figure 7 shows a word network considering this international panorama (*QS ranking*, *UI GreenMetric*, and education organizations) and the perspective of a particular institution, such as TEC MTY, where this sustainability concept is being lived. The network shares many of the main terms already shown in the word network for the top ten universities of the *UI GreenMetric* in Figure 6. However, a significant difference is the appreciation of words such as infrastructure, researching sustainability, and related SDGs such as SDG1 (no poverty), SDG2 (zero hunger), SDG5 (gender equality), SDG7 (energy), SDG14 (life below water), SDG11 (sustainable cities), and SDG17 (partnerships). The keywords *Education* appears again in the center of the network as a noun in this integral vision of sustainability trends, indicating that this aspect is fundamental for the incursion of universities in sustainability.

Few HEIs compete in the *UI Green Metric*. An explanation can be found in the interaction studies between the top 500 universities in the *Global University Rankings* (GURs) and top 500 universities in the *UI GreenMetric* ranking, reviewed by Muñoz-Suarez et al. in 2020. At the same time, a low correlation between academic performance and sustainable practices was identified, showing that older universities tended to be well located in the GURs. In contrast, the younger ones did in the *UI GreenMetric*. Geographically, it was evident that the European and North American universities were at the top of the GURs, and the Asian universities were at the top of the *UI GreenMetric* ranking [47]. An important conclusion that may be obtained is that the *UI Green Metric* is relatively young, and many universities have not participated in it yet. This idea is reinforced in our research because some universities encouraging sustainable education or research, individually or collectively, do not appear in the rankings (for example, three cases analyzed in the *SERinA* project: the University of Victoria, Massachusetts Institute of Technology, and Oxford University). In parallel, the changing historical performance of TEC MTY in the *UI GreenMetric* supports these ideas. Additionally, when the top ten universities in the recent the *THE Impact ranking* are observed, none of it matches with those in the *UI GreenMetric* or organizational initiatives.

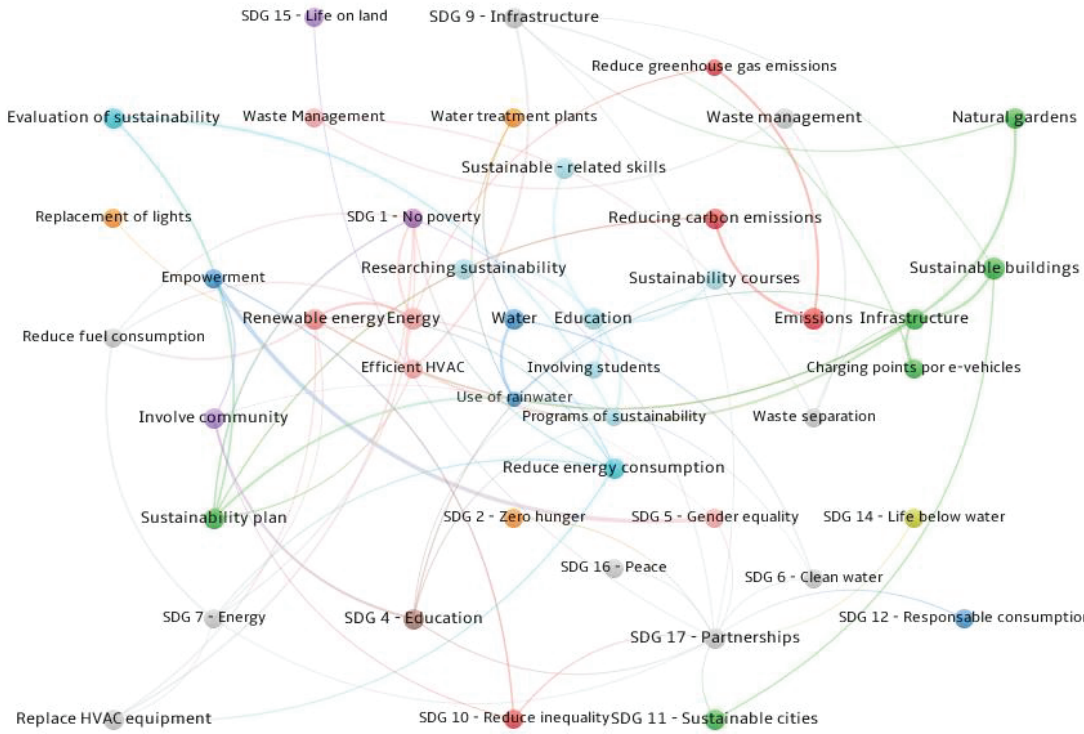

Figure 7. Word network of trends for universities and sustainability. (Source: own elaboration).

The same idea works as a driver for the analysis and recommendations performed in this section of our work since many HEIs are absent to be evaluated and considered; as stated in the introduction, it might require a little time for the GURs to incorporate sustainability as a category. The tendencies observed in the actions and word network presented here for the top ten universities should be attended.

Based on the analysis of the top ten universities of the *UI GreenMetric* and *THE Impact Ranking*, particularly TEC MTY, we suggest recommendations to simultaneously achieve sustainability in universities and participate in rankings (Figure 8). These recommendations will depend on the current location of universities in one of four stages, essentially defined according to the previous participation of HEIs in the most accepted sustainability ranking, *UI GreenMetric*, and summarized findings derived from this research work. The 4 stages are proposed: Stage 0 identified when a university is not involved in any sustainable activity or at least it is of their ignorance; in Stage 1, the institution has decided to progress toward sustainability due to the concept being well assimilated; for universities in Stage 2, sustainability is included in their mission, vision, and plans. For example, the Tecnologico de Monterrey may be classified in this stage. Stage 3 is reserved for HEIs well consolidated in sustainability and with a continuous sustainability program.

A common mistake that a university community may commit is only linking sustainability with "greenness" and beginning to create many "green areas" on their campuses, focusing only on the environmental aspect without attending to social or economic factors, as Sonetti et al. have pointed out [48]. This misconception of sustainability would have its origin in scarce diffusion, comprehension, and transcendence of the term, which is why we have set sustainability education as an initial step in recommendations. Awareness is a fundamental step to follow in adopting more complex sustainable measures. Little-compromised people will not adopt sustainable actions and thinking in their lives. Hence, it will not be a natural, standard, and attitudinal practice with a positive social effect and advancing to Stages 2 and 3. It even may be said that sustainable awareness is one of the ingredients for a university in Stage 3. A second key element to be in mind for HEIs in Stage 3 is innovation; they must always be the vanguard offering new solutions related to crucial aspects of transport, climate, waste, and water treatment, as a result of the research and collaboration fostered in Stages 1 and 2.

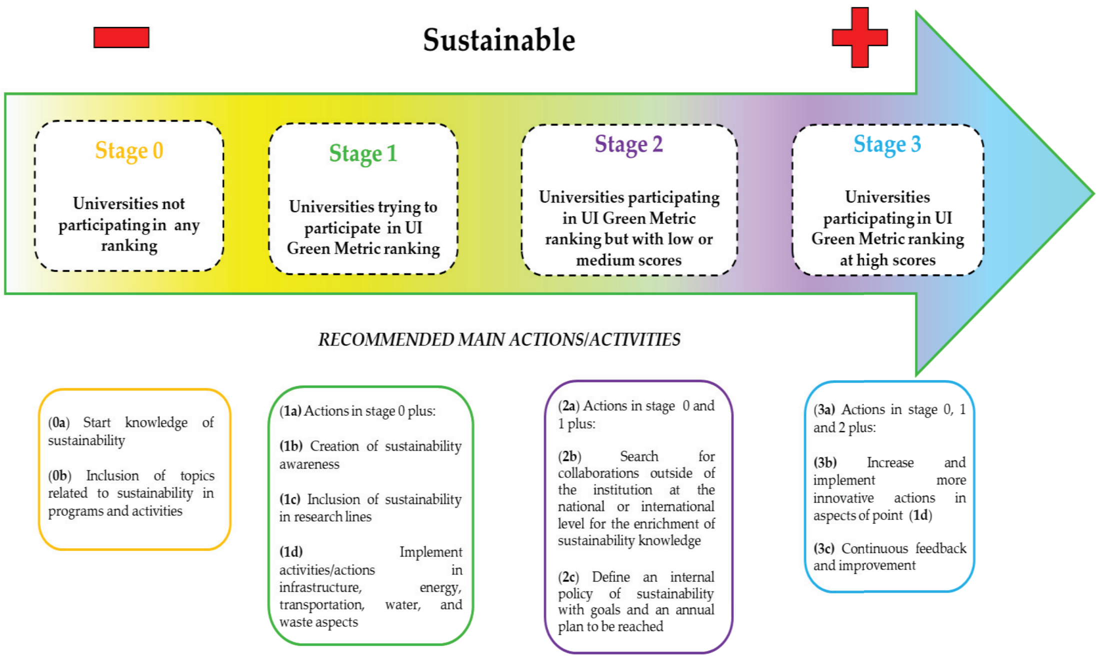

Figure 8. Main actions/activities suggested for HEIs on the way to participate in sustainability rankings and adopt sustainability. (Source: own elaboration).

4. Conclusions

Currently, there are two rankings for measuring sustainability in universities: *UI GreenMetric* and *THE Impact Ranking*. The first one is the most accepted ranking. The most sustainable universities in the *UI GreenMetric* ranking are characterized by implementing carbon emissions reduction, using renewable energy sources, waste treatment, green buildings and construction areas, and promoting biodiversity and healthy habits on campuses. The second one, the *THE Impact Ranking*, highlighted the universities that are attending primary SDG5 (gender equality), SDG6 (clean water and sanitation), SDG11 (sustainable cities and communities), and SDG12 (responsible production and consumption). The top ten universities in both rankings are different. Many other HEIs are carried out as sustainable actions without participating in rankings but through sustainability promotion in international associations for professional development and education, such as IACEE and SEFI. Particularly, the Tecnologico de Monterrey, in Mexico, is well located in both rankings (274th and 100–200th positions in the *UI GreenMetric* and *THE Impact Ranking*, respectively), and the carried-out actions cover five pillars: culture, mitigation, adaptation, education, and research and outreach. In general, it is noted that not only the efforts to maintain a sustainable building and environment are those that determine the degree of sustainability of a university but also the academic programs that form sustainable skills and graduates committed to sustainability in its three dimensions (social, economic, and environmental). Hence, education is the keyword found when necessary actions are analyzed. The recommendations with specific actions or activities to follow for sustainability adoption by universities, considering four stages: sustainability ignorance; sustainability principles knowledge; sustainability adoption and planning; and consolidation in sustainability and continuous improvement. In this sense, sustainable education must be considered as the first step toward sustainability and ranking participation. It is essential to mention that there are still no indicators to measure the impact of education on the sustainability of the environment; what is the effect of carrying out actions to climb in the HEI sustainability ranking? It will be an incomplete objective to only be oriented to stay or advance in the rankings. Future research aims to measure the transformation toward a sustainable culture and their positive effects on each university community. However, even without these indicators, the IES sustainability rankings are helpful to ensure that students obtain the necessary sustainable competencies; their future application will depend on the strength of the teaching, the appropriate educational models, and personal commitment. There is still a lot of work to be performed, but this study will surely be helpful for HEIs in their reflection on the future of sustainability.

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sustainability

Review

Revising Technology Adoption Factors for IoT-Based Smart Campuses: A Systematic Review

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Abstract: Smart education and the sustainable development of smart campuses have drawn significant research attention. This is enabled by intelligent devices that are widely attracting massive applicability in personal and big business contexts and can increase efficiency and convenience. This paper aims to present a solution to address the lack of a proper adoption model for smart campus initiatives. The evaluation and synthesis of the literature were conducted by following the systematic literature review (SLR) procedure. The study's findings revealed the taxonomy and IoT technologies leading to the wide adoption of IoT-based smart campuses. The technology adoption models and their corresponding variables help the authors identify and classify a suitable adoption framework for smart campuses. The limitations and challenges of adoption theories as they pertain to smart campuses are discussed. Finally, the study adapts perceived scalability, perceived replicability, perceived reliability, perceived privacy and security, perceived trust, the cost of deployment, usefulness, enjoyment, and technicality as adoption factors of sustainable smart campuses. This study offers practical and theoretical implications regarding the adoption and propagation of emerging smart campuses.

Keywords: smart campus; IoT; sustainability; adoption; SLR; factors

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1. Introduction

Enterprise executives ranked the Internet of Things (IoT) as an essential technological advancement, surpassing artificial intelligence (AI) and robotics in importance [1]. The IoT is considered a significant development in information technology that can potentially increase convenience and efficiency in daily life. Hence, Hsu and Lin [2] believe that the IoT has the ability to integrate numerous technologies to improve overall quality of life. The number of IoT service users has widely increased, but little is understood about what motivates the continued use of such services [3]. According to [4], "smart terminology" is a buzzword that was initially coined to describe cell phones that dominate the market. An electronic device managed via smartphones is called a "smart device", and comprises music devices, smartwatches, smart locks, smart lights, smart washing machines, etc.

The IoT has had a profound and widespread impact on the world of information technology [5], and impacts everyone from individual users to large organizations. Similarly, the IoT is significant in the development of smart homes for private users and in the automation, logistics, manufacturing, commercial elements, and other business or educational perspectives of small and large educational institutions [5]. Hence, implementing IoT solutions across universities will undoubtedly benefit all individuals on and off campus. Furthermore, Min-Allah and Alrashed [4] reaffirmed that the implementation of the smart city concept could be realized at a different level of the environment (building, town, or region) and the IoT is an enabler of the sustainable smart environment. The growth of smart cities and sustainable development has established a new standard for urbanization [6]. Accordingly, citizens of smart cities can benefit from a smart living environment, easy access to services, ubiquitous connectivity, intelligent decisions enabled by smart governance, and resource optimization. Similarly, smart cities can provide the highest quality services to improve healthcare, energy usage, transportation, and education [6,7].

Hence, the concept of smart cities can be extended to improve sustainable education infrastructure [7] with examples such as smart classrooms, smart payments, smart stadiums, and smart parking [8]. Universities have seen an explosion of several electronic devices used by students and on campus that are connected to the university network, resulting in a huge amount of data that could be used for decision making [9–11]. The promise of smart cities via the usage of smart technologies and IoT devices has pushed universities towards adopting the smart city concept on various campuses [4]. However, the notion of smart cities as well as smart campuses is still emerging. Despite their tremendous promises, security concerns continue to grow, such as data security, authentication, unauthorized access, and sustainability [6,7].

Nonetheless, the adoption of information technology enables universities to strengthen their economic sustainability and create a sustainable education system [12,13]. However, the success of this depends on the commitment of all stakeholders (government, industry, academia, and end-users) involved in the initiation, planning, and implementation [4,14–18]. Chuling et al. [15] identified three patterns pushing the realization of smart campuses: initiatives that are technology-driven, smart city-driven, and business process-driven. Recently, a knowledge management model for smart campuses [19], smart campus key performance indicators [20], a student management system for smart campuses based on 5G networks and the IoT [21], a mobile application for smart campuses [22], an IoT-based hybrid renewable energy system for smart campuses [23], a methodology proposal for smart campuses [24], and a roadmap to smart campuses based on the IoT were introduced [5]. Hence, there is a lack of an adoption model for smart campuses.

Nevertheless, there is a lack of common understanding concerning the concept of smart campuses in the literature [18,25]. A smart campus is a term used to describe digital technologies designed to optimize the maintenance and utilization of a campus' physical infrastructure to reduce overall energy consumption [4]. Moreover, the phrase "smart campus" refers to combining and implementing smart technology (IoT devices) with physical infrastructure to achieve significant service, decision, and sustainability improvements in educational institutions [4]. Thus, it is under the umbrella term "smart campus", which comprises a variety of solutions such as smart classrooms, smart grids, smart attendance via smart cards or facial recognition and student management, and infrastructure surveillance and monitoring [20,21,26,27]. Numerous towns and universities have implemented innovative solutions to enhance campus sustainability [4,20,28] in terms of energy conservation and security [28].

Accordingly, a generic model that can be used for smart campuses has not been established [4]. However, Omotayo et al. [29] applied a systems thinking analysis and further evaluated the systems thinking-SWOT analysis [30] to facilitate successful and sustainable smart campus transitions. Additionally, Ahmed et al. [8] investigated the stakeholders' perception of smart campus criteria, and Pandey et al. [5] proposed a new method of smart campuses which focuses on the IoT and explains the idea of smart campuses through the IoT. However, there is a lack of studies about the adoption of IoT-based smart campuses facilitated by technology adoption theories. Therefore, this study aims to review the current literature on the adoption of the IoT to help proliferate and provide insight concerning the adoption of the smart campus concept and ease the adoption process for the administration and decision-makers of higher educational institutions [11]. Thus, the objectives of this literature review include: identifying the taxonomy of the studies on IoT technologies and IoT applications leading to the smart campus concept; ascertaining technology adoption models and common variables suitable for studying the adoption of smart campuses; and classifying technology adoption factors of smart campuses for full-scale use. Therefore, the following questions help the researchers address the objectives of the research:

- What is the taxonomy of IoT application areas or technologies leading to smart campuses or education?
- What are the technology adoption theories and common variables for IoT adoption that are suitable for the adoption of smart campuses?
- How are technology adoption factors for IoT-based smart campuses classified, and what are the criteria behind this classification?

Notably, this paper presents a solution to address the lack of a proper adoption model for smart campus initiatives. The paper is presented as follows: Section 2 presents the related literature review and motivation of the study. Section 3 describes the research methodology adopted to the selection of articles relevant for this review. Section 4 answers the research questions sequentially: the taxonomy of IoT application areas and technologies for smart campuses, technology adoption models and variables widely used in IoT adoption, and the classification of technology adoption factors. Section 5 discusses the open issues and challenges faced by IoT-based smart campus solutions and the rationale for smart campus adoption based on existing technology adoption theories. Moreover, this section also discusses a conceptual model for smart campus adoption. Finally, Section 6 offers concluding remarks.

2. Related Review and Motivation

The main focus of this work is to conduct a literature review concerning the theoretical framework for the adoption of technology as it relates to smart campus adoption and usage in order to promote the concept of smart campuses or smart education in the literature. Although there are few review papers in the literature concerning the concept of smart campuses, there is a limited number of papers concentrating on the technology adoption aspect of smart campuses. Table 1 summarizes the focus of various review papers on smart campuses.

Table 1. Summary of existing literature studies on smart campuses.

Related Work	Year	Focus
[31]	2018	A systematic review on smart learning which compares two databases and provides authors' details and the locations of their publications.
[32]	2019	Research on the current educational programs and issues in smart cities and a summary of several recent educational programs and issues.
[33]	2019	Investigates the role of the IoT in smart campuses and smart universities, highlighting IoT, cloud computing, big data, and artificial intelligence as the primary technologies used to implement smart campuses and smart universities. The authors emphasize the variety of devices that are used to support smart campuses, ranging from low-resource devices such as sensors to high-resource devices such as cell phones.
[4]	2020	Proposes a sketch of a smart campus based on smart city concepts. The authors also develop a list of smart campus initiatives that can be prioritized based on the university's needs and geographical location, using a variety of smart campus solutions.
[34]	2021	Summarizes existing directions focusing on education in the context of smart cities. The article focuses on the challenges and difficulties associated with education in smart cities.
[27]	2021	Discusses the surveillance system challenges and solutions of IoT-enabled smart campuses. The study covers five key dimensions including enabling technologies, physical infrastructure, system security, software analytics, and research methodology
[35]	2021	Focuses on smart campus implementation and initiatives in Malaysian universities, revealing that most institutions implement some aspect of smart campus initiatives such as smart management, smart learning, and green campus initiatives.

As presented in Table 1, the existing review or survey studies about smart campuses are deficient on the adoption issue of smart campuses. Precisely, Durán-Sánchez et al. [31] conducted a systematic review of smart learning, which reported the authors and locations of publications related to smart learning. The work by [32] provides an overview of current educational programs and issues in the smart cities research direction of several recent educational programs and issues in smart cities. Furthermore, the study conducted by Rico-Bautista et al. [33] is one of the early works that investigated the role of IoT in smart campuses and smart universities by highlighting the IoT as one of the primary technologies used to implement smart campuses and smart universities. Moreover, Min-Allah and Alrashed [4] reviewed the literature and proposed a sketch of a smart campus based on smart city concepts. The authors developed a list of smart campus initiatives based on the university's needs and geographical location. In addition, Molnar [34] covers education in the context of smart cities as well as challenges and difficulties associated with the concept. Furthermore, Anagnostopoulos et al. [27] reviewed the challenges and solutions of surveillance systems on IoT-enabled smart campuses, and [35] surveyed smart campus implementation and initiatives in Malaysian universities, covering smart management, smart learning, and green campus initiatives. Remarkably, none of the current studies address the adoption issue for smart campuses. Thus, this review study is distinguished from existing review papers by focusing on a different set of research questions with the intention of conceptualizing an IoT-based smart campus adoption model. Hence, the work focuses on leveraging the existing adoption models of IoT technologies to build an adoption model appropriate for smart campus solutions [9].

3. Method

A breakdown of the research methodology is presented in Figure 1. The stages were adapted to address the research questions formulated in the study. Specifically, after the motivation of the study was identified, the process of paper selection was conducted through a systematic review method, which specified the articles used for this study. The second phase was to determine the theoretical models used to adopt IoT in the literature, with their corresponding factors. The third stage involved filtering the factors to delete duplicates, which were used for the classification in the fourth stage. Additionally, the literature provided the researcher with a justification for conducting a systematic literature review (SLR), especially when it came to selecting the research studies for this review [36]. These include the fact that the SLR reviews are primarily focused on the challenge of obtaining empirical evidence, which is employed in information system research. SLR is a well-defined process that reduces the influence of literature bias and can provide information and evidence concerning consistent and inconsistent outcomes across a wide range of empirical methods [36,37]. The SLR process was conducted based on the recommendations identified from previous studies [37,38] and applied by many researchers [39–41]. The selection process of the research papers is presented in Figure 2.

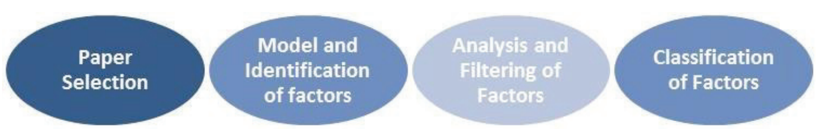

Figure 1. Breakdown of the research methodology.

As demonstrated in Figure 2, the method of paper selection consisted of using three online databases to collect research articles regarding IoT smart campus adoption and usage. The inclusion and exclusion criteria of the papers are based on the recommendations by [32]. The selection methodology was conducted based on accompanying advances in the literature. This involved the utilization of the leading online databases to collect research papers (ScienceDirect, IEEE Xplore, and Springer) that are used for this review. We filtered the research papers according to qualification criteria such as publication period, the context of the paper, and QoS assessment measurements. Finally, we conducted an evaluation of the eligibility criteria and carried out the final selection [42]. The selection methodology used and the context that was followed enabled the researchers to identify many research articles without having the issue of duplication. This can serve as a further guide for academic researchers on the importance of quality research articles. Similarly, the articles that did not satisfy the eligibility criteria were not considered for further assessment. These articles comprise book chapters or conference papers, white papers, surveyed papers, short papers, papers not in QoS performance metrics, non-English papers, and papers that do not cover technology adoption models or smart campus technologies. The usage of these criteria may contribute to the success of the adoption of smart campuses. A further breakdown of the search and selection process and the query used during the search process are presented in Figure 3.

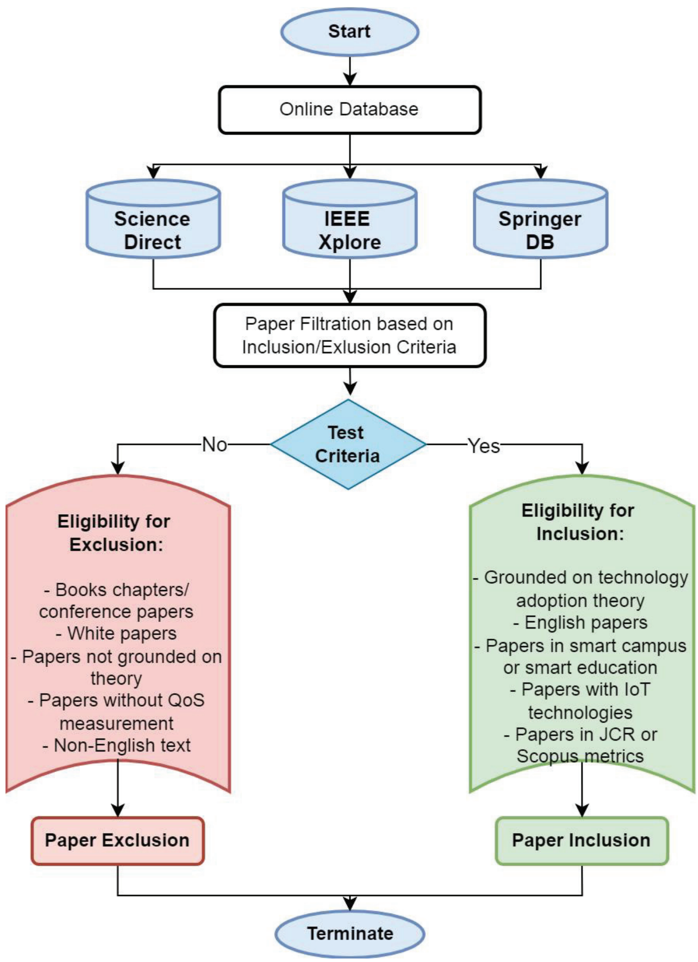

Figure 2. Paper selection methodology.

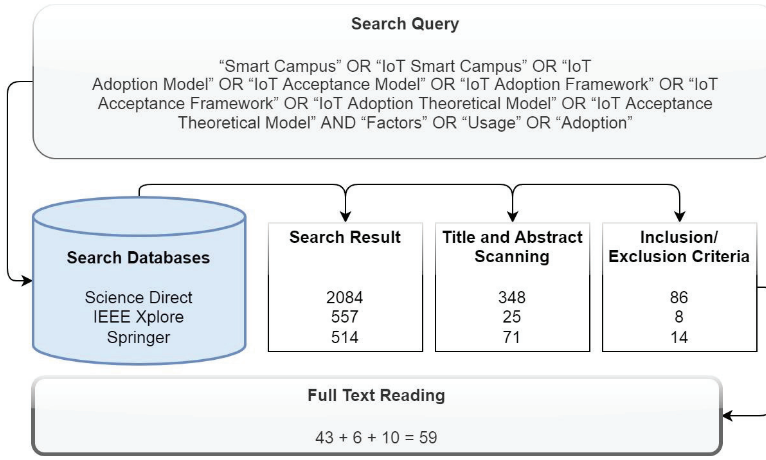

Figure 3. Paper search and selection process.

4. Results

In order to conduct the literature review, this study follows the SLR guidelines that have been published in the literature [37,38,41]. As a result, the SLR is broken down into four steps, which are depicted in Figure 2 and, later, Figure 3. The SLR begins with a search for relevant articles, which is the first stage. Accordingly, a query is constructed based on keywords discovered in the literature and is used to search for published research, which is illustrated in Figure 3. The search results retrieved 2084 publications in ScienceDirect, 557 publications in IEEE Xplore, and 514 publications from Springer, according to the results of the search. Following that, the publications were screened based on the titles and abstracts that were scanned. During this stage, articles that were not connected to the research theme were not taken into consideration. Following this stage, additional inclusion and exclusion criteria were implemented to the publications that had been selected for further evaluation. Articles that are excluded from consideration include conference papers, non-English texts, and articles that are not open access. In contrast, articles that were considered are Index JCR or Scopus papers, as well as articles that have adopted or adapted technology acceptance theories in the research design. As a result, the final sample is composed of 108 articles that will be examined for full-text consideration. As indicated in Figure 3, a total of 59 publications were chosen as final study samples because they met all of the final eligibility criteria during full-text reading.

4.1. What Is the Taxonomy of IoT Application Areas or Technologies Leading to Smart Campuses or Smart Education?

This section focuses on the first research question: what is the taxonomy of previous studies in terms of IoT technologies and IoT applications? Hence, the evaluation of existing studies identified many IoT smart device applications, as shown in Figure 4. Specifically, some studies focus on adopting the IoT in a general application that does not consider any specific IoT devices [43–45]. However, location-based services have been investigated in [46], while smart cities with autonomous vehicle (AV) acceptance were evaluated in [47], and the adoption of smart cities for public services was investigated by [48]. Furthermore, the investigation of NFC and RFID was reported in the literature concerning their adoption in industry logistics and supply chain management [49–51]. The study concerning the adoption of smart farming technologies (SFTs) in agriculture and agricultural supply chains was also identified in the literature [52–55]. The use of a wireless sensor network (WSN) was investigated by [56]. Moreover, the adoption of smartwatch wearables [57–60] and IoT wearable fitness trackers for healthcare/fitness [61], smartphone [62], voice assistants (VAs) [63], and smart TV terminals [64] was studied by various researches. Moreover, studies encouraging the adoption of IoT-enabled smart homes and services were revealed during the review [65–68].

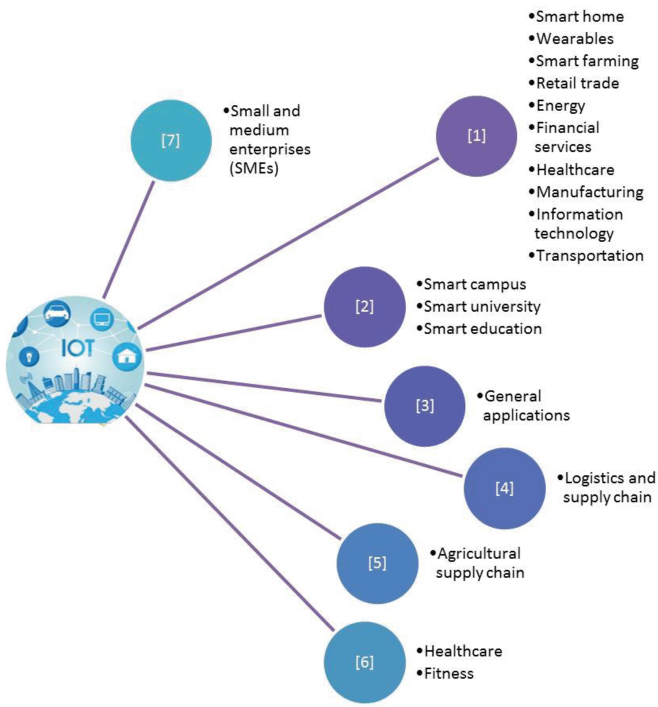

Figure 4. Taxonomy of IoT applications areas: [1] Nord et al. (2019); [2] Min-Allah and Alrashed (2020), Muhamad et al. (2017); [3] AlHogail (2018), De Boer et al. (2019); [4] Caffaro et al. (2020); [5] Jayashankar et al. (2018), Yamin and Alyoubi (2020); [6] Kao et al. (2019); Kim et al. (2016); [7] Won and Park (2020).

Furthermore, smart healthcare devices such as glucose monitoring systems (GCMS) and electronic medical records (EMR) to support healthcare service delivery for IoT-based healthcare have been recognized in the literature [60,69–71]. Additionally, many IoT technologies have been identified from existing studies concerning technology acceptance theories. The user adoption of EMR/IoT-based home energy services was examined by [72,73]. Moreover, the propagation of smart factories via small–medium enterprises (SMEs) was reported in previous studies [74,75]. The studies concerning the adoption of other IoT technologies such as AI-based intelligent products [76], IoT-based smart meters [77], IoT service orchestration [78], mobile cloud services [67], and cloud computing [79] were investigated.

Equally, the IoT technologies investigated by various studies were used to solve a particular problem in a specific area of application. Several areas of application were identified in the literature. Hence, Figure 4 presents the IoT application areas that were uncovered by the literature evaluation, analysis, and synthesis.

Smart Campus Concept and Technologies

The literature regarding smart explanations differs, but the focus is on how smart technologies leverage education services. A smart campus is viewed as an integration of computing technologies in the cloud and IoT devices that assist the university's management, teaching, and research activities [4,9–11,80]. Nevertheless, work by [14] has categorized IoT-based solutions into two classifications that reflect smart education concepts, namely, smart universities and smart campuses. Thus, the authors highlighted that the concept of smart universities concentrates on the applications that will improve the universities' infrastructure and administration of academic services. The smart campus concept is used for external entities with financial and economic perspectives. However, several works have suggested that smart campuses and smart universities are used interchangeably, with the concept of smart campuses appearing to be more popular [15,81] as cited in [4].

However, the concept of smart campuses is still emerging [82], and this concept refers to smart education that allows the application of emergent smart technologies that collaborate with advanced educational practices, techniques, and tools [83] for the effective delivery of learning services [84]. The concept of the smart campus is derived from smart cities. Min-Allah and Alrashed [4] insist that a smart campus should share many things with a smart city since the university campus is similar to a small-scale city. Thus, smart cities aim to improve the quality of people's lives through technology. Education is found to be one of the entities of smart cities. Therefore, smart education terminology is a term that describes education delivered by smart cities [34]. Some of the major entities of smart campuses and smart education derived from the concept of smart cities are depicted in Figure 5. The smart campus concept was based on several works in the literature [4,34,85].

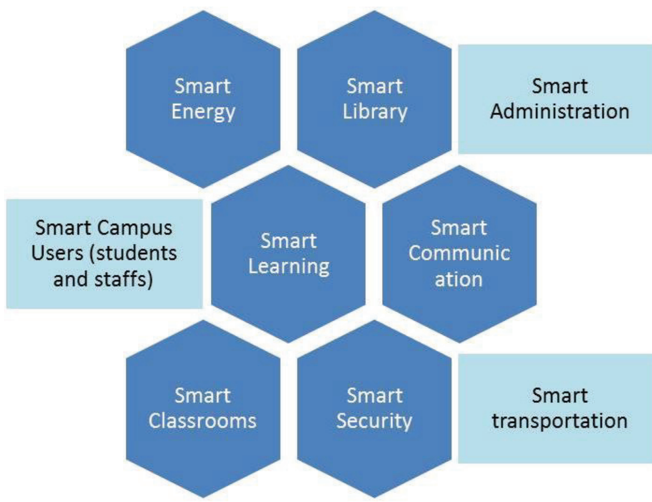

Figure 5. Major entities of a smart campus based on the smart city concept [4,34,85].

Various technological advancements have pushed for the realization of smart cities and smart campuses. For example, Kiryakova et al. [83] reported the penetration of technological advancements such as social media and internet-enabled resources into society, making citizens rely on technological resources to achieve their daily activities. As a result, citizens share more connections and effectively engage in the digital space to carry out their daily activities. Thus, the data generated by smart education approaches are, to a large extent, generated from the actions of students, teachers, and employers online [82]. Similarly, many solutions have embraced operating based on the data and information generated by IoT and other smart devices regarding smart campuses. A few examples of such solutions include the central intelligence layer introduced to provide services at the application level [86], services which comprise socializing, sharing events, mobility, and signaling problems [87]. The solutions are classified into three domains: practical life, social life, and academic life [88].

Moreover, many contactless technologies that are better than keyboards are used to provide an easy method to access buildings or equipment. In addition, IoT supports the real-time monitoring and reporting of environmental status. The transition in education has made IoT a mandatory course for all engineering students [89]. The concept of cloud computing is also adopted to manage various information effectively and efficiently and provide real-time data services [16,79,90]. iCampus is a popular model considered for smart campuses that maps technological applications implemented in smart campuses [18]. Figure 6 summarizes the technology solutions supporting smart campuses identified through this investigation based on empirical research, as well as technologies for future research. These taxonomies of the technologies were derived from our investigation of the existing studies.

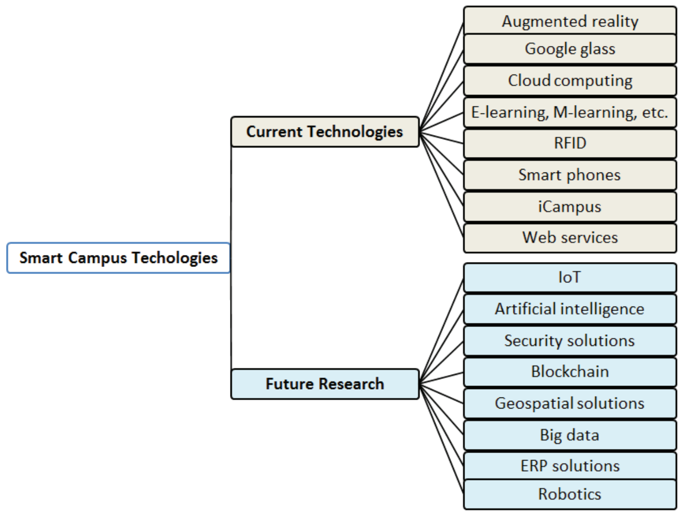

Figure 6. Technologies supporting smart campuses [16,18,79,85,90–98].

The technology in augmented reality (AR) can provide a video-based interface to support training and provide different experiences for trainers [91,92,99,100]. The work by [91] investigated whether AR-based online wearable guides improve learners' situational awareness, while [92] studied the adoption of AR in training. Google Glass is another smart technology used in educational institutions to support teachers and learners [93]. Moreover, Ashwin and Guddeti [101] introduced an automatic inquiry-based instruction system as a teaching strategy. The system was tested and evaluated in four different learning environments: e-learning, classroom, flipped classroom, and webinar environments. Mobile learning (M-learning) is also considered a new approach for learning, helping students access learning resources and easily conducting educational tasks [94]. M-learning avoids spatial or temporal restrictions by using model devices that are considered robust devices that support smart, easy and flexible learning.

Several studies have considered the smart campus to be a promising trend that was discovered as a result of digital campus development [15,16,18,90] through the usage of suitable technologies and the provision of internet services [102]. These technologies comprise the usage of various IoT service solutions [103] and cloud computing to integrate isolated systems [16,79,90]. The IoT services are created by transforming common solutions and objects within the educational institution's environment as intelligent solutions or objects through sensors [104,105]. The transformation of a common object into a comprehensive intelligence device is for supporting intelligent decision-making within the campus environment [106]. A smart campus supports the learning cycle within and across the campus ecosystem and aids the development of services and applications effectively [107]. Additionally, this increases the performance of the campus and improves student graduation quality [102]. The realization of the smart concept simplifies the three aspects of campuses, namely, teaching, management, and the service of the campus stakeholders [15,18].

Big data plays a significant role in smart cities; this role can also be provided to the smart campus model. Thus, the big data for smart campuses can significantly transform every area in the educational institution's economy as it does in the city through smart cities [108]. The transformation can enable universities to actualize the requirements and learning principles of smart city applications by identifying the key characteristics and features of a smart environment. The features and characteristics could comprise sustainability, improved quality of life, governance, resilience, and the intelligent management of resources and facilities [97,98]. Additionally, the application of artificial intelligence (AI) through machine learning (ML) and deep learning (DL) was encouraged to provide the smart campus with the capability to optimize the usage of resources and facilities [85]. Moreover, Sinha et al. [96] supported these claims by investigating the acceptance of robotics in the workplace [96], a typical example of a programmable machine learning system.

Additionally, the study conducted by Tavana et al. [95] unveiled the application of enterprise resource planning (ERP) systems that use the IoT to collect and transfer data between individuals and databases stored in the cloud and managed by ERP solutions. Moreover, cloud computing provides the efficient storage and processing of data; AI provides intelligence processing; big data manages a large volume of real-time data collected from IoT devices; IoT ensures the communication of the network of devices; blockchain handles trusted transactions and agreements; and security solutions provide mechanisms and protocols to secure IoT devices and systems. In addition, data visualization and IoT were exploited for increasing the sustainability and safety of smart campuses [28]. Figure 6 shows technology solutions supporting smart campuses for future research. This taxonomy of the technologies is derived from existing studies.

4.2. What Are the Technology Adoption Theories and Common Variables for IoT Adoption That Are Suitable for Smart Campus Adoption?

This section focuses on addressing the second research question concerning the existing theories and common variables studied in previous research. To address this question, the present study recognizes that the papers downloaded for this study based on the eligibility criteria do not provide enough papers on technology adoption for a smart campus to answer this research question. Nevertheless, the present study identified and selected 31/59 papers based on technology adoption theories for IoT devices across various application areas, and 28/59 papers are based on technologies supporting smart campuses. Thus, Table A1 (Appendix A) presents a summary of various constructs corresponding to the theoretical model found during the synthesis of the literature. Additionally, the frequency and popularity of theoretical models can be observed in this section. Hence, the analysis of the existing research concerning the adoption of IoT technologies or smart devices via technology acceptance theories has shown that the technology acceptance model (TAM) is the most popular theory tested in this context. The generic constructs of TAM include the perceived ease of use (PEoU) and perceived usefulness (PU). Several other studies have introduced and tested new constructs to improve the weakness associated with the TAM theory (Appendix A; Table A1).

Similarly, several other theories exist in the technology acceptance literature. Some of these theories include the unified theory of acceptance and use of technology (UTAUT) and UTAUT2, the theory of planned behavior (TPB), the value-based adoption model (VAM), and the theory of reasoned action (TRA). Table A1 (Appendix A) presents the list of the theoretical models and their corresponding constructs (i.e., whether they are generic or improvement constructs). The findings also reveal integrated models, a relational structure/hierarchical map, an ordered logistics model, and a trust framework. Most of the constructs and variables found in these models were presented in the models reported in Table A1 (Appendix A). The researchers observed that most of the research conducted based on an integrated model was linked to the most popular technology adoption theories.

The Popularity of Technology Adoption Models

According to [82], there is a rapid increase in academic research concerning smart education. However, the existing studies do not show the new artifact design of the smart campus. This would provide insight and knowledge to help the progress of smart campuses and address the aspirations of educational institutions. Moreover, the study conducted by Adamkó and Kollár [86] is one of the popular works that discuss the concept of smart campuses more broadly, specifically focusing on improving some of its aspects. However, Min-Allah and Alrashed [4] insisted that the need for developing a generic model is still very important. Thus, this study was conducted to close this gap by introducing a technology adoption model based on existing literature to guide the developers and policymakers of smart campuses' technological resources and design new smart education solutions that will be easily integrated and accepted by the users of educational institutions. Therefore, the technology adoption framework can be viewed as a conceptual solution model that would support students' and staff's adoption of smart campus solutions to improve learning and career development for a better future.

The literature analysis has revealed that TAM is the most studied theory for the adoption of IoT. However, the strength and limitations of the theoretical models used for technology acceptance theories are available in the literature, although the literature concerning IoT adoption is still emerging.

However, according to [48], there is much criticism regarding technology adoption models such as TAM since they do not take into account behavioral intention derived from complicated relationships involving earlier use perceptions and other factors. The work by [109] insists that the general factors of TAM (usefulness and ease of use) are insufficient for describing a complicated situation since the variables do not take into account users' existing relationships. The TAM model is straightforward and ineffective, as it does not include any potential variables that could be relevant [57]. The assumption about the relationship between intention and actual behavior has been questioned in many pieces of literature since it cannot ensure actual use [57]. The authors of [110] also assert that the TAM constructs have a weakness because of a lack of explanatory capacity and contradictions that exist between them. Additionally, the UTAUT theory highlights distinct technologies while failing to adequately justify the users' expectations and beliefs that are likely to arise while utilizing the technology [111].

Furthermore, UTAUT places a greater emphasis on expectation performance than it does on personal expectation. As a result, the UTAUT model is more appropriate for workplace situations than it is for public adoption. Despite this, numerous studies contribute to the prediction of intention and behavior based on the UTAUT model [48]. Figure 7 demonstrates the popularity of the adoption models.

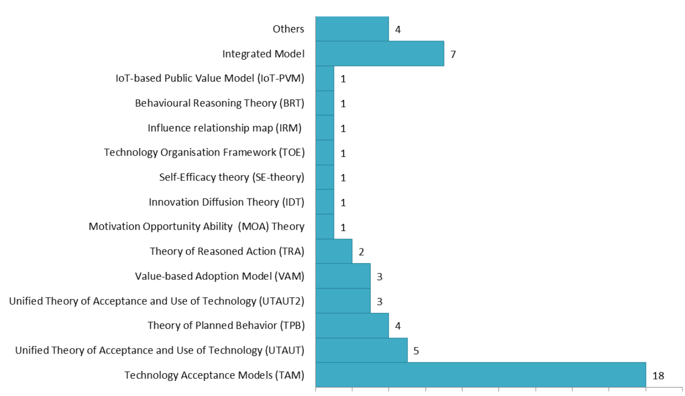

Figure 7. Frequency of technology adoption theoretical models.

4.3. How Are Technology Adoption Factors for IoT-Based Smart Campus Adoption Classified, and What Are the Criteria behind This Classification?

The taxonomy of the technology adoption factors is created based on the several studies that conducted a hierarchical analytical process (AHP) or have previously classified the factors. This could be based on some criteria by the previous researchers. Specifically, one of the used criteria is the technology–organization–environmental (TOE) framework. For example, Sharma et al. [112] classified the technology, organization, environment, and economic factors. The relative advantage, compatibility, complexity, security, and the quality of service are categorized under technology. The organizational category includes readiness, resistance to change, organization size, and top management support, most of which were not found in this study, except for innovativeness from the users' perspectives.

Furthermore, the environmental and economic factors cover pressure (competitive and partner) and cost (transaction, service, or losses). Secondly, Lanzini et al. [113] classified the factors into technology, organization, and environment. Similarly, the technological factors cover cost, governance, results observability, perceived compatibility, perceived ease of use, perceived usefulness, privacy, security, and trialability, among which only governance was not found in our study. Additionally, the organizational category covers people readiness, process readiness, technology readiness, top management enthusiasm, top management expertise, and top management support and the environmental factors include customer influence, competitive pressure, cooperation with ICT providers, environmental impact, government support, regulatory status, reputation, and trading partners. The classification in reference [114] was broken down into technology, organization, environment, security, perceived usefulness, and ease of use. Similarly, the technological category includes reliability, complexity, compatibility, and availability; the organizational category includes cooperated strategy, management support, technology competence, cost effectiveness, and budget availability; the environmental category includes regulation, the convenience of use, pressure from external factors, and consumer expectations; the security category includes authentication, authorization, integrity, confidentiality, non-repudiation, and privacy; the perceived usefulness category includes sharing, medical history, time sharing, error identification, and quality care; and, finally, the perceived ease of use category covers usability, customization, accessibility, responsiveness and user interface. Lastly, the classification of Pal et al. [66] covers service-specific characteristics (usefulness, innovativeness, perceived reliability, interoperability, service cost), end-user-specific characteristics (privacy concerns, psychological barriers, self-efficacy), and environmental characteristics (home administrative policies, government policies).

The Classification of the Factors

The factors identified in the literature were collated. Remarkably, this study identified many factors (112) classified based on the knowledge acquired from previous studies and thematic analyses [66]. Firstly, duplicate filtering revealed 77 factors. Then, the second duplicate filtering was applied through thematic analysis, which resulted in 52 factors, as presented Figure 8. While analyzing the factors obtained from the articles studied through systematic review, we tried categorizing the technology adoption factors into certain themes [66,112–114]. Four broad themes are recognized as: (a) technology-specific factors, (b) organizational-specific factors, (c) environmental-specific factors, and (d) end-user-specific factors. Figure 8 presents the broad themes and their corresponding factors. Hence, 52 reasonable technology adoption factors are finally classified accordingly.

During the thematic analysis, this study did not identify the complexity factor; it was discovered and classified as a technological component in previous research that applied AHP [112,114]. Moreover, prior studies have classified and merged factors according to their contextual meaning. For example, perceived usefulness, performance expectancy, effectiveness, personal and societal benefits, and perceived benefits are conceptually similar; they are considered a single factor (usefulness), rather than five. As a result, perceived usefulness and performance expectancy were combined into a single factor. Similarly, perceived ease of use, effort expectancy, perceived technicality, usage barrier, and perceived behavioral control shared conceptual commonalities. Therefore, they are treated as a single component (ease of use) rather than five. Since all five factors were associated with problems in usage, they were merged into a single factor [63,76]. In addition, Kao et al. [61] adopted the technological awareness notion of domain-specific knowledge [115]. Accordingly, technological awareness refers to users' knowledge and comprehension of a certain technology or product [116]. Numerous studies have established the importance of perceived enjoyment (similar to hedonic motivation) in examining individuals' intrinsic motivations for adopting and using commercial products [59,73].

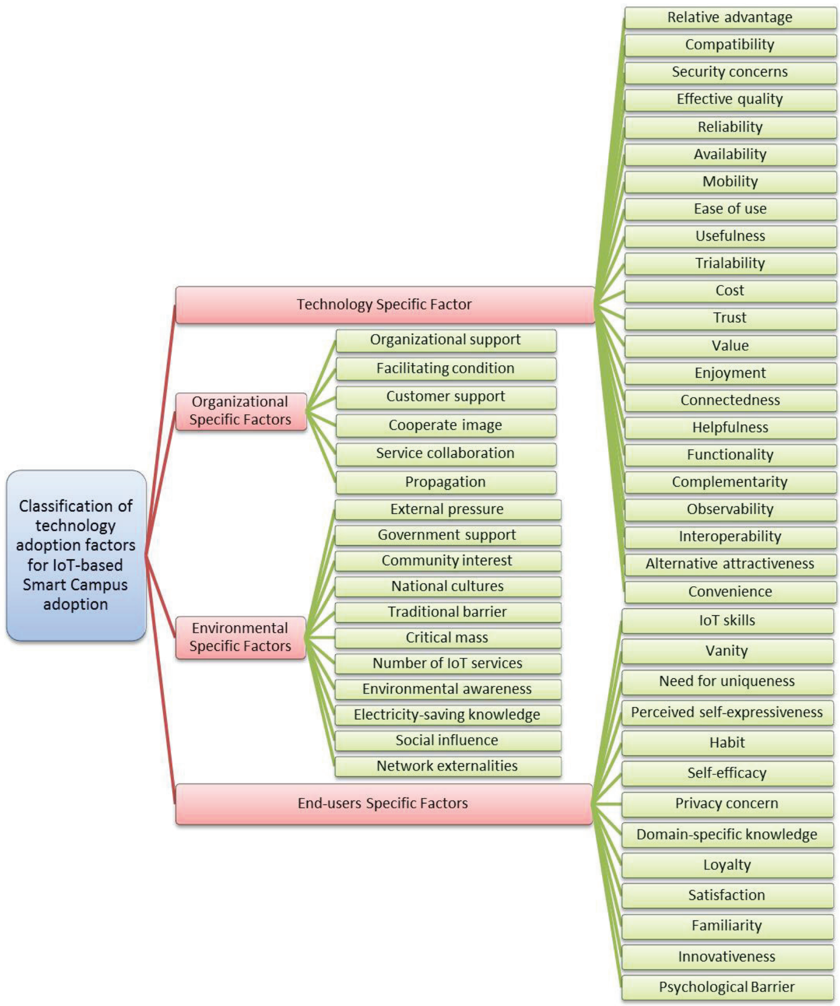

Figure 8. Classification of technology adoption factors for IoT smart campuses.

5. Discussion

This section discusses the open issues and challenges of smart campus adoption, motivations for future research, and the adoption of smart campuses.

5.1. Open Issues and Challenges of Smart Campuses

According to [4], a smart campus adheres to smart cities' challenges and issues. Technology drivers and smart cities are influencers of smart campuses [15]. IoT solutions are entities driving smart cities through IoT-based smart devices. Thus, this study identifies and reveals some unresolved problems and challenges facing the concept of the smart campus. The most important are system security, identity management, access control, and trust in IoT smart products and services [27]. Insecure authentication methods create a trust gap across IoT network gateways [25,117] that may be part of a smart campus system, exposing these devices and their data to criminals. Another issue is the use of centralized, conventional IT computing systems and network models in a smart campus ecosystem that is decentralized and self-governing. The IoT smart devices themselves are still emerging, and any entity that has a part to play in the smart campus must adapt to the demands of this new ecosystem. The complexity, scalability, and management of the environment are all open issues in these systems that include an ever-increasing number of devices and applications.

The IoT network's complexity issue from the various types of devices that link to the edge, fog, and cloud could affect the success of a smart campus. Furthermore, the constantly changing attacks and threats lurking in IoT systems and services and the sheer number of factors that lead to security breaches are outstanding issues due to this heterogeneous existence. As a result, the network's scalability is undoubtedly a significant concern [117]. Furthermore, even though IoT is a decentralized environment, system management is not always considered, particularly when it comes to credential and certificate distribution and revocation, and transactional traffic is often mixed with administrative data movement. Similarly, security is considered a central aspect of any model. Other security challenges may include data confidentiality, device management, the integrity of cyber-physical systems, pivotal device pairing [118], and information security [119]. Moreover, the rapid adoption of smart cities has created concerns about data security, authentication, unauthorized access, device vulnerability, and sustainability [6,7]. As a result, as explained in the paper, generic and effective security solutions should be used in the design stage to mitigate risks and vulnerabilities.

The nature of IoT deployment and cloud computing for smart campuses, which raises issues about privacy, security, and trust, is a source of concern [120–122]. Security and privacy have been identified as the most significant impediments to the growth of the IoT and cloud computing [121,122]. Furthermore, privacy and security issues have an impact on the intention of IoT adoption, as evidenced by [43]. In accordance with the findings of [123], the issue of trust is considered difficult. Despite the fact that trust does not have a precise definition, it is widely recognized as being crucial in the field of information systems literature [124]. The concept of trust is closely associated with the concepts of reputation and dependability [125]. Trust in the relationship between entities (users) and trust in the system from the perspective of the users are two aspects of trust [126]. When it comes to adopting and using IoT technologies, trust is essential [1]. According to the framework developed by [127], trust should be considered throughout the entire IoT development process. A further contribution was made by [128], which presented trust computation models and provided recommendations for trust computation research. Figure 9 depicts the IoT security challenges as concerns for the success of smart campuses.

The complexity of a decentralized IoT environment has made the system independent from enforcing proper security solutions from a single party; rather, it is the responsibility of all actors concerned, from suppliers to producers, policymakers, developers, and the end-users. Although, it is possible to mitigate the risks associated with security breaches if the security issues are identified early in the product planning and design process and if certain simple mitigation measures are in place. Enactment and standardization would make production and development processes easier, provide a business catalyst for mass adoption, and improve the protection of IoT products and services. However, security will have to be built in for IoT and smart campus devices to stand a chance against the challenges that technological advances will bring [25]. With advances in quantum computing, artificial intelligence, and cognitive systems and the continued growth and widespread acceptance of the IoT ecosystem, existing security practices and methodologies will become obsolete [117].

Figure 9. Smart campus IoT security challenges [1,43,120,121,123–127].

Moreover, Miloslavskaya and Tolstoy [129] present four classifications for data circulating in smart devices from an information systems perspective: data collected from smart devices, applications, and other sources; data in IoT data streams (network traffic or network packets); data segregated by IoT users; and data locked up in disparate security devices, applications, and databases. The storage of each of these types of data generates enormous amounts of data in various formats, for various purposes, and frequently with a variety of different information systems policies and even compliance requirements. One issue is figuring out how to structure, consolidate, and visually present all of these types of storage in a way that enables smart campus information systems management to make timely and informed decisions. Furthermore, the smart campus can address specific issues and improve the overall quality of education and student and staff life. Similarly, Ande et al. [130] emphasized that one of the most significant global challenges we face today is reducing energy consumption. Energy has developed into a critical human commodity.

5.2. Motivation for IoT-Based Smart Campus Adoption

This review aims to identify a technology adoption model suitable for promoting the concept of smart campus adoption for future studies. Thus, present studies concerning IoT adoption were reviewed to identify the existing studies' weaknesses. Accordingly, the findings revealed that there is a consensus regarding research methodology and additional validation procedures to validate new models [54]. Reference [74] emphasized that weak research design and analysis methods will not reveal a strong relationship between the variables. Some studies lack an investigation of a specific application of IoT devices [44,45]. Hence, there is a strong need for theoretical extension in the context of IoT-specific devices [50]. Similarly, having a small sample size is among the weaknesses of the research designs of existing studies, preventing them from providing a significant result [51,59,69,74]. One key benefit of the literature review is linking present studies with previous work based on existing theory.

Moreover, the dependent variable in the study of [57] is not the actual adoption but the intention to adopt. Similarly, Alraja et al. [71] do not investigate actual use behavior for healthcare services. Additionally, Park et al. [67] draw further variables related to wireless services exposed to the risk of a security breach. The five risk factors presented in [67] require an additional analysis of the causality effects. Many predictors of the adoption of the IoT such as culture, lifestyle, social influences, personality, and cost were lacking from the literature. Logistics information platforms from the enterprise perspective is another area requiring future research [43]. The study of [64] does not consider users' characteristics such as smartphones or IT service habits and their capacity for personal innovation. Moreover, Han et al. [49] insist that factors such as technology readiness and facilitating conditions that can affect the use of NFC by other visitors to improve their understanding of NFC use limited their study concerning NFC adoption. However, facilitating conditions are one of the key constructs in the UTAUT model and were tested by many studies showing significant results. However, the perceived enjoyment and usefulness were not significant, according to the study by [67]. Hence, the hedonic motivation or perceived enjoyment and price value are among the extensions of UTAUT found in UTAUT2, which are overlooked by existing studies [52,65,69]. The coping behaviors that were employed as an ultimate consequence in the study of [46] were examples of perceptual decision making rather than actual behavior. The model proposed by [47] is based on the current perceptions of Millennials. Perceived concerns and mobility-related efficiencies were not addressed. This could offer new insight into IoT adoption and usage.

The analysis unit focused on cross-cultural perspectives rather than citizens' perspectives and behavior towards IoT use in public sector services [48]. Behavioral constructs that can explain patients' behavioral and psychological traits in the time of pandemics are not covered [70]. The work by [72] is limited to risk perception and overlooks other variables. The influence of the correlation and control variables between the independent variables was not analyzed as reported previously [75]. Furthermore, the work of Chohan and Hu [78] does not address privacy and user trust; however, IoT devices' security and trustworthiness need to be studied to increase public trust. Similarly, individual characteristics and empirical tests thereof, which can be associated with the intention to use information-oriented services, are lacking in a study conducted by [68]. Recently, Pal et al. [63] encouraged wider demographics comprising individuals, households, and business environments to help understand the adoption factors. Additionally, the perceived value was not considered by [71].

Furthermore, the work by [59] could be extended to smart technologies, such as smart medical devices. Moreover, other factors that are identified as limitations of existing studies include risk-taking behavior, innovation, cultural factors, and demographic factors [45,60], as well as the dynamics of users' behaviors toward IoT-based wearable fitness trackers [61]. Additionally, perceptions of value, risk, and even value-in-use evolve across various phases of IoT adoption, and need to be addressed [55]. A moderation effect was lacking from existing studies [53,58]. Expressly, the studies of Yamin and Alyoubi [56] are limited due to a lack of addressing mediating and moderating causal relationships among task technology factors. In addition, Alkawsi et al. [77] omitted the UTAUT2 moderators of experience, gender, and age. Moreover, a lack of a widely accepted research technique that connects existing ideas, frameworks, or models is a barrier to robust validation [54]. The majority of the study has not been applied to university settings in order to promote the concept of smart universities or smart campuses.

5.3. Adoption Model of IoT-Based Smart Campuses

This study aims to review IoT technology adoption models in order to conceptualize an adoption model appropriate for the adoption of smart campus solutions [9]. Hence, the literature review has identified a dearth of research on the adoption of IoT-based smart campuses as supported by technology adoption theories. Moreover, there is a lack of previous reviews and surveys on smart campuses that comprehensively address the adoption issue [4,27,32–35]. Surprisingly, very few of the current studies address the topic of smart campus adoption [8], which focuses on stakeholders' perception criteria of smart campuses. As a result, the effort focuses on IoT technology adoption to develop an adoption model tailored to smart campuses. Therefore, the conceptualization of the smart campus adoption model is discussed as follows.

Firstly, the knowledge obtained through the literature analysis has shown that technology adoption studies are classified into four primary classifications. As previously reported, four broad themes are recognized as (a) technology-specific factors, (b) organizational-specific factors, (c) environmental-specific factors, and (d) end-users-specific factors. The technology-specific factors cover the technological features that are significant to the users. The organizational-specific factors relate to the organization's characteristics and resources (higher institutions), including the size, the degree of centralization, the degree of formalization, managerial structure, human resources, the amount of slack resources, and the linkages among employees. The environmental-specific factors encompass the size and structure of the institutions, their competitors, the macroeconomic background, and the regulatory environment such as government policies. Finally, the end-user-specific factors entail the personal characteristics of the users [131,132]. Hence, Figure 10 represents how the classified technology adoption factors affect the adoption intention of IoT-based smart campuses.

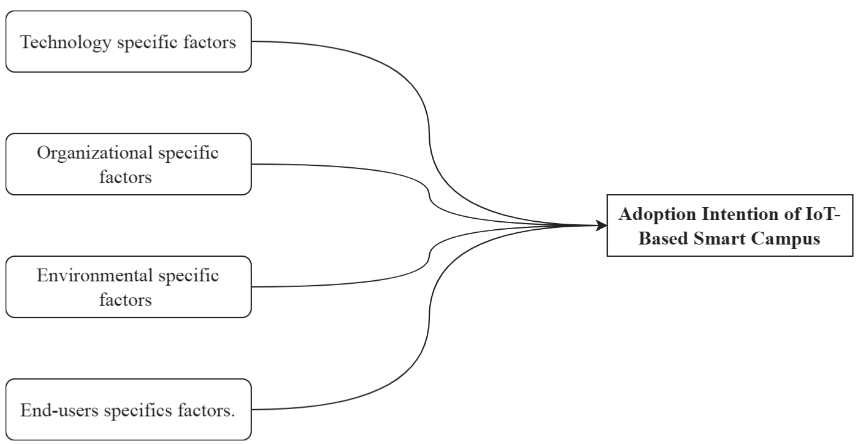

Figure 10. Adoption intention of IoT-based smart campuses.

Secondly, according to the literature review, current research has compared TAM, TPB, UTAUT2, and the value-based adoption model (VAM) [63,76], and it was discovered that VAM performed the best when it came to modeling user acceptance. The findings of these studies demonstrate that consumers are willing to tolerate extremely innovative products that have little practical usefulness. The literature has also demonstrated that the VAM has greater predictive power than other models [63,76]. As a result, the VAM model is the most accurate in predicting the values associated with higher education institutions as a result of the adoption of the smart campus idea. Hence, the adoption model intends to demonstrate the impact of smart campuses to help stakeholders and policymakers see the value derived from the adoption of smart campuses to improve effective resource utilization, energy savings, informed decision making, improved services, and risk mitigation [10,80,133,134]. Therefore, the conceptual model adopted the generic VAM constructs (usefulness, enjoyment, technicality, and cost), trust, and privacy and security as factors influencing the intention to adopt IoT-based smart campuses, as shown in Figure 11.

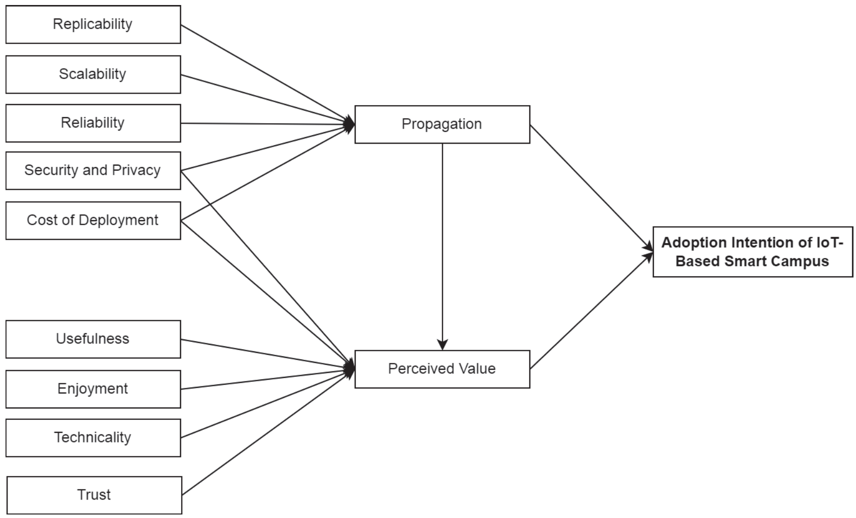

Figure 11. Conceptual model for IoT smart campus adoption.

Therefore, the VAM's usefulness, which is similar to the perceived usefulness of TAM, has been empirically tested to predict the behavioral intention or adoption of new technology [43,44,47,48,50–53,57–59,63–65,67,70,73,75–78,111,135,136]. Hence, the usefulness is the degree to which an individual believes that using the IoT or smart device will help them to attain gains in job performance. Similarly, the enjoyment was regarded as hedonic motivation in UTAUT theory, which explained the extent to which the activity of using IoT devices is perceived to be enjoyable, aside from any performance consequences resulting from technology use [57,59,63,67,72,73,76]. Furthermore, TAM's perceived ease of use and VAM's technicality are conceptually similar, and are associated with problems in usage [63,76]. Similarly, the perceived ease of use or perceived technicality have been tested extensively in the technology adoption literature, and refer to the degree to which a person believes that using the IoT or smart systems would be free of effort [44,50,52,53,57–60,63–65,67,68,70,73,76–78,111,135,136]. In addition, the "value" was identified in several studies as the benefits that could be derived from using a system [48,49,55,59,60,63,69,76]. Therefore, the value is the users' evaluation of the benefits to be derived from the IoT or smart devices against the cost of the device. Thus, the value provides the underlying direction to the individual's choice and/or their evaluation of the behavioral alternatives, which is adopted as a mediator in this study model, similar to the VAM concept [59,63,76]. Hence, the usefulness, enjoyment, and technicality are presumed to affect smart campus adoption.

Moreover, the perceived fee is one of the generic constructs in the VAM, and it is treated as the price value in UTAUT, and has subsequently appeared in the work of [4] as the cost of deployment. Accordingly, the cost of deploying smart programs should be straightforward to comprehend and quantify; of course, the cost of hardware and software licenses would rise when replicated on a larger scale. The cost is referred to as the unit cost which a consumer incurs by using IoT devices such as purchasing, installing, maintaining, and repairing the various components and devices of the IoT system [51,54,59,62–64,66–68,76,112,113], which has been tested to predict the technology adoption behavior. Similarly, existing studies using TAM and/or UTAUT approaches have discovered that trust is necessary for the acceptance of new digital technology [137–139]. Trust is described as the "willingness to rely" on the partner, which, in this case, is the IoT or smart devices [45,51,55,58,59,67,69–71,73,78]. However, the various foundations for trust and the varying levels of trust in societies are frequently overlooked. Thus, the fact that a sizable portion of the citizenry lacks trust and the existence of differences between cultures, cities, and nations are overlooked [140]. Privacy and trust are widely regarded as multidimensional concepts, with various personal and contextual factors influencing people's perceptions [141]. Hence, privacy and security are adopted in the concept model as a single dimensional construct [4]. This is because privacy and security are related. The privacy is concerned with the right to select what personal information should be known to other people, and security focuses on how that information is protected from unauthorized access [4,43,45–48,55,59,60,66–68,70–73,112–114].

Securing data, infrastructure, and individuals' privacy is a challenge inherent in smart technology, and the smart campus is no exception [4]. Consideration should be given to protecting digital credentials for students, faculty, and staff, among others. A smart campus must have adequate security protocols and encryption mechanisms in place. Similarly, there is broad agreement on the importance of privacy, security, and trust as important criteria for IoT deployment and acceptance [125,142–145]. However, from the perspective of smart universities, empirical research focused on the implications of privacy, security, and trust remain insufficient. The effort of Chohan and Hu [78] has fallen short of addressing privacy and user trust; nonetheless, the security and trustworthiness of Internet of Things devices must be investigated in order to boost public trust. This research gap could provide universities with new insights into the full-scale use of IoT-based smart campuses, which would be particularly beneficial in developing countries. The success of IoT smart campus adoption in the future is thought to be dependent on the privacy, security, and trust of users. Hence, privacy and trust are related concepts that exhibit a range of preferences depending on the person and the context. However, current notice and consent procedures, most notably the use of privacy policies, do not adequately resolve customer privacy and trust preferences [141]. IoT systems implemented in public spaces as part of 'smart campus' initiatives present complicated privacy, security, and trust concerns. They pose complexities related to spatial implementation, alignment with existing systems, and a lack of clarity about data collection and usage practices. The concept presented in Figure 11 depicts how these typical elements may affect IoT-based smart campus adoption.

Thirdly, the concept of smart campus propagation was introduced by [4] to promote sustainability, which comprises several factors such as replicability, scalability, reliability, security and privacy, and the cost of deployment. The propagation is the ability of the smart campus to be replicated conveniently at various places or locations. Hence, the performance of smart campuses is contingent upon the model being easily replicable at different levels, ranging from academic departments to small communities to small cities and even consortia of cities. Numerous universities are housed in scattered buildings and have satellite campuses in distant geographical locations. This means that the structure of any smart campus model must promote its integration. Therefore, scalability, reliability, and replication are all planned factors of the conceptual model. The scalability describes how IoT-based smart campus solutions can adapt to the changes, or can be used in a range of capabilities. Hence, the scalability ensures that the system has the flexibility to address the needs of the users as they arise [4,146,147]. Similarly, the reliability factor ensures that there is no possibility of the IoT-based devices malfunctioning and not being able to provide the intended services, ensuring that they consistently operate properly and predictably [4,45,66,68,114]. At the same time, the replication is the ability of IoT smart devices to be repeated consistently and to obtain the same result [4,148,149].

Hence, the smart campus adoption model aims to propose a minimal model that can easily help relevant stakeholders understand the value of the smart campus initiative. The model's replication and scalability variables should be straightforward, demonstrating how the concept can be expanded with no or minimal development costs. Given that many smart campus programs can be directly replicated at the city level, these projects must be easily deployable at that level. When replicating the campus model in other locations, such as a town, city, or another campus, it is critical to protect the users' privacy. Still, understanding the potential cost will be essential for organizing and financing smart campuses. Similarly, the data produced should be trustworthy, and feedback from different sources should be checked before obtaining and filtering the data. Redundant hardware is recommended when installed at critical facilities to ensure the data's integrity and, ultimately, the entire smart campus system. The replicability, scalability, security and privacy, reliability, trust, and cost of deployment are considered factors of propagation [4]. Moreover, any smart campus solutions should be easy to use, beneficial to the users, and enjoyable in order to add value to the system.

6. Conclusions

This study serves as a reference guide for smart campuses, emphasizing adoption patterns. As a result, this study proposes a solution to the lack of an adoption model for the smart campus initiative. In order to accomplish this, the researchers conducted a literature review, identified the commonalities among IoT adoption models that were suited for smart campus adoption, and developed a technology adoption model for smart campus adoption. In particular, the current study emphasized the crucial role that IoT-based smart campus adoption can play in the development of a sustainable campus environment. The research examines the major benefits and motives for establishing an IoT-enabled smart campus. A general overview of smart campus technology and applications is provided, emphasizing the importance of the adoption challenges that must be overcome to establish a sustainable smart campus. Hence, the present investigation discovered a range of models in the technology adoption or acceptance literature that can be used to improve technological adoption. According to the findings of this study, TAM and UTAUTs are the most prevalent models. On the other hand, the VAM model has lately gained popularity in the literature and has been adapted to investigate the adoption of the smart campus concept. Hence, the adoption model comprises security, privacy, and trust which are some of the challenges attracting discussion from several studies and are slowing the adoption and usage of IoT smart devices and applications. These factors affect the widespread, effective and efficient application and implementation of smart campus initiatives. At the same time, variables such as perceived scalability, replicability, reliability, security, trust, the cost of deployment, technicality, usefulness, and enjoyment are promising elements that could influence smart campus adoption.

Limitation and Future Work

The study presented a solution addressing the lack of a smart campus adoption model. The work is not without limitations. The selection of the papers focuses on the smart campus adoption concept linked to technology acceptance theories, but we realized that these categories of papers are severely limited. Thus, the focus was shifted toward IoT adoption to address the key objectives of this study, which is to propose a technology adoption theory for smart campuses. Future research can expand the inclusion criteria and other databases to see if more relevant studies could be identified. In the future, the researchers will focus on validating and verifying the conceptual framework introduced in this study. Moreover, future research may compare and prioritize the factors via AHP to select suitable factors to investigate the adoption of IoT-based smart campuses. The adoption model will help promote the concept of smart campuses, which is more sustainable and contributes to the development of a sustainable campus.

Author Contributions: This study was designed, directed and coordinated by Y.Y.J. and M.A.J. Y.Y.J., as the principal investigator, provided conceptual, financial, and technical guidance. M.A.J. assisted in planning the SLR and the data was analysed by R.S. and S.A. Moreover, R.S. generated and characterized the literature, while S.A. assisted in the organization and synthesis of the data. The manuscript draft was written by R.S., and commented on by all authors. All authors have read and agreed to the published version of the manuscript.

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Appendix A. Technology Adoption Factors

Table A1. Constructs or factors from various theories/models.

Theoretical Models	Constructs	References
Technology Acceptance Models (TAM)	Perceived ease of use (PEoU), perceived usefulness (PU), behavioral intentions (BI), attitude, usage, mobile skills, social skills, information navigation skills, creative skills, IoT skills, perceived affective quality (PAQ), mobility, availability, trust, consumers' perceived innovativeness and intention to use, lack of sub-services, low network quality, low usability, low usefulness, low usage intention, alternatives, usage costs, personal information, personal formal, impersonal, privacy concern, perceived compatibility, vanity, need for uniqueness, perceived self-expressiveness, subjective norms or social influence, perceived behavioral control, security, familiarity, risk perception, perceived enjoyment, perceived connectedness, perceived cost, perceived system reliability, functionality and reliability, helpfulness, social network, community interest, product or service security, perceived risk, trust, IoT adoption, dimensions of national cultures	[44,45,47,50,52,57,58, 63–65,67–71,74,76,78]
Unified Theory of Acceptance and Use of Technology (UTAUT)	Performance expectancy (EE), effort expectancy (EE), social influence (SI), facilitating condition (FC), individual factors (IF), behavioral intention (BI), use behavior, technologically minded individuals, personal and societal benefits, society, mobility-related efficiencies, safety, technological and legal concerns, task technology fit (technology characteristics and task characteristics), awareness and self-efficacy, intention, data integrity, confidentiality, non-repudiation, authentication, availability, authorization, error, secondary use, collection, social influence trust, and enjoyment.	[47,53,56,63,73,76]
Theory of Planned Behavior (TPB)	Attitude, subjective norm, perceived behavioral control, and behavioral intentions.	[50,69]
Unified Theory of Acceptance and Use of Technology (UTAUT2)	Performance expectancy, effort expectancy, social influence, habit, facilitating conditions, behavioral intention (BI), environmental awareness, electricity-saving knowledge, use behavior, perceived fee, perceived enjoyment, and hedonic motivations.	[59,77]
Value-based Adoption Model (VAM)	Perceived fee, perceived technicality, purchase intention, behavioral intention, perceived privacy, perceived value, perceived trust, perceived health increase, and intention to use.	[59,63,76]
Theory of Reasoned Action (TRA)	Attitude, subjective norm, and behavioral intention (BI).	[50,69]
Motivation Opportunity Ability (MOA) Theory	Information quality, organizational support, users' self-efficacy, NFC value, satisfaction, reuse intention, expo satisfaction, and expo loyalty.	[49]
Innovation Diffusion Theory (IDT)	Compatibility, trialability, and observability,	[65]

Table A1. *Cont.*

Theoretical Models	Constructs	References
Self-Efficacy Theory (SE-theory)	Interpersonal influence, personal innovativeness, trustworthiness, attitude toward wearable, self-efficacy, health interest, perceived value, and intention to use.	[69]
Technology Organization Framework (TOE)	Perceived trustworthiness of technology, perceived benefits, perceived cost, external pressure, and IoT adoption intention	[51]
Influence Relationship Map (IRM)	Perceived utility, perceived expectancy, perceived usability, network externalities, adopting intention, domain-specific knowledge, user innovativeness, and usage behavior	[61]
Behavioral Reasoning Theory (BRT)	Value of openness to change, ubiquitous, relative advantage, compatibility, convenience, usage behavior, traditional barrier, risk barrier, attitudes towards the adoption of healthcare wearables, and adoption intention of IoT-based healthcare wearables	[60]
IoT-based Public Value Model (IoT-PVM)	System quality, information quality, service quality, PEoU, decision transparency, the trust of government, public trust, service collaboration, service effectiveness, service transparency, public engagement, PU, usage BI, and public value creation	[78]

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Review

Achieving Sustainability and Carbon Neutrality in Higher Education Institutions: A Review

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Abstract: Universities and higher education institutions play an important role in achieving a sustainable future through their teaching and by undertaking cutting edge research to combat climate change. There have been several efforts towards a sustainable future and achieving carbon neutrality at higher education institutions in Australia and around the world. This study has reviewed the sustainability strategies of numerous universities in Australia and has identified as study cases six universities that are committed to and leading the implementation of initiatives to achieve carbon neutrality. The initiatives implemented at the selected universities were classified into eight "sustainability categories", namely, built environment, energy, food and gardens, GHG emissions, natural environment, resource and waste management, transport, and water. Among the selected leading universities in sustainability, Charles Sturt University and the University of Tasmania (UTAS) are the only universities in Australia certified as carbon neutral. An interesting aspect of this review is the way in which universities are implementing sustainability initiatives in line with their mission and strategies. Despite striving towards the same end goal of achieving carbon neutrality, different institutions offer individually unique approaches towards sustainability. For example, UTAS values the creation, expansion and dissemination of knowledge and the promotion of continual learning, which is clearly demonstrated through its initiatives and policies. The findings in this review are critical in identifying those institutions of higher education which are role models in their strong commitment to achieving carbon neutrality. Such role model universities can pave the way for similar climate action at other universities.

Keywords: global warming; net zero emissions; sustainable campus; climate action; GHG emissions

1. Introduction

Global warming is one of the most pressing concerns facing humanity today. Anthropogenic activities have been shown to result in negative impacts on the environment through increasing greenhouse gas (GHG) emissions [1]. Climate change and its effects are a fact of life that people are currently confronted with. There have been talks about intergenerational equity and developing a sustainable way of life as an approach to combatting this worldwide threat [2]. As sustainability can be a difficult concept to grasp, there are many different perspectives on what it means to be sustainable [3]. In 2015, 196 nations signed the Paris Climate Accord with the objective of limiting global warming to far below 2 °C above pre-industrial levels and pursuing extra measures to reduce it to 1.5 °C above pre-industrial levels. To keep global warming below 1.5 °C, immediate action is needed to cut global GHG emissions by 44% below 2010 levels by 2030, with net zero emissions by 2050 [4–7]. Carbon neutrality is defined in a variety of ways; thus, it is critical to have a common consensus in order to avoid any misunderstanding. The Publicly Available Specification by the British Standards Institution (BSI PAS 2060) defines carbon neutrality as the absence of net GHG emissions during a certain time period, while the Carbon Neutral Cities Alliance (CNCA) describes it as a goal of cutting GHG emissions by 80–100% by 2050 or sooner when compared to the baseline year of 1990 [8]. The two documents, BSI PAS 2060 and CNCA, are similar in their conclusions in the sense that a city's net GHG emissions should be zero at some point in the future during a predetermined period.

It is a widely held view that higher education institutions have the capacity to influence climate change responses not only through their research and education, but also through their commitments to renewables and climate change mitigation and adaptation within their operations [9–12]. Reassessing a university's quest to achieve sustainability through commitments and implementing sustainable development policies are important steps towards reducing its GHG emissions and achieving carbon neutrality [13,14]. According to the three categories of infrastructure, community, and learning, these should unfold and interrelate to transform sustainable practices and make up the foundations of a sustainable campus [15]. Although it takes time to integrate sustainable development policies and practices into an institutional process, especially in the higher education sector, numerous universities around the world are working to achieve this transition, recognising their moral obligations to address the environmental consequences of their own actions and to inspire and educate the next generation to act responsibly. Universities can help to reduce GHG emissions and to make the transition to carbon neutral systems. The educational benefit of achieving carbon neutrality is enormous, as these activities provide hands-on learning opportunities for tomorrow's citizens and climate leaders [16]. A carbon-neutral university is one of numerous local initiatives being implemented by higher educational institutions throughout the world to promote sustainable development via systematic institutional changes at the local level [17]. The fundamental difficulty for universities is to determine how to reduce their own carbon footprint. Fortunately, the universities that have been able to break the barrier and overcome this difficulty can be a major resource to help many other universities achieve this goal towards sustainability.

Australia is dedicated to meeting the United Nations Sustainable Development Goals (UNSDGs); however, compared to commitment and action at the global level, Australia has achieved rankings below the regional average score when assessed in 2018 with 155 other countries. This shows that in terms of development towards the UNSDGs, Australia falls behind other advanced nations. According to the findings of one study, Australia shows a mixed performance in achieving the UNSDGs, with excellent development in health and education targets but a slow growth in climate action goals [18]. While many Australian universities are basing their activities on the UNSDGs, which include drastically reducing carbon footprints, there is no general guideline for Australian universities to follow as each university has implemented initiatives in a variety of different areas. Examples include Charles Sturt University and the University of Tasmania, which have audited and reduced their emissions, and received carbon neutral certification in 2015 and 2016, respectively. These are the only two universities in Australia to have already achieved carbon neutrality. A few institutions have been making divestment from fossil fuels the centrepiece in their climate action plans, with the movement started by La Trobe University in 2016. Along with universities integrating divestment in their actions, efforts are underway to persuade other organisations related to Australia's higher education sector, such as UniSuper, a 450,000-member higher education superannuation fund, to divest from fossil fuel. While this is important, some universities have focused on generating their own renewable electricity. Deakin University has established an industrial scale microgrid, while the University of Queensland has built and operated a million-dollar solar farm to offset their power. Other universities have followed closely, with hopes of transitioning to 100% renewable power [19]. While several universities have made a start toward achieving sustainability and carbon neutrality, they must be more ambitious to put Australia back on track towards meeting the UNSDGs.

There is very limited literature available on the subject of achieving 100% carbon neutrality among higher education universities, and the purpose of this study is to contribute to the scant literature. This paper is mainly focused on selected leading universities in Australia, and provides an analysis and comparison of their plans and initiatives towards sustainability and achieving carbon neutrality. This analysis will provide valuable inputs on how universities in Australia compare to one another and how their progress towards carbon neutrality can be achieved. To obtain a global perspective on sustainability in higher education institutions, some leading universities from around the globe will be examined as well. The goal is that the knowledge and ideas presented as outcomes of this study may be useful to other higher education institutions in their attempts to improve sustainable development and move towards achieving carbon neutrality and beyond. This research will assess the carbon neutral status of universities in Australia and across the globe in order to determine how they incorporate sustainable practices and how they work with the UNSDGs to achieve carbon neutrality within the set timeframe. This will influence how numerous institutions around the world utilise different or similar means to reach the same target. Furthermore, this will aid in providing comparisons between universities in Australia as they plan various frameworks and strategies to achieve carbon neutrality. This study also demonstrates what needs to be done to reach carbon neutrality. As a result, it compares and analyses the various available sustainability strategies which universities can implement. Although case studies on carbon neutral universities from other parts of the world are available, they do not compare initiatives on a national level [17]. Unlike previous studies, this research will serve as a general guideline for higher education institutions through an analysis and comparison of sustainability initiatives at universities in Australia, which will help such institutions contribute to climate action and the UNSDGs.

Thus, the specific scope of this study can be summarised as follows:

- Determine the major contributing factors of GHG emissions in universities
- Look at ways to reduce these major contributing elements
- Identify the key strategies that have been implemented in universities mainly in Australia to be fully carbon neutral
- Compare and analyse selected leading universities in Australia and outside Australia in terms of their strategies to achieve sustainability and carbon neutrality
- Create common guidelines or directions about strategies and initiatives which other universities can follow.

This review paper is structured as follows. The second section presents the methods used in selecting the case study universities. This is followed in Section 3 by a detailed review of sustainability strategies implemented at selected universities in Australia and outside Australia. The fourth section then presents a detailed discussion based on the outcomes of this study; finally, conclusions drawn from the study are presented in Section 5.

2. Methods

In recent years, human activities have contributed to significant climate change around the globe. As a result, countries worldwide are focusing on reducing greenhouse gas emissions and mitigating climate change [20]. The undertaking of critical research on combating this problem through carbon reduction and promotion of sustainable strategies stems from higher education institutions, which play a significant role through their research, teaching and implementation of strategies and policies to address these concerns.

The review undertaken in this study was conducted in two stages. The initial Stage 1 of this review aimed to undertake a thorough online review of the literature to identify the higher education universities in Australia that are implementing sustainability initiatives with the aim of achieving carbon neutrality. The online literature comprised research journal papers from scientific databases (ScienceDirect, Scopus and Google Scholar), books, and university reports and publications. University publications were obtained from their respective websites. It was imperative that the data collected be as recent as possible, with relevant information that addresses climate action at higher education institutions. Since university strategies were only available through their publications and were constrained in terms of how recent they were. In Stage 1 of this literature review, fifteen universities in Australia which were implementing various sustainability initiatives were identified.

The way in which these fifteen universities in Australia identified in Stage 1 implemented various sustainability initiatives was observed and how they are achieving carbon neutrality was assessed to varying degrees. The initiatives implemented at the selected universities were classified into eight "sustainability categories", namely built environment, energy, food and gardens, GHG emissions, natural environment, resource and waste management, transport, and water.

In the Stage 2 of this review, the initially identified list of 15 universities was further narrowed down to select 'case study universities' which were potentially making significant progress towards achieving carbon neutrality. The case study universities were identified based on their performance in the above-listed eight sustainability criteria and their strong commitment to achieving carbon neutrality. Another criterion for selecting the case study universities was based on the Climate Active Neutral Standard and whether the universities are taking steps to achieve that certification. Based on these criteria, six "case study universities" in Australia were identified in Stage 2: the University of Tasmania (UTAS), Charles Sturt University, the University of Melbourne, the University of New South Wales (UNSW), Monash University, and RMIT University. As mentioned earlier, thus far only Charles Sturt University and UTAS have been certified as carbon neutral in Australia. While most universities have a net zero aim of 2050 or sooner, the six universities chosen as case study universities have demonstrated greater commitment and progress in their sustainability programmes and ambitions to achieve carbon neutrality. The criteria considered for selecting the case study universities are summarised in Figure 1.

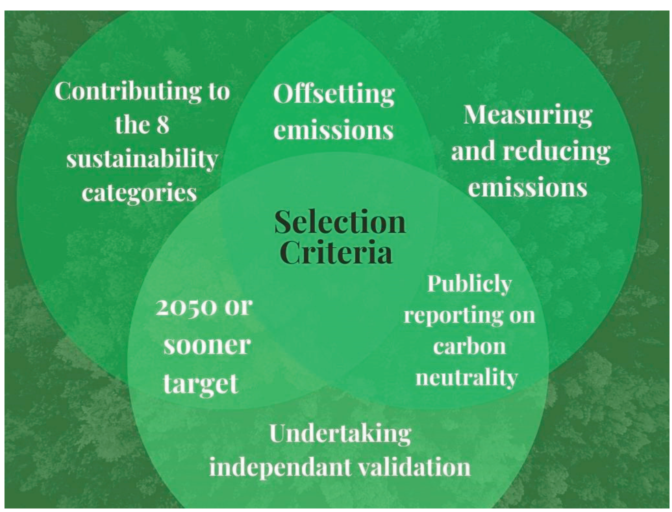

Figure 1. Selection criteria used for identifying the case study universities. Data Source: [21,22].

In the next section, the sustainability strategies being implemented by the six case study universities are analysed and compared across the eight identified sustainability categories.

3. Sustainability Strategies

Since the focus of this paper is to review the sustainability initiatives undertaken at universities in Australia and the steps they are taking towards achieving carbon neutrality, this section will first discuss in detail and compare how Australian universities have taken up various sustainability initiatives. A brief discussion on the goals and strategies of some leading universities outside Australia is also presented in this section.

3.1. Sustainability at Australian Universities

In Australia, universities need to consider the Climate Active Carbon Neutral Standard for Organisations set by the Australian government to obtain their climate neutral certifications. This is a voluntary standard for reducing GHG emissions and attaining carbon neutrality. It gives best-practice recommendations on how to monitor, reduce, offset, validate, and report emissions generated by an organisation's operations. Climate Active is Australia's collaborative climate action project, and it is the only government-backed programme that allows all levels of Australian society to collaborate to reduce carbon emissions. The Organization Standard is based on international norms that have been adjusted to the Australian context. Emissions are divided into three scopes (Scope 1, Scope 2 and Scope 3) to better distinguish between different emission sources as illustrated in Figure 2, the data for which is taken from the Climate Active Carbon Neutral Standard for Organisations [21]. It can be noted that university-owned fleet vehicles for fossil fuel powered internal combustion engines are Scope 1 emissions but are classified as Scope 2 emissions if electric vehicles are powered by off-site generated electricity.

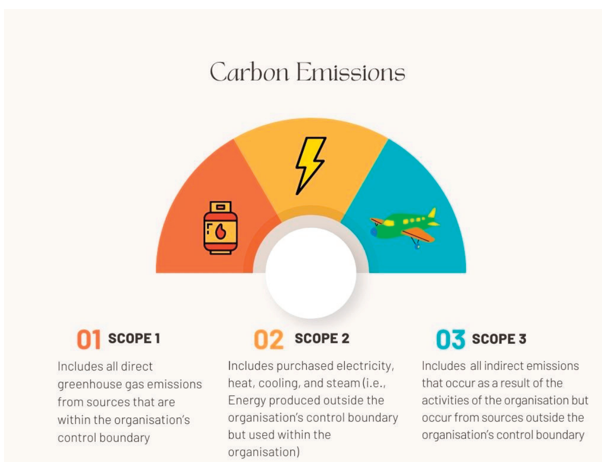

Figure 2. Classification of carbon emission scopes. Data source: [21].

To achieve carbon neutral certification by the Climate Active Carbon Neutral Standard, universities must:

- Measure and reduce emissions where possible
- Offset remaining emissions
- Publicly report on their carbon neutrality
- Undertake independent validation (i.e., audit or verification) by an environmental auditor or carbon consultant at least once every three years.

The following sub-sections break down the sustainability initiatives according to the eight identified sustainability categories. It is aimed at identifying similarities as well as differences in strategies that the case study universities are implementing to pave a pathway towards achieving carbon neutrality.

3.1.1. Built Environment

The term "sustainable building" refers to both the structure of a building and the application of environmentally responsible and resource-efficient techniques throughout its life cycle: planning, design, construction, operation, maintenance, renovation, and deconstruction [22].

The Sustainability Integration Program for Students (SIPS) at UTAS links sustainability outcomes with student experience, allowing them to experience real world sustainability challenges; it has been an important part of all university initiatives, including in its impact on the university's performance in the sustainability categories. The university established Governance Principle GLP9 on Environmental Sustainability in 2005, stating that "environmental preservation and sustainability are fundamental concerns in how the University functions". The first Sustainable Environment Designs Policy was authorised in 2008, followed by the creation of the "Design Requirements—University of Tasmania" document, which was first made public in 2009 [23]. Following a review of the university's policy approach, which used lean concepts, the built environment principles of the university were incorporated into the sustainability policy in 2020. At all phases of the design and construction processes, any actions that have an impact on the natural and built environment are identified and resolved. Environmentally sustainable design (ESD) elements are discovered throughout the preparation of university clearance alternatives along with all building operations, including demolition and deconstruction. Several big projects have gained 5-star Green Star certification or above in recent years. In 2012, their Medical Science Precinct 2 became Tasmania's first educational building to get a Green Star designation for environmental design [22].

A set of guidelines have been prepared to allow and promote the incorporation of ecologically friendly projects into the built environment at Charles Sturt University. These rules are part of the operational project design requirements of the university. Through sustainable building design and construction, they have integrated sustainability into the built environment of the university. Charles Sturt University has a sizable and diverse property portfolio spread throughout its campuses. Typically, the university owns a building from design and construction to operation, restoration, and re-purposing, and demolition. Charles Sturt is conscious of the impact of these assets' running expenses and benefits from the building stock's whole-of-life efficiencies. The footprint for the running costs is established during the design and construction phase. Charles Sturt's Port Macquarie Stage 2A building project applied the ARUP Sustainable Project Appraisal Routine (SPeAR) during design and construction. This allowed the building to incorporate sustainable features such as a 164 kW rooftop solar energy system to maximise self-generation, a high-performance building façade designed to maximise benefits through shading, glazing and other materials, traffic light control for the air conditioning system designed to provide building users with feedback on when to use natural ventilation, smart metering linked to the university energy management system to monitor utility consumption, and local and sustainable materials [24].

The Green Building Council of Australia (GBCA) has awarded the University of Melbourne's Parkville campus a 6-star Green Star—Communities designation, recognising international leadership in sustainable master planning. It is the first time an Australian university has received a 6-star—Communities grade [25]. The Green Facility Council of Australia awarded the university's new Melbourne School of Design building a 6-star Green Star Design—Education Design v1 Rating. Only 12 buildings in Australia have been awarded a 6-star Green Star Education Design—v1 certification, and this is the largest. Notably, this structure is the only one to have ever received all ten innovation points available in the evaluation criteria. The Old Quadrangle, the oldest building on the Parkville campus, is being redeveloped as the university's major cultural, civic, engagement, and ceremonial heart. To maximise sustainability outcomes while honouring the heritage and uniqueness of this historic precinct, adaptive reuse and novel heating and cooling techniques are being used. The university's priority actions include embedding ESD principles throughout project lifecycles, investigating leading global standards applicable to precinct-level design and development, reviewing, and updating the University's Design Standards to enable the integration of sustainability commitments, developing guidelines for ESD standards for both major and minor refurbishments, and implementing a zero-emissions-ready approach to all campus deconstruction [26].

The development of the UNSW campuses provides a chance to establish healthy and regenerative environments for study and employment that use natural resources as little as possible in their construction and operation. A framework has been developed to establish their approach to sustainable design in new building and refurbishment projects, resulting in fit-for-purpose and future-proofed facilities. The Roundhouse public domain project was finished in 2020, resulting in the activation of the first portion of College Walk, a new pedestrian-focused route connecting to the recently inaugurated light rail terminus on Anzac Parade. In the same year, a new UNSW Health Translation Hub (HTH) and a new multi-level Biomedical Science Centre schematic design was created in accordance with UNSW minimum sustainable design criteria, which are comparable to the 5-star Green Star Design and As Built and 5.5-star NABERS Energy ratings. The university has also set a target for 2022 where new buildings must be designed and built to achieve a minimum of 5-star Green Star Design and As Built or equivalent and 5.5-star NABERS Energy equivalent [27]. The institution is dedicated to incorporating leading environmental sustainability ideas and practises into the design and operation of buildings and campuses.

The new Chancellery and Woodside Building for Technology and Design, which opened in 2020, demonstrates Monash University's dedication to designing and constructing buildings that provide occupant comfort and healthy interior environments. Both of these structures were designed and constructed using the Passive House 'fabric first' design process. Both the Woodside Building for Technology and the new Chancellery have received formal Passive House accreditation, and both are well-insulated, sealed, and shaded, with dedicated fresh-air systems. Both buildings contain an all-electric power plant and rooftop solar panels. These buildings will be connected to the campus microgrid (electricity) and collected water network, in addition to having low energy and water use, to enable more efficient use of resources both within the buildings and throughout campus. Water-sensitive landscapes have been created around each of these structures. By 2030, the university intends to include ecologically sustainable development in all new building and renovations, as well as to electrify all existing structures [28].

RMIT University's Sustainable Design Principles give explicit advice for capital project designers and consultants to guarantee that industry best practise sustainable results are delivered throughout the lifecycle of RMIT's new and existing venues. The university strives for sustainable outcomes in capital projects by encouraging design and operation practises that promote passive design to reduce building energy consumption, materials selection that prioritises low toxicity, low environmental impact materials, supply chain transparency, circular economy principles, active and sustainable transportation, and good health and wellbeing for all occupants. RMIT has a long history of support for the Green Star rating methodology as a founding member of GBCA and regards the Green Star framework as a clear and consistent methodology for recognising sustainability successes. All new developments and large refurbishments must attain a minimum 5-star Green Star As Built accreditation. The university currently has seven 5-star Green Star rated buildings, with Building 106 recently 5-star rated in 2021. This facility was created with health and wellness in mind, with fresh air and plenty of natural light throughout. The lighting control was created with the goal of maximising natural light in the space. Particulate and toxin levels in paints, sealants, carpets, furniture, and cleaning chemicals have been kept to a minimum, and the furniture chosen must have high third-party sustainability and ergonomic ratings. Indoor plants have been evenly placed throughout the building to improve the quality of the indoor environment and to ensure that people feel connected to nature even when they are indoors [29]. Table 1 presents a summary of built environment-related sustainability initiatives at the six selected Australian universities.

Table 1. Summary of initiatives at the six selected universities under 'built environment' category.

University of Tasmania	Sustainable environment design policy approved in 2008 Built environment policies now included in the sustainability policy Environmentally sustainable design is made aware and included in all projects Major projects have received/registered for 5-star Green Star certification SIPS built environment related projects conducted
Charles Sturt University	High-performance building facade, modelled to achieve maximum benefits through shading, glazing and other materials selected Local and sustainably sourced materials used in buildings
University of Melbourne	Redevelopment project of the Old Quad building with sustainable features First university to achieve a 6-star Green Star Communities rating for Parkville campus in 2017 More than six 5-star Green Star Design rated buildings
University of New South Wales	New buildings designed to be zero emission in operation Roundhouse public domain works completed, new pedestrian focused route linking to the newly opened light rail stop Schematic design completed for new Health Translation Hub and Biomedical Science Centre buildings in line with UNSW sustainable design requirements Planning to design and build new buildings to minimum 5-star Green Star Design by 2022
Monash University	All new buildings are electric, with roof top solar All new buildings designed to Passive House principles Existing campus buildings are to be electrified by 2030
RMIT University	RMIT Sustainable Design Standards used for all projects Currently has seven 5-star Green Star rated buildings

3.1.2. Energy

Sustainable energy entails the consumption of less energy from non-renewable energy sources (such as fossil fuels) and use of more renewable energy sources (such as solar, wind, rain and geothermal heat). Energy management at UTAS aims to reduce carbon emissions and energy consumption costs by implementing strategies, systems, procurement, and development. Energy performance contracts, including building management and control system upgrades, are among the recent energy reduction initiatives taken by the university. Buildings and systems are monitored to verify that they are operating efficiently. Other initiatives include photovoltaic and solar hot water system installation, upgrading lighting systems to LED (light emitting diode), LPG (liquified petroleum gas) and diesel fuel replacement with natural gas, and ensuring that all large new construction projects receive a 5-star Green Star rating. Energy challenges and competitions for university faculty and students are also being organised and conducted. The university's Energy Strategic Plan commits to monitoring, evaluating, and reporting on key indicators, for which UTAS collects a variety of data.

Charles Sturt University had the largest rooftop PV system in 2017, and this deployment has continued to the point where solar is now installed on the great majority of structurally sound rooftops. The university's 2030 Clean Energy Strategy lays forth a plan to become more energy resilient, efficient, and prepared for a low-carbon future. They plan to eliminate all scope 1 and 2 emissions from their activities by 2030; however, this will be a considerable task given that natural gas derived from fossil fuels accounts for half of the university's stationary energy demands. The strategy will focus on primary areas such as external power purchase agreements that will contract energy only from solar and wind sources, energy efficiency, further onsite renewable and energy storage, electric vehicles, elimination of natural gas, and energy productivity The Enterprise Space Register Integration project aims to share instructional space utilisation data recorded in the university timetabling system in order to improve space management. The university can improve security and reduce energy consumption in scheduled instructional rooms by sharing this information. This is accomplished by transitioning from generic weekly schedules for when spaces should be unlocked and air-conditioned to actual, timetabled bookings driving the operation of these systems.

The University of Melbourne is reinforcing its commitment to reduce fossil fuel use and take advantage of possibilities to source emissions-free energy both on and off campus. The university consumes a large amount of energy for its power needs, primarily from electricity and gas. The global warming impacts of fossil fuel use have a meaningful impact on this need. Through on-campus energy projects, the goal is to reach zero net emissions from electricity by 2021 and to reduce emissions by 20,000 tonnes of carbon per year by 2020. The university received funding from the Clean Energy Finance Corporation (CEFC) in 2015 to carry out a number of renewable energy generation and energy efficiency initiatives on campuses. Rooftop solar generating, voltage optimisation, and efficient freezer renovations are among the measures that are intended to lower the university's carbon footprint by almost 9000 tonnes per year.

Since November 2020, UNSW has begun receiving emissions-free renewable electricity, allowing the university to realise their aim of generating net zero energy-related emissions by 2020. The 15-year solar supply arrangement with UNSW and Maoneng is the first of its kind in Australia, bringing together a retailer, developer, and corporation. UNSW considers itself the first university in the world to achieve full energy carbon neutrality, with solar photovoltaics meeting 100% of its demands [30]. The central energy plant's building controls at Ainsworth Building (J17) were upgraded to improve system performance and energy efficiency. Furthermore, to properly condition occupied spaces, a demand-based control for the Hilmer Building (E10) air conditioning system was implemented which included the installation of extra passive infrared motion sensors (PIR) and integration with the building management system (BMS). To reduce heating and cooling demand, air conditioning setpoints were adjusted based on ambient temperature for most big buildings with BMS.

In 2018, Monash University agreed to a Power Purchase Agreement with Murra Warra Wind Farm. The construction of Monash's turbines was commenced in September 2019, and the practical completion occurred on 1 January 2020. This arrangement supplied enough capacity to meet the university's existing electricity use. In 2017, a substantial rooftop solar programme began, increasing total capacity across all campuses by 300%. Combined with the Murra Warra Wind Farm Power Purchase Agreement, Monash University is on track to meet its 2020 and 2030 renewable energy targets of achieving 55% renewable electricity and 4MW of on-site solar capacity by 2020. In 2019–20 three new solar PV systems were erected, giving Monash a total rooftop solar capacity of 4.1MW. An additional 11,500 LED lights were installed in 2020 to replace inefficient T8/T12 fluorescent lighting. Heating, ventilation, and air conditioning (HVAC) plant optimisation, equipment schedule optimisation and pump and variable speed control were accomplished as essential energy conservation measures at the Clayton and Caulfield campuses as part of stage one of the Building Optimisation Program. By modernising and utilising campus assets, the university's Net Zero Initiative intends to support the transition to an energy-efficient, renewable energy-powered future. Its foundational principles include significant energy saving measures in existing buildings, performance criteria for new construction, and collaboration with industry partners and communities to help create a more sustainable future [31].

In Australia, RMIT has gained the lead in renewable energy contracts, starting with the original Melbourne Renewable Energy Project (MREP) in collaboration with the City of Melbourne and 12 additional partners in 2017. It was the first time in Australia that a consortium of local governments, cultural organisations, colleges, and corporations bought renewable energy from a freshly constructed facility. The 14 members of the purchasing club pooled their purchasing power to enable the development of a 39-turbine, 80-MW windfarm near Ararat. The university then led a second, much larger buying group known as Melbourne Renewable Energy Project 2 (MREP2) to contract long-term renewable energy in 2020. Since January 2021, 22 RMIT buildings across the City and Bundoora East campuses have been powered by 100% carbon neutral electricity [29]. RMIT is not only improving its energy supply profile through this role, it is also taking other organisations along for the experience and leading by example. RMIT has invested in solar PV on the roofs of the university's buildings, maximising the usage of on-site renewable energy generation whenever practical. The university's existing solar 603kW PV portfolio produced 595,000kWh of renewable electricity in 2020. Table 2 presents a summary of energy-related initiatives at the six selected Australian universities.

Table 2. Summary of initiatives at the six selected universities under the category of 'energy'.

University of Tasmania	Energy strategic plan monitors, evaluates and reports key indicators Building performance data collected with GHG emissions from university's energy use Energy reduction initiatives including PV installation, LED lightings, and monitoring buildings/systems SIPS energy related projects conducted
Charles Sturt University	Solar installations across all campuses Publishing a Clean Energy Strategy 2030 Planning to contract electricity only from solar & wind sources Further onsite renewables and energy storage added Eliminating natural gas with clean electric systems
University of Melbourne	Target to achieve zero net emissions from electricity by 2021 Obtained finance in 2015 for renewable energy generation and energy efficiency projects including solar installations, voltage optimisation and efficient freezer upgrades
University of New South Wales	Switched to 100% renewable electricity from 2020 Energy efficiency initiatives implemented including building controls and set point optimisation
Monash University	Power purchase agreement with Murra Warra wind farm in 2018 Target for 55% renewable energy and 4MW solar capacity by 2020 Installation of solar PV systems Installation of LED lighting and HVAC plant optimisation Implementation of Net Zero Strategy
RMIT University	100% carbon neutral electricity on all 22 RMIT buildings since January 2021 Signed a second renewable contract in 2020 under MREP2 Installation of solar PV on rooftops

3.1.3. Food and Gardens

Agriculture, forestry, and fisheries, when done properly, can supply nutritious food for all while also generating acceptable incomes, supporting people-centred development, and conserving the environment.

UTAS's Procurement Policy oversees all university procurement-related activities and specifies the university's commercial strategy to managing the acquisition of products and services from vendors, contractors, and suppliers. UTAS has a long history of environmental education and research, as well as of raising public awareness of the necessity of competent environmental management. Consistent with this, the university focuses on best practise management of the environmental effect of university operations. This is reflected in UTAS's Strategic Plan 2019–2024, which shows the university's commitment to enhancing Tasmania's environmental sustainability. Fresh food can be obtained on campus from a variety of edible gardens, orchards, food allotments, and individual trees. Some are open to all employees and students, while others have limited access. UTAS has begun using STARS (Sustainability Tracking, Assessment, and Rating System) to track its sustainability performance as of 2019. Food and beverage purchases and sustainable dining are two relevant food categories within STARS. The concluding category includes attempts to reduce food and eating waste as well as assistance for sustainable food systems.

Professor Geoff Garr at Charles Sturt University is the leader of an Australian and worldwide research team and has spent the last 22 years exploring ways to achieve food security while lowering reliance on non-renewable, ecologically damaging inputs via biocontrol methods. The university's sustainability advisors conducted a program in 2020 in which each of the advisors chose a focus area for the year including growing the collection of food and organic waste in the Albury–Wodonga campus. They were also able to expand the collecting of food organic waste into dwellings utilised for defence staff housing when manning border closures.

Bees@UniMelb is a new programme at the University of Melbourne aimed at educating employees and students on campus about bees and beekeeping. The university maintains many beehive locations on campus and started Bees@UniMelb Honey in 2016. In addition to producing delicious honey, these bees help to increase inner-city fruit and vegetable production by pollinating neighbouring plants. A student-led Fair Food Challenge at the university in 2017 engaged in a co-design process established a set of fair food principles to effect positive change in Australian university campus food systems. For the challenge, the Fair Food UniCycle was built, a movable cargo bike meant to make fair and sustainable on-campus food and cooking easier. The bike enabled students and the broader community to participate in food education, skill development, and outreach programmes [32].

While the introduction of a Plastic Free Dining programme at UNSW was delayed due to a decline in campus activities, it included the development of a supporting marketing campaign and was launched at the start of Term 1 2021. This included requiring all single-use campus food packaging to be 100% compostable by 2021, as well as encouraging UNSW students and employees to dine in and bring their own (BYO) cups and containers. As part of the university's Green Impact programme, a crew created an Indigenous edible garden on College Walk near Alumni Park. The garden is filled with Banksia Scrub from the Eastern Suburbs, native Geraniums, and creeping violets, all of which can be collected for traditional bush tucker. The garden is designed to serve as a hub for educational and awareness programmes.

Monash University collaborated with Monash Green Steps students in December of 2020 to conduct a rigorous materials audit of the pre-packaged beverages offered on campus. The goal is to better identify what types of pre-packaged beverage materials are offered on campus and how the new Victorian Container Deposit Scheme to be implemented in 2022/2023 will affect Monash University. The goal of this research was to identify problems with packaging and to make recommendations. The university launched a BorrowCup programme, which was put on hold in 2020 due to the COVID-19 pandemic. This reusable BorrowCup at campus cafes allowed students and staff to return it to any of the specific collection bins situated throughout campus or at participating cafes. Many on-campus cafes also provide a coffee discount to promote participation in the programme.

The university's operational footprint and food supply chain have a substantial impact on RMIT. This enables the university to use its purchasing power to improve supply chain processes and support the strategic goal of altering the world. RMIT welcomed three Indigenous companies to its catering panel and one to its marketing panel in 2019. Several catering panel members collaborate with food organisations such as SecondBite to ensure that good quality leftover food is donated to those in need rather than going to waste. The Sustainable Retail Framework was also developed to assist and encourage RMIT retailers to become more environmentally friendly in their day-to-day operations. Participating RMIT merchants can implement up to 20 environmental or social sustainability projects and be awarded a bronze, silver, or gold rating based on the number of sustainability initiatives completed. Among these initiatives are discounts for customers who bring their own containers and coffee cups, developing menus that use seasonal fruit and vegetables, increasing the proportion of vegetable dishes and purchasing only high welfare meat while serving vegetarian and vegan meals daily, purchasing products from local or fair-trade suppliers, and eliminating single-use plastic drink bottles and coffee cups.

A summary of sustainability initiatives related to 'food and gardens' at the six selected universities in Australia is presented in Table 3.

Table 3. Summary of initiatives at the six selected universities under the category of 'food and gardens'.

University of Tasmania	Edible gardens, orchards, food allotments and individual trees available to source fresh food on campus Embedding sustainability principles into catering contracts Working with progressing procurement of local food in Tasmania SIPS food & gardens related projects conducted
Charles Sturt University	Professor Geoff's research leads an Australian and international team that has spent the last 22 years investigating how to achieve food security whilst reducing dependence on non-renewable, environmentally hazardous inputs through the biocontrol solutions Food organic waste collection program implemented
University of Melbourne	The University has several beehive sites on campus and, in 2016, launched Bees@UniMelb Honey Fair Food Challenge involved establishing fair food principles
University of New South Wales	Encouraging dine in and BYO food containers at campuses Indigenous edible garden developed
Monash University	Providing discounts on BYO coffee cups and reusable BorrowCup Pre-packaged beverage audit conducted by students
RMIT University	Collaborating to ensure leftover food from caterers is donated Sustainable Retail Framework created to encourage retailors to becoming sustainable

3.1.4. Greenhouse Gas (GHG) Emissions

GHG are gases that absorb and radiate heat from infrared radiation. Almost all of the rise in GHG in the atmosphere during the last 150 years can be attributed to human activities. This is the primary activity contributing to global climate change.

UTAS is committed to assisting in the construction of a zero-carbon society, as evidenced by its carbon neutral certification since 2016 by the Climate Active Carbon Neutral Standard and its commitment to complete divestment by the end of 2021. The university has committed to using a negative investment screen for fossil fuels and a positive investment screen for companies and funds that support the UNSDGs, with the goal of totally divesting from fossil fuel-exposed investment funds. In April 2021, the University joined Race to Zero, which is a global effort that seeks to mobilise leadership and support from businesses, cities, regions, educational institutions and investors for a healthy, resilient, zero-carbon recovery that prevents future risks, provides good employment, and unlocks inclusive, sustainable growth. The Race to Zero criteria includes achieving net zero emissions by 2050 or sooner, describing the steps that will be followed to achieve net zero, taking action towards net zero while documenting where carbon reductions are being made and making a commitment to report progress on an annual basis. By participating in Race to Zero, UTAS has agreed to meeting these criteria as a carbon neutral organisation. UTAS reports its GHG emissions through their GHG Inventory.

Charles Sturt University, Australia's first certified carbon neutral university, maintained its emissions reduction objective by offsetting its remaining total emissions through the acquisition of certified carbon credits. In accordance with Climate Active's carbon neutrality standards, the university acquires and retires offsets in arrears of the reporting period. This is done once the annual carbon emissions inventory has been established, resulting in the total number of offsets needed. Charles Sturt University has devised a set of four criteria to help guide judgments regarding carbon offset acquisition. These are the guiding principles:

- Financial assistance for locally based projects to the degree that they are deemed financially viable
- A preference for initiatives that are in line with the principles of Charles Sturt University and provide a high level of engagement
- Projects that provide regional linkage with the university's foreign partners are being considered
- The offset option's unit cost.

The projects that are being carried out include a biodiversity reserve project in Indonesia, a wind power project in India, and an indigenous savanna fire project in the Northern Territory in Australia.

The University of Melbourne releases information on GHG emissions, energy production and energy consumption under the National Greenhouse and Energy Reporting Act 2007. The University is committed to bringing forward its carbon neutrality target, which they expect to reach before 2030. The University of Melbourne is also the first in Australia to conduct a nitrogen footprint assessment of its activities and to implement the Green Impact sustainability engagement programme. The nitrogen footprint tool created by researchers at the university measures reactive nitrogen, which is the nitrogen released into the environment as a result of daily activities such as food consumption, transport, and energy usage. The researchers discovered that the University of Melbourne has a nitrogen footprint of 139 tonnes of nitrogen, with three components dominating: food (37%), energy use (32%), and transportation (28%). It might be lowered by 60% if action is taken to minimise emissions from those three major contributors. The investigation discovered that 96% of nitrogen emissions occurred outside the university's limits.

UNSW's attention now shifts to indirect (scope 3) emissions across their value chain, having reached net zero energy-related (scope 1 and 2) emissions by 2020. Scope 3 includes emissions from acquired goods and services, construction, investments, and travel, which can be higher but are more difficult and require longer-term organisational reform and supply chain engagement. Typically, value chain emission sources are not mentioned in university targets and emissions policies. During 2020, the UNSW Council accepted UNSW's new carbon reduction target, which was produced using the Science Based Targets Initiative's (SBTi) process. Total emissions must be reduced in accordance with a 1.5 °C science-based target, which corresponds to a 30% reduction by 2025, a 50% decrease by 2030, and net zero emissions by 2050. UNSW's Net Zero Strategy was developed in the same year and sets out how they plan to achieve their 2030 target of a 50% reduction, focusing on their largest remaining emissions sources, supply chain and investment activities. The Net Zero Strategy comprises nine initiatives through which the university will reduce emissions by engaging suppliers, changing behaviours, and adapting processes. After revising its divestment resolution in 2019, UNSW also built a Responsible Investment Framework to properly align UNSW's investing activities to the Environmental Sustainability Plan, its aims, and UNSW's other responsible investment commitments.

Monash University pledged in 2017 to achieve net zero emissions for its Australian campuses by 2030. Since 2005, Monash University's carbon footprint has been calculated for each year. Since 2009, the carbon footprint has included GHG emissions linked with Australian activities over which the university has operational control, as the university continues to conduct carbon audits. When compared to the 2018 carbon footprint, the university's gross total emissions dropped by 3.2% in 2019. In comparison to 2019, GHG emissions from gas used for heating and cooling (included in Scope 1 emissions) increased by 1.1%, while emissions from electricity use (included in Scope 2 emissions) declined by 6.2%.

RMIT is making tangible efforts and launching creative programmes to achieve carbon neutrality by 2030 and adapt to climate change. Guided by the Carbon Management Plan, the university engages in a variety of emissions-reduction measures to achieve this goal. This plan provides strategic advice for RMIT to manage its operational GHG emissions profile and explores future scenarios. It also acts as the university's commitment to accurately measure, report, and manage the university's emissions profile. The Plan is updated every two years and aims to represent best practises in pollution management. RMIT achieved a 62% reduction in operational emissions from the baseline emissions in 2007. The institution accounts for all energy and emissions produced and consumed within the building profile under the Australian operating emissions profile. RMIT calculates all building emissions (Scope 1 and 2 emissions, intensity, and reductions) using the required Australian Government factors, which are consistent with the National Greenhouse and Energy Reporting (NGER) Act.

A summary of sustainability initiatives under the category of 'GHG emissions' at the six selected universities is presented in Table 4.

Table 4. Summary of initiatives at the six selected universities under the category of 'GHG emissions'.

University of Tasmania	Certified as carbon neutral since 2016 Committing to full divestment by the end of 2021 Joining Race to Zero for zero carbon recovery in 2021 GHG emissions data collected and published in an inventory SIPS GHG related projects conducted
Charles Sturt University	Australia's first carbon neutral certified university since 2016 Focussing on reducing emissions through offsets
University of Melbourne	Target to achieve zero net emissions by 2030 GHG inventory reports published to provide an assessment of GHG emissions First university in Australia to undertake a nitrogen footprint of its operations
University of New South Wales	Target to achieve zero net emissions by 2050 Completed their Net Zero Strategy Developed a responsible investment framework updated investment policy to reflect divestment
Monash University	Target to achieve net zero emissions by 2030 3.2% gross GHG reduction in 2019
RMIT University	Aims to become carbon neutral by 2030 Carbon Management Plan published to manage GHG emissions

3.1.5. Natural Environment

The natural environment includes all living and non-living objects that have evolved naturally over millions of years inside the biosphere: landscapes, oceans, water, atmosphere, and biodiversity. A healthy natural environment allows human life to flourish and is crucial to our well-being. Human actions, on the other hand, have impacted the natural environment on a vast scale in the modern world.

By adopting the Governance Principle GLP9 on Environmental Management in 2005, UTAS recognised that environmental preservation and sustainability are essential priority in the way the university functions and subsequently developed the University's Environmental Management Plan 2009–2011. This strategy sought net positive environmental outcomes, with one of the primary goals being to manage and promote biodiversity in an ecologically suitable manner in collaboration with the many campus communities. So far, this goal has been met by including the protection and enhancement of the natural environment as a key component for the University Reserve's Fire Management Plan (Sandy Bay campus), which includes weed suppression and encouraging endemic flora and fauna communities, significant multi-year efforts delivering protection and improvement of Newnham Creek (Newnham campus), feral animal and weed control, and penguin nesting protection. A University Natural Space Management Strategic Plan is currently being prepared, and when completed, it will be made public. This strategic plan will lead the entire university community in attaining their natural environment objectives, which include the conservation of native species and their habitats, as well as the reduction of human environmental impacts.

Charles Sturt University's Summer Hill Creek rehabilitation is still ongoing due to a collaboration between the university, Orange City Council, the Department of Primary Industries, and Landcare. Following the removal of willows from this portion of the stream last year, about 810 native trees and shrubs suited to the local environment were planted over 2020 in the area known as Risky Paddock alongside Summer Hill Creek as it flows through the Charles Sturt farm. Tree planting events were also held in the Wagga Wagga campus, with 1200 seedlings planted across three sites. In summary, a total of 2205 native trees were planted across all campuses in 2020, with approximately 22,000 trees planted since 2010. The Successful Sustainability at Charles Sturt University Grant has established squirrel glider habitat and nesting sites on the Albury–Wodonga campus. In late 2020, a volunteer team lead by Dr. Jonathon Howard constructed roughly 40 nest boxes and planted hundreds of indigenous and appropriate trees in an effort to support the campus's remaining squirrel glider population, as these have been listed as a vulnerable species in New South Wales.

The System Garden at the University of Melbourne, founded in 1856, is one of the country's oldest teaching gardens. Plants in the garden are divided into subclasses and families, allowing visitors to learn by comparing the form and floral structure of various plant species. It is a member of the Climate Change Alliance of Botanic Gardens and is actively working with organisations worldwide to protect cherished botanical landscapes from climate change [33]. To attract pollinator species to Parkville's System Garden, an insect motel has been erected in an unused entryway of the Botany Building. A minor renovation of the System Garden is planned for 2021, which will include the introduction of indigenous plants. The university's Melbourne Business Practicum (MBP) is a rigorous subject in which a small team of Masters students is assigned to an industry partner to address a current, pressing need. MBP students collaborated with the Royal Botanic Gardens Victoria on one of the earliest projects, beginning a carbon audit of the gardens' whole operations.

Along with complementing the built environment, the Roundhouse public domain works at UNSW saw a net increase of 17 native trees, with additional plants carefully selected to promote species diversity and be fit for a heavily pedestrianised region. Trees at the UNSW campuses are managed using a tree database system and an interactive campus tree plan [34].

Monash University intends to draw on the distinctively Australian experience to create multi-functional spaces that provide enjoyment for humans, the wider community, and wildlife, including flocks of bird species that seek refuge and food among gardens each year on their migration treks. The clever, sustainable design of the university's gardens will see the continuous implementation of permeable pathways, rainwater harvesting and treatment networks, and permeable pathways to capture, reuse, and re-purpose this valuable resource throughout campus landscapes. From 2015 to 2020, there was no net decline in canopy cover on any Monash University campus, as the institution aims for 30% canopy cover by 2030 [35]. The university's key projects also include establishing vital habitats and productive gardens on campus, as well as growing an urban forest to create comfortable landscapes and microclimates.

RMIT demonstrates its appreciation for trees and the environment by including a tree heritage path on the Bundoora campus, where more than 90 river red gums are placed along the Keelbundoora Scar Tree and Heritage Trail. Six of them are scar trees, from which the bark was cut to build carry-alls, infant beds, and canoes, a harvesting process used by hundreds of generations of Australia's Indigenous people. Although the trees are centuries old, the trail, named for a Wurundjeri clan progenitor, was established in 2008 to conserve the vegetation's significant cultural and biological significance. Shadeways, a new digital platform developed by RMIT researchers, is assisting local governments in determining where to prioritise tree planting to increase shadier walkways for pedestrians and bikers during the hotter months. Ngarara Place, located in the heart of RMIT's City campus, is an Indigenous garden. The unique location, created, constructed, and built primarily by Indigenous people, contains an Indigenous-themed courtyard area, amphitheatre-style seating, a sculptural laser-cut smoking pit, and a space to host Indigenous ceremonies, meetings, and events [36,37].

A summary of sustainability initiatives under the category of 'natural environment' at the six selected Australian universities is presented in Table 5.

Table 5. Summary of initiatives at the six selected universities under the category of 'natural environment'.

University of Tasmania	Inclusion of the protection and enhancement of natural environment through suppression of weeds and encouraging flora & fauna communities Feral animal control and protection of penguin nesting habitat at West Park campus Protection and improvement of Newnham Creek at Newnham campus Conducting assessments related to threated species, weeds, and natural values & threats SIPS natural environment related projects conducted
Charles Sturt University	Annual planting events with targeted habitat zones and species More than 20,000 native trees planted in the last 10 years Re-establishing nest boxes designed to create a resilient squirrel glider population
University of Melbourne	The System Garden in Parkville is a member of the Climate Change Alliance of the Botanic Gardens working with organisations around the world to protect botanic landscapes
University of New South Wales	New native trees and shrubs planted to provide species diversity
Monash University	No net decrease in canopy cover at each campus from 2015 to 2020, targeting 30% canopy cover by 2030 Establishing valuable habitats and growing an urban forest targeted
RMIT University	Tree heritage trail on campus Digital tree planting platform developed Indigenous garden on campus

3.1.6. Resource and Waste Management

Sustainable resource and waste management entails the use of material resources efficiently in order to limit waste production while dealing with waste in a way that actively contributes to the economic, social, and environmental goals of sustainable development. University students and staff consume a considerable number of products and services as a result of their studies, teaching, research, and overall living and working at the university. Each purchase has an impact because of the cumulative impact of the product's creation, transportation, use, and disposal.

The Sustainability Committee approved the UTAS Waste Minimisation Action Plan 2021–2025 in April 2021. This plan directs the entire university community in accomplishing their resource recovery and waste minimisation goals by implementing a waste hierarchy in all university operations and activities. UTAS generates a considerable amount of discarded furniture that can be reused each year. The Re-Use Program is a university-wide online catalogue and furniture redistribution system. The university promotes improved resource recovery on campus through its expanding Resource Recovery Program (RRP), with the goal of quantifying waste generation, improving opportunities for resource recovery from all waste types, and determining the infrastructure, services, and logistics solutions required to support a comprehensive resource recovery programme. UTAS, with the assistance of Hobart City Council, established a trial recycling wall for difficult-to-recycle objects on the Sandy Bay campus in December 2019. Because of the pilot wall's initial success, the service is being expanded to other southern universities and buildings. The university is committed to monitoring and reporting key metrics related to resource purchase and recovery, for which it gathers a variety of data.

The Green Labs Program at Charles Sturt University, which is separated into four units, energy, water, purchasing, and recycling, describes activities that can be implemented at both individual and organisational levels. Sustainable laboratories are crucial for the institution considering they take up 5.6% of the total floor area. Since laboratories provide potential for conservation, the Green Labs Program seeks to reduce waste generation without jeopardising integrity or safety. On the Wagga Wagga campus, a dedicated food organics collection system was implemented in 2020. This system collects organic waste from the principal commercial kitchen and composts it at a nearby commercial processing facility. Improved procedures were implemented to handle old office furniture through a donation program created with local schools and non-profit organisations. This equipment is now put to good use and is being kept out of landfills. To assist divert computers from landfills, the Finance and Welfare Team distributed 18 reconditioned staff laptops to students in need through the laptop equity initiative in 2020. Building contractors have always been required to document and report on their waste and recycling activities at Charles Sturt and are now proactively urged to reuse and recycle remodelling waste.

The challenging environment at the University of Melbourne, with a continually shifting population, has resulted in an adaptive waste management strategy that trials, tests, and monitors in diverse ways. Priority initiatives include considering waste minimisation in purchase decisions, increasing recycling rates by improving bin labelling and placement, increasing the scope of the Reuse Program to include the recovery of all equipment and furnishings, looking at larger-scale recycling options for organics, measuring waste data by disposal method on a daily basis and reporting on a regular basis, and enhancing contractor management to guarantee proper garbage disposal. Waste audits are undertaken with the goal of reducing waste to landfill to 20kg per person by 2020, which is a 70% reduction from the original baseline in 2012.

UNSW completed a revised Waste Management Plan in early 2020, outlining the future course for sustainable waste management. It provides a plan of action to increase waste segregation, satisfaction, and sustainability. The introduction of a new three-bin system for outdoor areas means that the university now classifies waste into food waste and compostable packaging, drink containers, and general waste. A new furniture reuse portal was created allowing used furniture to be kept when not in use and made available to any UNSW unit via an easy-to-use online interface. The approach fosters the reduction of trash to landfill while making optimum use of university resources. In early 2021, 126 furniture items were sold to students and employees at low cost during an overflow furniture sale. In addition, all campuses adopted 100% single-use biodegradable packaging as part of the Plastic Free Dining effort. UNSW targets to conserve natural resources, save money, and raise waste awareness among students and employees by improving waste procedures and behaviours.

Using the concept of the circular economy, Monash University has established a strategy to transform the university into a zero-waste facility. The method focuses on maximising the value of all resources by reducing trash from campuses and leaving only lucrative recycling streams. The approach covers a wide variety of waste streams, with organic waste separation and treatment being a top objective. An important goal for the university is to reduce total trash to landfill by 20% per FTE (Full Time Equivalent) + EFTSL (Equivalent Full-Time Student Load) in 2020, compared to 2015 levels (tonnes/EFTSL+FTE), along with being able to recycle 50% of the university's total waste. Monash University has prioritised reducing the overall volume of paper purchased, which was greatly decreased in 2020 due to the COVID-19 pandemic. In 2019–2020, recycled content paper accounted for 41% of all paper purchases. Monash Print Services' conversion to carbon-neutral virgin paper was the most significant change in paper supply in 2019. Despite the fact that this reduced the percentage of paper with recycled material, 80% of Monash's paper purchases were certified by both the Programme for the Endorsement of Forest Certification (PEFC) and the Australian government's National Carbon Offset Standard (NCOS) Carbon Neutral Program. Monash intends to seek paper with 100% recycled content and carbon-neutral certification by 2021.

RMIT intends to enhance waste management practises across its campuses by following the Waste Management Plan. The plan is intended to divert garbage from landfill by adhering to the waste hierarchy of avoidance, minimisation, and recycling. RMIT's waste profile includes operating waste from collection locations on campus as well as construction and demolition debris from projects. Throughout the year, data is collected from numerous contractors. RMIT's operational waste contractor provides information on waste to landfill, mixed recycling, paper/cardboard, and organic waste from all on-campus locations. Confidential paper waste is collected separately from operational garbage. RMIT operations in Australia generated 498 tonnes of garbage in 2020, with a diversion rate of 23.1%. The whole waste profile was 60% lower than in 2019. RMIT has begun rolling out the three-bin system in office areas across all campuses (including the removal of under-desk bins). The removal of under-desk bins enhances recycling rates and reduces the usage of plastic bin liners dramatically. The same system is used in communal spaces and kitchens for general garbage (landfill) and mixed recycling, with paper and cardboard deployed to printer and utility facilities. RMIT currently has mechanisms in place for the waste streams of batteries, fluorescent tubes, e-waste, toner cartridges, and furniture.

A summary of the sustainability initiatives at the six selected Australian universities under the category of 'resource and waste management' is presented in Table 6.

Table 6. Summary of initiatives at the six selected universities under the category of 'resource and waste management'.

University of Tasmania	Re-Use program allowed unwanted furniture to be re-used Encouraging resource recovery and recycling through a Resource Recovery Program Pilot recycling wall set up on Sandy Bay campus in 2019 for difficult to recycle items with expansion in more campuses Waste data and material resource use collected and published SIPS resource and waste management related projects conducted
Charles Sturt University	Green labs program that reduces purchasing of material goods and cut down waste production Waste reduction program that converts organic waste to compost Encouraging contractors to reuse and recycle waste e.g., furniture when renovating Laptop equity program helping to divert laptops from landfills
University of Melbourne	Regular waste audits conducted to understand composition of their waste sent to landfills The University complies with government obligations relating to waste and develops strategy in alignment and collaboration with key stakeholders Expanding their waste program to include recovery of all equipment and furniture Maximising recycling rate by enhancing bin placement and labelling

Table 6. *Cont.*

University of New South Wales	Plastic free dining at campuses with 100% single use compostable packaging New furniture reuse portal established, allowing furniture to be stored when not required and made available to any unit Three-bin system introduced to outdoor areas to capture food waste, drink containers and general waste
Monash University	A 20% reduction in total waste to landfill per FTE + EFTSL in 2020, compared to 2015 levels (tonnes / EFTSL + FTE). 50% of the University's total waste recycled in 2020 Second-hand furniture available for sale at Reuse Centre 100% recycled content and carbon-neutral certification paper to be purchased
RMIT University	Published a Waste Management Plan with waste profile and an action plan Implemented a three-bin system Process in place for recycling batteries, toner cartridges, furniture, etc.

3.1.7. Transport

Sustainable transportation is defined generically as transportation that prevents or minimises negative environmental effects and the depletion of natural resources, while also taking into account social justice, community health, and economic development. As part of the efforts to reduce scope 3 emissions, this emphasis area encompasses how people travel to and around campuses, as well as how employees and students travel for university purposes.

UTAS has created the Sustainable Transport Strategy, which includes information on transportation patterns within the university community as well as a five-year plan for more sustainable transportation practises and outcomes. The strategy applies to all UTAS sites and facilities, and it tackles transportation challenges for the whole UTAS community, including students, faculty, staff, and visitors. The sustainable team at UTAS coordinates a biannual Travel Behaviour Survey to collect information on the university community's travel behaviour and patterns across all campuses and facilities. The university is committed to assisting employees and students in selecting sustainable transportation methods to access UTAS facilities, including carpooling, car sharing, public transportation, electric cars and bicycles, cycling, walking, and virtual transportation.

Twin bay EV charging stations for charging two vehicles were built on Charles Sturt University's Port Macquarie Campus in 2020. Prior to the conclusion of this project, the university did not have any EV charging infrastructure established on any of its campuses, which hampered fleet's adoption of EVs as a critical component of a Clean Transportation Plan under the Clean Energy Strategy. This project enables Charles Sturt University to be a leader in the adoption of EVs throughout regional Australia, while also preparing the university to meet the changing needs of staff, students, and other campus users as they embrace the vehicles for personal use. Charles Sturt automobiles were responsible for 1232 tonnes of carbon emissions in 2018. Through the use of renewable energy to charge the vehicles, the transition to EVs will allow this amount to be reduced to zero over time.

Reducing vehicle fleet emissions is an important aspect of the University of Melbourne's broader commitment to sustainability. Since 2007, the university has used Greenfleet to offset all motor vehicle carbon emissions. Initiatives such as the adoption of a pool car system and recommendations for environmentally friendly vehicles have aided in the reduction of fleet size. The timely adoption of sustainable vehicle solutions such as hybrid and electric vehicles are also being encouraged. Air travel by university workers is anticipated to be the second largest source of carbon emissions, amounting to 60,000 tonnes in 2015. Reporting air travel through a travel management system and providing alternatives such as high-quality teleconferencing services are some of the efforts being taken to reduce air travel, with leftover emissions being offset gradually. Pedestrian and bicycle transportation as well as end-of-trip facilities are being prioritised as a strategic priority across campuses.

The L3 Kingsford Light Rail Line, which arrived in 2020, was welcomed by UNSW. Light rail is one of the most important pieces of infrastructure to benefit the university in its 70-year history, providing a high-capacity, clean, dependable, and sustainable transportation option for staff and students. Light rail now serves the upper and lower ends of UNSW's Kensington campus in conjunction with the L2 Randwick Line, which debuted in 2019. Transport for NSW announced the installation of pop-up cycleways on Todman Avenue, Kensington, and High Street, Randwick, providing a safe alternative to taking public transportation or driving during the COVID-19 pandemic. For many years, UNSW has campaigned for separated cycleways in the local area, notably on High Street, and welcomed the new cycleway, which opened on 21 April 2021. The institution has set a goal of reducing air travel emissions by 1% by 2022 and increasing the ratio of employees and students who commute by active modes to 20%.

Monash University's integrated campus access strategy intends to reduce GHG emissions related with campus mobility by shifting away from single-occupancy automobiles towards sustainable options like public transportation, university shuttle buses, carpooling, walking, and cycling. The university has established an aim of having more than 80% of employees and students using sustainable transportation to commute to Monash campuses by 2030. In 2020, Monash University replaced its fixed annual carparking permit system with a dynamic 'pay as you use' (PAYU) virtual parking system. PAYU parking facilitates a more flexible work and study arrangement. This new technology provides additional choice for staff and students to select their method of transportation on a daily basis, as well as to incentivise those who opt to use sustainable transportation. The virtual parking system's data insights will also be important for future transportation planning. The university's priority areas also include continuing campus pedestrianisation and campaigning for improved pedestrian safety around campuses, increasing the number, quality, and sustainability of transportation services used to connect between campuses, and considering opportunities to reduce transport emissions across the university.

RMIT generates a considerable amount of travel, with 50,000 staff and students travelling practically every day for business and education in a typical year. The Integrated Sustainable Mobility Plan offers the structure to enable and incentivise more employees and students to walk, ride, and utilise public transportation, and guides RMIT's approach to sustainable transport. To encourage students and staff to bike to campus, the university provides a variety of high-quality bicycle infrastructure options. Features include secure bike parking, complete change facilities, and a large number of bike hoops available on all onshore campuses. RMIT encourages new employees and students to cycle by hosting a series of bike workshops throughout the year, which are led by student clubs and other providers. RMIT also sponsors important cycling events throughout the year, such as Ride to Uni Day.

A summary of sustainability initiatives at the six selected Australian universities under the category of 'transport' is presented in Table 7.

Table 7. Summary of initiatives at the six selected universities under the category of 'transport'.

University of Tasmania	Encouraging carpooling, public transport, electric vehicles, cycling, walking Adding more electric charging spots Collecting sustainable transport data through travel behaviour survey, monitoring and reporting key indicators in their Sustainable Transport strategy SIPS transport related projects conducted

Table 7. *Cont.*

Charles Sturt University	Planning to drop transport costs through electric vehicles Electric vehicle charging stations created in 2020 under the clean transportation plan
University of Melbourne	Reporting air travel emissions and investigating opportunities to reduce air travel Providing greater sustainable transport choices for students, staff and visitors Prioritising pedestrian and bike transits Reviewing university fleet vehicles policies to promote hybrid/electric vehicles
University of New South Wales	Light Rail L3 Kingsford Line opened for an easy and sustainable transport option New pop-up cycle way introduced for a safe option Planning to reduce air travel emissions by 1% by 2022 and increase the percentage of staff and students commuting by active travel modes to 20%
Monash University	Goal of at least 80% of staff and students to use sustainable transportation by 2030 Introduction of PAYU virtual parking system in 2020 Advocating for improved pedestrian safety around campuses Continue exploring opportunities to reduce transport emissions
RMIT University	Developed Integrated Sustainable Mobility Plan for sustainable transportation to and from campus Free secure bike parking and facilities available at all campuses Bike workshops conducted for staff and students

3.1.8. Water

Water is a limited natural resource. Australia has frequent droughts that result in severe reductions in water storage in its enormous lakes and waterways. The goal of sustainable water management is to ensure the availability of high-quality water in the future.

UTAS is made up of a diverse community of employees, students, contractors, and visitors. Water is used in a variety of activities by all groups, including everyday requirements, cleaning, and research. In addition, all schools' landscapes (including athletic fields) require watering. The university is dedicated to reducing water usage and pollution, as evidenced by many documents such as its sustainability policy and chemical management procedure. UTAS currently has water harvesting and water efficiency infrastructure in place across its three campuses, including rainwater tanks at Newnham and Inveresk campuses and dual-flush toilets and low flush urinals in many buildings, and has been installing water-efficient fittings in all new buildings since 2009. Water harvesting capacity and water efficiency are expected to grow further in the coming years as a result of infrastructural enhancements and behaviour change activities.

Overall, Charles Sturt municipality water use in 2020 was 31% lower than in 2019. To continue conserving water specific internal interventions were implemented, such as water conservation signage and an education campaign that was rolled out across all campuses, an audit of town water leaks, the elimination of town water for farm use, the minimisation of town water for irrigating turf and grounds including the installation of irrigation controllers, and specific irrigated turf-reduction projects that are expected to have long-term benefits. The task for Charles Sturt in the coming years is to maintain the lower consumption attained in 2020.

The University of Melbourne is a major water user in Melbourne, consuming 447,000 kilolitres of mains water in 2015. Priority actions include completing the annual report and reviewing the Water Management Plan for each campus, commissioning the existing Parkville purple pipe network to enable the use of harvested water, and implementing infrastructure to monitor all harvested water usage. The university has obligations to water authorities and is an active participant in voluntary collaboration programmes and initiatives as a significant stakeholder. The university aims to cut mains water usage per floor area by 12% by 2020, representing a 40% drop from their original baseline in 2006.

UNSW intends to significantly boost water-use efficiency across all sectors while ensuring sustainable withdrawals and supply of fresh water in order to address water shortage and significantly reduce the number of people suffering from it by 2030. Water efficiency is also expected to rise by 2% per EFTSL by 2022. Furthermore, the university is committed to reducing potable water consumption and returning water to the hydrological cycle. Reduced campus activities in 2020 resulted in a decline in water use by 45%, which enhanced water target performance after falling short in 2019.

Monash University's water management plan prioritises water conservation, water harvesting, and community awareness. The university's overall potable water use decreased by 22% in 2019–20 compared to 2018–19. As part of the university's water management project the final parts of the Clayton campus collected water ring main and the biofilter bypass filtration system were commissioned in 2020. This involved installing smart metering on the largest stormwater harvesting systems to ensure optimal utilisation and to improve data collection and quality. As part of the university's Urban Space Maintenance contract, a water conservation incentive programme and a specialised manager for non-potable water systems were also developed.

RMIT is dedicated to reducing water use intensity across campus by focusing on water efficiency, harvesting, and reuse. In the "RMIT Design Standards" document, RMIT prioritises water efficiency by establishing minimum standards for fixtures and fittings, supporting water capture and storage, and incorporating water sensitive urban design in landscaping [38]. The institution has 40 smart meter devices deployed throughout its building portfolio, providing visibility into consumption characteristics. In addition to the smart meter gadgets, RMIT has 1.3 million litres of on-site storage tanks, which reduces the need for potable water usage. The on-site storage enables the collection of rainwater and stormwater, which is often used for toilet flushing or irrigation. RMIT collects stormwater in natural basins on the Bundoora Campus, and when the water levels are high enough the extra water is used in cooling tower applications on campus. As part of the university's reaction to COVID-19 in minimising the number of touch points in high traffic areas, RMIT added a total of 524 sensors to existing bathroom taps in 2020. This project also lowered potable water use because the more efficient taps were turned on for shorter periods of time.

A summary of sustainability initiatives at the six selected Australian universities under the category of 'water' is presented in Table 8.

Table 8. Summary of initiatives at the six selected universities under the category of 'water'.

University of Tasmania	Water harvesting and water efficient infrastructure across all campuses including rainwater tanks, dual flush toilets and water efficient fittings Water consumption and wastewater data collected SIPS water related projects conducted
Charles Sturt University	Water conservation signage and education campaign rolled out in all campuses Audits and minimisation of town water done
University of Melbourne	The university has obligations to water authorities and participates actively as a key stakeholder in voluntary collaborative programs and initiatives Implementing infrastructure to monitor all harvested water usage
University of New South Wales	Commitment to reduce potable water use and return water to the hydrological cycle Planning to Increase water efficiency per EFTSL by 2% by 2022

Table 8. *Cont.*

Monash University	22% decrease in potable water for 2019–20 Commissioning of a harvested water ring main and biofilter bypass filtration system completed Smart metering on stormwater harvesting systems installed Establishment of a water conservation incentive program done
RMIT University	Installed water efficient appliances on campuses Total capacity of 1.3 million litres of on-site storage tanks, reducing requirements for potable water usage Over 40 smart meter devices installed across campuses to give real time access to water consumption Water harvesting initiatives undertaken

3.2. Sustainability at Universities Outside Australia

As more universities around the world have pledged to be carbon neutral, this sub-section will briefly look at the goals and strategies from some leading universities outside Australia. As this study focusses on sustainability initiatives towards carbon neutrality in Australian universities, the authors would like to point out that the universities discussed in this sub-section are only a snapshot in the context of universities outside Australia that are leading in sustainability and achieving carbon neutrality.

In North America, The University at Buffalo (UB), the largest public university in New York, has pledged to minimise GHG emissions and to serve as a leader in the worldwide climate change mitigation campaign. It is worth mentioning that in the Times Higher Education Impact Rankings on Climate Action (SDG 13) for 2021, UB is ranked first in terms of the impact it makes in working towards net zero carbon emissions [39]. Conservation, as demonstrated by the university, can reduce entire campus energy consumption by 30% or more. On March 15, 2007, UB President John B. Simpson signed the American College and University Presidents Climate Commitment (ACUPCC) as part of a broader campaign to elevate UB's standing as an intellectual and economic force for change. This requires the university to not only measure and reduce its GHG emissions, but also to devise and implement strategies to achieve its climate neutrality goal by 2030 [40].

In Canada, the federal government has expressed renewed interest in supporting climate action, and hence universities like the University of British Columbia have dedicated operations to comply with provincial climate legislation. An emissions profile has suggested that the university reduce its usage of natural gas to reach a 2050 target of carbon neutrality [41].

In the United Kingdom, the carbon policy for universities states that "within the next ten years, the higher education sector in this country will be recognised as a major contributor to society's efforts to achieve sustainability through the skills and knowledge that its graduates learn and apply, as well as through its own strategies and operations". Universities such as the University of Nottingham have contributed consistently towards carbon management; this university has also received numerous honours, rising to the top of national and international rankings. A framework to reduce CO_2 emissions and to fulfil university targets towards carbon neutrality by 2028 is also underway [42].

In the Oceania region, the Victoria University of Wellington in New Zealand has a major goal to achieve net zero GHG emissions by 2030. This has allowed the university to be placed in the top 40 universities in the world for its social impact and commitment to the UNSDGs in April 2020, recognising its leadership in this area [43]. The activities that will achieve this goal will also have a positive impact on the community and the university.

4. Discussion

There is no question that universities are at the forefront of achieving carbon neutrality through various sustainability initiatives [44]. With the current push for the phasing out of fossil fuels, employing renewable energy sources, facilitating behavioural change, increasing energy efficiency, and implementing strategies for achieving carbon neutrality are all essential approaches that need to be implemented across universities.

This study has reviewed the sustainability strategies of six selected universities in Australia that are leading in implementing initiatives to achieve carbon neutrality. It is clear from this review that although some universities stand out with exceptional performance in terms of their initiatives to achieve carbon neutrality, many other universities in the overall university cohort require additional efforts to increase the quality of their initiatives. Sustainability strategies and initiatives at several universities outside Australia were also briefly discussed: the University at Buffalo (New York) in the United States and the University of British Columbia in Canada, which were ranked first and third, respectively, in the 2021 Times Higher Education Impact Rankings on Climate Action [39].

This review has also identified eight sustainability categories to reduce a university's carbon footprint, namely, built environment, energy, food and gardens, GHG emissions, natural environment, resource and waste management, transport, and water. It is worth noting that sustainability initiatives in transport is a category which most higher education institutions in Australia have started to implement. Sustainable campus practices in the selected universities were discussed under the eight sustainability categories in order to elicit the importance of envisioning and implementing sustainable practises in all parts of campus life. As mentioned earlier in the paper, Charles Sturt University and UTAS are Australia's only certified carbon neutral universities. Although Charles Sturt University was the first university to be certified as carbon neutral, there is not very much publicly available information on the university's journey to carbon neutrality or documenting and maintaining its carbon neutral status. Reporting activities publicly is imperative for carbon neutrality, as demonstrated by the Climate Active Carbon Neutral Standard. As a result, not only can this help maintain carbon neutrality, it can also act as an incentive for other higher education institutions to improve their sustainability efforts. On the other hand, UTAS has facilitated public engagement in their sustainability initiatives through a variety of platforms. All important information about sustainability initiatives at UTAS can be found via a user-friendly sustainability portal. More detailed information may also be found in the publications which have been made accessible through this online portal. The university also has a sustainability podcast series created by their Sustainability Integration Program for Students (SIPS) that features interviews with staff and students at UTAS. As one current initiative, the university is committing to divesting from fossil fuel-based investment funds by the end of 2021, as reflected in the relevant university policies, strategies, and procedures. Thus, this study has identified UTAS as a university with sustainability initiatives, strategies and research that can pave the way for similar climate action at other universities in Australia and elsewhere.

An interesting finding of this review is the way in which universities are implementing sustainability initiatives in line with their mission and values. Despite striving towards the same end goal of achieving carbon neutrality, different institutions offer individually unique approaches towards sustainability. UTAS values the creation, expansion and dissemination of knowledge and the promotion of continual learning which is clearly demonstrated through their initiatives and policies. Similarly, each university has tailored its initiatives according to the environment in which it operates. For example, a comparison can be made between the approach by UTAS to water in Tasmania, where there is an apparent abundance of fresh water, and Charles Sturt University's commitment in regional New South Wales, where fresh water is scarce.

It is also worth discussing that, according to recent research, the COVID-19 epidemic has resulted in decreased carbon emissions, as evidenced by data collected through questionnaires [45]. Universities in Australia have also reported significant decreases in their emissions due to the COVID-19 pandemic, which suggests that universities and university teaching can be reinvented to be more sustainable. Researchers have also suggested that the digitalisation of higher education in light of sustainability and in times of the COVID-19 pandemic is highly recommended [46].

This study has clearly identified how some of the leading universities in Australia are working in alignment with the UNSDGs for a more sustainable future.

5. Conclusions

According to the research findings of this review, higher education institutions seek to prioritise the efficient use of natural resources throughout the educational process as well as to ensure a balanced, fair, and integrated socioeconomic development through teaching, research, and good governance, not only for their staff but also for the broader community. Although there are barriers to achieving sustainability goals and carbon neutrality, various universities have adopted transformational plans that aim to provide leadership through sustainability strategies and practises. Based on the case studies of selected universities that are leading in their efforts to achieve carbon neutrality, it is recommended that universities develop long-term strategic approaches towards this critical area to stimulate, implement, and develop sustainability strategies. Using case studies of universities that are leading in making an impact through their sustainability strategies and/or have already achieved carbon neutrality, this research has provided guidelines, particularly to Australian universities, on how similar strategies, initiatives and policies can be identified and implemented by universities that are nearing carbon neutrality or wish to achieve it the future. Implementing such initiatives in all the sustainability categories identified in this review is critical to achieving carbon neutrality.

This study also indicates that the contributions presented in this review may be limited, as not all universities in Australia and outside Australia were evaluated; however, readers can gain an overview by analysing the current research findings to understand how universities can contribute to mitigating climate change and achieving carbon neutrality. It would be relevant to further examine how Australian universities contribute to the UNSDGs at the international level. There are great prospects for comparing sustainability initiatives at higher education institutions nationally in Australia as well as globally in order to gain deeper insights from their experiences.

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Article

The Show Must Go On: A Snapshot of Italian Academic Working Life during Mandatory Work from Home through the Results of a National Survey

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Abstract: During the COVID-19 pandemic, universities worldwide have provided continuity to research and teaching through mandatory work from home. Taking into account the specificities of the Italian academic environment and using the Job Demand-Resource-Recovery model, the present study provides, through an online survey, for the first time a description of the experiences of a large sample of academics (N = 2365) and technical and administrative staff (N = 4086) working in Italian universities. The study analyzes the main differences between genders, roles or work areas, in terms of some job demands, recovery experiences, and outcomes, all important dimensions to achieve goals 3, 4, and 5 of the 2030 Agenda for Sustainable Development. The results support the reflections on gender equality measures in universities and provide a general framework useful for further in-depth analysis and development of measures in order to improve well-being (SDG 3), quality of education (SDG 4), and gender equality (SDG 5).

Keywords: mandatory work from home; Job Demand-Resource-Recovery model; Italian academia; gender differences; Sustainable Development Goals (SDGs) and universities; academic sustainability

1. Introduction

Mandatory work from home (Kniffin et al. 2021; Ghislieri et al. 2021b) at universities worldwide allowed academic organizational life to continue during the COVID-19 pandemic and ensured continuity of research and teaching, despite some well-known limitations (such as lack of access to laboratories and lack of informal interpersonal relationships). Remote academic work has prevented students from having to interrupt their careers, thus also helping to compensate for the lack of social and activities time, despite heavy study loads and not always satisfactory support from faculty (Aristovnik et al. 2020). However, how was this experience lived by the academics and the technical and administrative staff (TAS)[1], in terms of some important variables modulating the organizational experience?

Taking into account the specificities of the Italian academic context (Ghislieri et al. 2014; Converso et al. 2019) and using as main reference the Job Demand-Resource-Recovery model (Kinnunen et al. 2011), the present study provides, for the first time, a snapshot of the experiences of a large sample of academics and TAS working in Italian universities.

In particular, the paper analyzes the main differences in gender (for academics and TAS), role (academics) and area of work (TAS), with respect to some demands (workload, cognitive demands, off-hours technology assisted job demands, workaholism, work–family conflict, remote working evaluation), recovery experiences (detachment, relaxation, mastery, and control) and emotional exhaustion as outcomes.

This paper is also embedded in the field of psychosocial aspects of sustainability: the aim of this approach is to promote healthier organizations and to balance the necessary changes in working conditions with the maintenance of adequate human well-being (Di Fabio 2017; Di Fabio and Rosen 2018; Molino et al. 2019). Citing the recommendation to include multiple disciplines in achieving sustainability goals (Findler et al. 2019), other contributions have highlighted the importance of interpersonal, social, and well-being dimensions as key elements in defining sustainable academic organizations (Gamage et al. 2022). Therefore, this study's approach is consistent with Goal 3 of the 2030 Agenda: by addressing the organizational life of universities, the study also lends itself as an important node for promoting quality education (Goal 4), as the well-being of academic staff is reflected in the quality of higher education. Finally, the focus on gender differences is consistent with the gender equality dimension (Goal 5).

This picture of some aspects of Italian academic working life at a specific point in time, namely the second lockdown since the beginning of the pandemic (winter 2020), unfortunately cannot be compared with other descriptions of the same indicators due to the lack of previous similar studies. This is one of the main limitations of this work, which, however, offers a broad look at the system of demands and resources of academics and TAS, with particular attention to the evaluation of mandatory work from home and differences based on gender and role. The study fills a gap in the availability of descriptive information on specific indicators of the quality of academic life and thus provides a useful framework for in-depth analysis of the relationships between the observed variables.

1.1. The Italian "University Job"

The Italian "university job" today is the result of a decade of implementation of the most recent university reform, which has brought significant changes in the Italian academic institution. Law 240 (30/12/2010), known as the Gelmini reform, introduced important transformations in academia, both for academics and for TAS.

Previous studies, shortly after the COVID-19 pandemic, have shown how it led to an increase in the demands on management and administration, with an increase in the number of steps, including bureaucratic ones, to certify continuous evaluation processes, both on the teaching and research side; this change has had an impact on the work of both academics and TAS (Ghislieri et al. 2014). In particular, the TAS were asked to contribute more and more to develop new knowledge and skills (e.g., in fundraising and evaluation processes or in transversal and digital skills), often without adequate training tools (i.e., at "zero cost", the mantra of the Gelmini reform). Even the academic profession, once considered prestigious, remunerative, socially recognized, and highly desirable (Rostan 2011; Ghislieri et al. 2014), has changed in the last two decades. The positive image of academic work has progressively faded, not only in Italy (Winefield et al. 2003), and this phenomenon has been associated with other aspects such as reduced funding, a decisive and protracted reduction in access to academic careers, an increase in precariousness, the blocking of turnover and salary jumps, limited promotion opportunities, and a significant increase in the bureaucratic burden associated with the management of teaching, mostly under the condition of limited resources.

Although it is not possible to make a systematic comparison between the data collected in this survey and previous data, the analysis of studies in the academic field prior to the pandemic period provides us with a framework that helps to highlight some pre-existing critical issues. For example, a study by Ghislieri et al. (2014) at a medium-sized university observed the differences between academics and TAS in the relationship between demands-resources and job satisfaction, highlighting the fundamental role of autonomy for academics and supervisory support for TAS. Moreover, work–family conflict was found to be negatively correlated with satisfaction, especially for academics. More recently, a study by Converso et al. (2019) found significant levels of workaholism among Italian academics: the study highlights that work engagement and workaholism can be considered as the positive and negative sides, respectively, of the high work investment of academics in Italy, pointing to the importance of promoting work resources (meaning of work, rewards) and controlling demands (especially work overload).

Using a person-centered approach, another study (Guidetti et al. 2020) identified different occupational profiles related to well-being in a sample of Italian university professors, defined by different levels of work engagement, emotional exhaustion, workaholism, and job satisfaction: detached (30.4%), exhausted-workaholic (21.4%), engaged-workaholic (26.3%), engaged-satisfied (21.8%). Whether engaged or detached, workaholism appears to be an important concern in academic work dynamics. The analyses also revealed significant differences between the different profiles in terms of perceptions of some specific job demands in the academic context, distinguishing between demands perceived as hindering (hindrance demands) and demands perceived as challenging (challenge demands).

1.2. Roles and Gender Distribution in Academia

As mentioned above, academic careers in Italy are regulated by Law 240/2010, which defines four different roles: Full Professor, Associate Professor, and two types of fixed-terms research contracts, an A-type (three years, possibly renewable for 2 years, without tenure track; RTD-A) and a B-type (with tenure track, with national scientific qualification; RTD-B); the two new types of fixed-term contracts replaced the former open-ended contract of the Assistant Professor, the so-called "Ricercatore Universitario" (RU), which can be considered a Senior Assistant Professor. The RU from before the Gelmini reform deserve a separate mention; although there are no new hires for this role, there are still a large number of RU in universities. Although institutional engagement and governance demands are higher in senior positions, all academic staff are required to engage in research, teaching, public engagement, and faculty bureaucracy.

According to 2020 data from the Ministry of University and Research (Ministero dell'Istruzione 2020), shown in Figure 1, the gender gap in academia still exists and widens in senior positions, with the largest gap among full professors. While there is almost no gender gap for RU, the peculiar nature of this role and the difficulties in career progressions, due to the redefinition of role advancement, do not necessarily indicate better career prospects for women. The situation is reversed for TAS, of which women constitute 60.1%; however, as noted in two recently published MUR documents (Ministero dell'Istruzione 2021a, 2021b), there are both vertical and horizontal gender asymmetries. In 2019, only 38% of technical staff were women, compared to 74% of administrative staff; in 2020, only 41.2% of administrative directors were women.

Concerning academics, the underrepresentation of women in top positions is linked to the underrepresentation of women in decision-making positions, highlighting the issue of the glass ceiling, as the She Figures 2021 (European Commission 2021b) report shows. Despite the progress made in gender equality, equality tools, and policies implemented, the phenomenon of cultural sexism persist in Italian academia (Savigny 2014) and women are still promoted less frequently than their male counterparts, and, as some studies show, are less likely to access the most "secure" academic positions. Picardi's (2019) analysis shows that women are less likely to occupy the first secure position in the academic career, taking into account data from the Italian Ministry of Education, University, and Research, confirming a reinforcement of gendered selection in access to the academic profession after the implementation of the Gelmini reform.

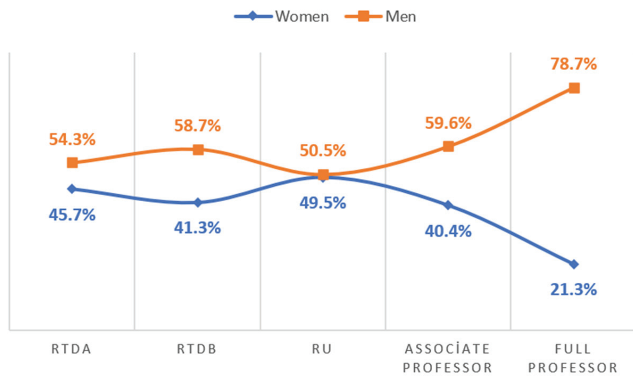

Figure 1. Gender distribution of academic roles in Italy in 2020.

Other studies confirm that the path to gender equality is slow and nonlinear (Gaiaschi and Musumeci 2020), noting that the (slow) growth of the feminization of the academic composition is the result of a demographic process and not of performance policies that contribute to narrowing the gap. Looking at the recruitment process, we find that with the Gelmini reform, women's access to the RTD-B role has been limited and that the possibility of obtaining a full professorship has remained essentially the same. Other studies, mainly related to bibliometric disciplines, had already highlighted that the lower likelihood of women advancing to higher positions in academic careers, despite systematically better scholastic and academic performance (Murgia and Poggio 2011), is neither due to lower scientific productivity nor to negative self-selection (Filandri and Pasqua 2019).

To understand the phenomenon of gender segregation in academia, it is well known that it is necessary to consider a number of possible causes (Murgia and Poggio 2018). Studies by Heijstra et al. (2016, 2017), also using Italian data, have shown a different impact of domestic work on the working conditions of women and men in academia at the beginning of their careers, as well as a different impact of "academic domestic work", understood figuratively as all that academic service work within the institution that is characterized by little recognition and enhancement for career purposes, which requires a large investment of time and energy. Given that the measures taken to contain the pandemic disproportionately impacted women, for whom the burden of care became even heavier (European Commission 2021a; Manzo and Minello 2020), it is of particular interest to examine the gender differences in academia during the pandemic.

1.3. *Work from Home*

Allen et al. (2015) predicted that remote working would be a useful tool for organizational continuity in the event of an epidemic. Notwithstanding this awareness, most Italian (and other) organizations were clearly not prepared for this eventuality. Despite pre-pandemic government calls to experiment with "smart" forms of remote working in public administration (smart working or agile working, regulated by Capo II of Legge 22 maggio 2017, n.81; the first term is used exclusively in Italy), few public administrations and especially, few universities, had moved in the indicated direction. Referring, for example, to TAS, in a national survey (Ghislieri et al. 2021a), only 8 of the 44 participating universities provided information on remote working before the pandemic, reporting a figure of around 16% of women and 10% of men involved in experimental remote working. In the same survey, 21 universities reported data on staff working remotely during the initial lockdown, with 67% of women and 62% of men working remotely. There were also shortcomings in remote teaching: academics were generally inadequately qualified and unfamiliar with technological tools; in addition, universities generally offered little or no technical support for remote teaching, including sparse development of web conferencing tools or online platforms for sharing materials and other resources.

In summary, during the first lockdown the Italian academy was in no way prepared to work remotely; knowledge and skills were developed during practice in the adversity of the situation. Between the first and the second lockdown, most organizational efforts involved building the conditions for a return to presence; important and necessary efforts, but again, only in rare cases did they involve training investments aimed at developing skills and competences for remote work, both in consideration of a physiological evolution of this work approach and to be prepared for an eventual new lockdown (Ghislieri et al. 2021a). The Three-Year Plan for Information Technology in Public Administration 2020–2022 (Agenzia per l'Italia Digitale 2020) has revealed a strong delay in the digitization process of the Italian public administration. The lockdown experience has elicited harsh shortcomings in technological tools, besides the need to redesign processes and promote a user-centered administration through the assignment of objectives and the monitoring of results. This delay helps to illustrate the difficulties that have been highlighted in studies on remote working during the emergency. However, these complications may provide a starting point for potential future interventions.

In the last two years, the topic of remote working has been widely discussed both in academia and in public discourse; in Italy, many organizations made a massive switch to remote work starting in March 2020 in order to contain the spread of COVID-19 and ensure continuity of work. However, this transition was quite sudden and resembled a large, unprogrammed experiment rather than a carefully planned work transition. This was particularly true in Italy, where remote working was not widespread and actually encompassed two different types of work arrangements (Ghislieri et al. 2021b).

Before the emergency, 570,000 people worked from home, mainly in large companies, while only 16% of public administrations had set up remote work projects, although there was much normative support in the past, including direct promotion by the government. Following the Decree of the President of the Council of Ministers promulgated on 11 March 2020 and the directives of the Ministry of Public Administration, which effectively extended remote working to all personnel bypassing the necessary trial period, the rate of remote workers in public administrations reached 68%. The legal situation is currently evolving and new measures are still being considered.

While the Italian government and public discourse in general have referred to the emergency remote work as "lavoro agile" or "smart working", the term "mandatory work from home" (MWFH), proposed by Kniffin et al. (2021), seems more appropriate. Specifically, we refer to a hybrid arrangement: especially in the early months, most people worked exclusively from home throughout the week, but often with their own devices and highly variable job verification and evaluation procedures that were either more traditional, such as time spent connected, or objectives-driven, which was more akin to agile working. Moreover, the pervasiveness of domestic care work, combined with social and professional isolation, could impair recovery experiences or at least reduce available options, which in turn negatively affects quality of life and work.

Regardless of the Italian context, there are numerous critical issues to consider regarding remote working, both in terms of the ongoing emergency and in terms of the so-called "new normal" (Kniffin et al. 2021; Rudolph et al. 2021). Several studies have examined the positive and negative aspects of remote work both before the COVID-19 emergency (Allen et al. 2015) and during (Barbuto et al. 2020; Mustajab et al. 2020), focusing on changes in work demands and the work–life interface, technostress, work quality and performance, and well-being (Fana et al. 2020; Hamouche 2020; Galanti et al. 2021; Molino et al. 2020; Oksanen et al. 2021; Toscano and Zappalà 2020; Aczel et al. 2021).

Specific to academia, Kaiser et al. (2021) observed a strong relationship between job demands and burnout in a sample of 236 employees at a Norwegian university, with autonomy being the most important resource for predicting commitment and reducing burnout. In addition, a study conducted with 300 employees of two international private universities in Thailand (Charoensukmongkol and Phungsoonthorn 2020a) while working remotely found that perceived uncertainties mediated the negative relationship between crisis communication and emotional exhaustion; informal communication may play a role in formal communication dynamics to reduce uncertainty during a crisis. Charoensukmongkol and Phungsoonthorn (2020b) also point out that the negative effect of supervisor support on employees' perceived uncertainties is only present in universities characterized by low intransigence, highlighting the importance of the overall work climate in universities. Deryugina et al. (2021), in their analysis of researchers' time allocation (identified by having written at least one academic paper in the last 5 years), show a decrease in working hours, especially in research, and an increase in unpaid care work, especially for mothers with younger children.

1.4. Job Demands-Resource-Recovery Model

The Job Demands-Resources model (JD-R; Bakker and Demerouti 2017) is a theoretical proposal that has been widely validated empirically and aims to provide a general model, adaptable to specific contexts, to explain both the motivational process (and thus work engagement) and the process of health degradation (burnout).

Recognizing the importance of recovery experiences, Kinnunen et al. (2011) proposed the Job Demands-Resource-Recovery model (JD-R-R; Kinnunen et al. 2011), a further elaboration of the JD-R model, that assumes that recovery experiences act as mediators in the relationships between job demands, resources, and the two JD-R processes. Indeed, recovery experiences replenish and create resources that are fundamental to well-being, by promoting pleasant activation (vigor) and helping to endure unpleasant deactivation (fatigue) (Bennett et al. 2018).

In this study, we focused on both academics and TAS in universities. According to the JD-R-R model, we examined recovery experiences along with various job demands, namely workload, cognitive demands, and off-hours technology-assisted job demands (off-TAJD); we also included workaholism and work–family conflict, which can be considered both outcomes and demands. In addition, we considered perceptions of advantages and disadvantages of remote working. Finally, we examined emotional exhaustion, an outcome related to the process of health degradation.

Job demands have been defined as "those physical, psychological, social, or organizational aspects of the job that require sustained physical and/or psychological (cognitive and emotional) effort or skill and are therefore associated with certain physiological and/or psychological costs" (Bakker and Demerouti 2007, p. 312). Given the nature of work in universities, which involves information seeking and processing, problem solving, and decision making, we chose to analyze workload and cognitive demands, demands that can lead to energy depletion, emotional exhaustion, and other health problems (Bakker and Demerouti 2017), such as burnout, which in turn prevents optimal use of cognitive resources and thus limits cognitive functioning and consequently job performance (Lemonaki et al. 2021).

The recovery process is fundamental to restoring energy depleted by job demands to pre-stressors levels (Meijman and Mulder 1998). Sonnentag and Fritz (2007) describe four different recovery experiences, i.e., the activities outside of work through which recovery processes occur. These activities can be traced to the effort-recovery (Meijman and Mulder 1998) and conservation of resources (Hobfoll and Wells 1998) models: (1) psychological detachment from work; (2) relaxation, a calm state of low arousal; (3) mastery, which refers to activities other than work that provide challenging experiences; and (4) control over one's leisure activities and time.

The literature has highlighted the positive effect of recovery on well-being (e.g., Kinnunen et al. 2011) and performance (e.g., Sonnentag and Bayer 2005), while also highlighting its role as a mediator in the relationship between work–family conflict, psychological tension, and life satisfaction (Moreno-Jiménez et al. 2009), between workload and work–family conflict (Molino et al. 2016), hindrance, and challenges demands with vigor and fatigue (Bennett et al. 2018) and, specifically during remote work, between off-TAJD and emotional exhaustion (Dolce et al. 2020).

However, the peculiar nature of MWFH could present additional barriers to proper recovery, such as the overuse of technology, which was often the only way to complete work-related tasks; also, given the prevalence of an always-on approach (Derks et al. 2015; Ghislieri et al. 2018; McDowall and Kinman 2017), this context could further increase technostress (Tarafdar et al. 2007). Specifically, we considered two technostress creators, technological invasion and overload, contained in off-TAJD, i.e., the perceived request to use technological devices to respond to work demands outside of regular work hours. Constant availability and further blurring of life and work domains can also worsen the work–life balance through work intensification (Bordi et al. 2018; Derks and Bakker 2014; Molino et al. 2020; Yun et al. 2012), affect job productivity and job and life satisfaction (La Torre et al. 2019), and impair recovery (Dolce et al. 2020).

Increased job demands, particularly workload, work intensification, and technology use, have also been linked to workaholism (Andreassen et al. 2019; Molino et al. 2020; Spagnoli et al. 2019), which is directly or implicitly promoted in some organizations (Molino et al. 2019). Clark et al. (2020) noted that workaholism is a multidimensional construct articulated in four dimensions: an internal compulsion to work, persistent and uncontrollable thoughts about work, feeling negative emotions when not working or when prevented from working, and excessive working beyond expectations and requirements. While the four dimensions refer to different aspects (motivational, cognitive, emotional, and behavioral), Tóth-Király et al. (2021) argue that the cognitive and motivational aspects of workaholism distinguish between excessive working, i.e., high work investment, and compulsive working, and that the risks associated with workaholism mainly stem from the second aspect. Workaholism is a state of high activation, similar to engagement, but associated with unpleasant emotions (Bakker and Oerlemans 2011). It could be argued that a tendency to work hard, coupled with disruptive work contexts, e.g., destructive leadership (Molino et al. 2016, 2019), personal traits such as perfectionism (Falco et al. 2013), and an increase in technology that allows one to work incessantly, anytime, and anywhere, could lead workers to develop the compulsion associated with workaholism and thus engage in workaholic behaviors.

Spagnoli and Molinaro (2020) elaborated on this last theme, stating that during the lockdown, workers suffered from the sudden deprivation of their usual working conditions and may have experienced an increase in negative workaholic emotions, which, as mentioned earlier, is related to emotional exhaustion. Moreover, workaholism impairs the natural recovery process (Bakker et al. 2013; Molino et al. 2018), also because workaholics who experience negative emotions at the end of the workday tend to engage in further work activities (Van Wijhe et al. 2013). Several papers have documented the consequences of workaholism, other than emotional exhaustion (Gillet et al. 2017): increased stress levels, less job and life satisfaction, and increased work–family conflict (Clark et al. 2016).

The work–family interface, particularly in the context of remote working, is a central variable for studying work-related well-being and the effectiveness of flexible work arrangements. Work–family conflict (WFC) stems from the role strain hypothesis (Goode 1960) in the context of role theory (Merton 1957), which posits that managing multiple roles, each of which requires an investment of energy and time, can lead to inter-role conflict that imply a discordance or incompatibility between work and life domains and their associated demands (Greenhaus and Beutell 1985). The context of the pandemic and the resulting temporary interruptions of educational and school services had obvious repercussions on the work–family interface, including social isolation, misuse of technology, difficulty in separating domains, and increased work demands (Chung et al. 2020). Both before and during the pandemic, it was highlighted that work-related demands contributed most to WFC, which in turn was related to other outcomes, such as emotional exhaustion, poorer job performance, increased turnover intentions, and lower job and life satisfaction (Allen et al. 2020; Amstad et al. 2011; Ghislieri et al. 2012; Vaziri et al. 2020).

Considering these facts, most studies have emphasized the negative sides or disadvantages of home-based work. Nevertheless, even during the pandemic period, past literature (Ipsen et al. 2021) focused on how people perceive working from home, both in terms of advantages and disadvantages. This could be one aspect to guide and manage the organization of remote workers and to take effective action. Based on previous research, in addition to the negative aspects such as role ambiguity, social isolation, deterioration of social support from supervisors, and challenges to work–life balance, the positive aspects of working from home should be considered. Previous studies have noted potential benefits such as increased productivity, better work–life balance, less stress from telecommuting, or more control over one's work and daily health routines (Anderson et al. 2015).

In this sense, and according to the JD-R model, the disadvantages of WFH can be considered as job demands that negatively affect employee's well-being, while the perceived advantages can be defined as job resources that protect against negative work- and health-related outcomes associated with WFH. According to Ipsen et al. (2021), there is a need to gain a deeper understanding of how people experience WFH and "how they perceive the advantages and disadvantages of their new situation" (p. 3). Accordingly, this study, along with the previously described dimensions, will provide insights into the perceived advantages and disadvantages of remote work.

2. Materials and Methods

2.1. Procedure

The study is part of a broader research-intervention project of the National Conference for Equality in Italian Universities. The Conference gathers representatives of the university committees working on issues of equal opportunities and well-being to promote collaboration among faculty in the areas of gender equality, work–life balance, well-being, and inclusion.

Following data collection, national findings were presented to member universities through a presentation and discussion workshop that identified current needs and potential general interventions. Consistent with an intervention-based research approach, each member later received a more detailed report explaining each examined area.

2.2. Participants

Participants completed an online self-report questionnaire on the Limesurvey platform; data were collected between December 2020 and March 2021. Response rates varied widely across universities. In the TAS sample, the average response rate was 26.57% (SD = 12.97%; Min = 4.33%, Max = 45.37%), while in the academic sample it was 22.08% (SD = 13.07%; Min = 4.79%, Max = 48.51%).

Prior to analysis, we performed preliminary data cleaning. For the TAS survey, we excluded 414 cases with more than 10% missing responses to the study variables (N = 3672); the same was done for the academics survey, where we excluded 190 cases (N = 2175).

The majority of the TAS sample was female (N = 2600; 72%); the mean age was 48.02 years (SD = 9.10) and ranged from 21 to 67 years. In the sample, 38.7% worked at large universities (20,000 to 40,000 enrolled students), 26.8% at medium universities (10,000 to 20,000 enrolled students), 16.1% at polytechnics, 14.5% at "mega" universities (more than 40,000 enrolled students), and 3.9% at small universities (up to 10,000 students). The majority of participants had a permanent contract (91.5%) and worked full time (88.1%), with a mean seniority of 17.79 years (SD = 10.44). On average, participants worked 36.94 h per week (SD = 8.26). To better protect individual privacy, we did not ask for information that could potentially be used to identify participants but examined the work area rather than the individual role to favor future interventions related to remote work.

Most individuals were employed in educational services (30.7%), followed by administration (18.6%) and research (18.3%). The other third of the sample was employed in ICT (9.5%), human resources (8.2%), finance (5.3%), internationalization (4.4%), logistics and maintenance (3.8%), and legal affairs (1.1%).

The academic sample was balanced in terms of gender (men N = 1086, 50.5%; women N = 1063, 48.9%). The mean age was 50.74 years (SD = 9.31) and ranged from 26 to 70 years. Moreover, 45.4% worked at large universities, 27.1% at medium universities, 17.1% at polytechnics, 8.1% at "mega" universities, and 2.3% at small universities. The majority consisted of Associate Professors (AP; 42.3%), followed by Full Professors (FP; 23.5%), permanent researchers (RU; 14.4%), and temporary researchers (RTD-B: 11%; RTD-A: 8.8%). The research did not involve procedures that might affect participants' psychological or social well-being, in accordance with the Declaration of Helsinki (World Medical Association 2013); all participants gave informed consent and were assured of data anonymity. The cover letter indicated the aim of the study, instructions for completing the questionnaire, the voluntary and unpaid participation, and information on data processing.

2.3. Data Analysis

We performed analyses of variance (ANOVA) for both samples to assess differences in study variables between women and men. For the TAS sample, we also tested for significant differences across nine work areas, while for the academic sample, we compared means across five academic levels. When comparing more than two groups, we conducted post-hoc tests (Tukey post-hoc test for variables that met the assumption of homogeneity of variance and Game–Howell for the others). All analyses were performed using IBM SPSS, version 26.

2.4. Measures

Workload was measured with 2 items (Bakker et al. 2004) on a Likert scale from 1 ("never") to 5 ("always"). An example item is "I have to work under pressure". The Guttman split-half coefficient was 0.82 for both samples.

Cognitive demands were assessed using 2 items (Bakker et al. 2003) already used in other Italian studies (e.g., Molino et al. 2019), with a Likert scale ranging from 1 ("never") to 5 ("always"). An example item is "My work requires constant attention". The Guttman split-half coefficient was 0.72 for the TAS sample and 0.58 for the academic sample.

Off-TAJD was measured with four items adapted from the Ghislieri et al. (2017) scale. Participants were asked to indicate how often they felt their organization required them to work beyond the agreed-upon hours using technology. Participants were asked to rate the statements on a five-point Likert scale ranging from 1 ("never") to 5 ("always"). An example item is "How often does your organization require you to answer phone calls and emails on weekends and/or non-workdays?". Cronbach's alpha was 0.92 in the TAS sample and 0.82 in the academic sample.

Workaholism was assessed with the Italian adaptation of the Bergen Work Addiction Scale (BWAS; Andreassen et al. 2012; Italian version Molino 2013). The measure consists of 7 items on a 5-point Likert scale ranging from 1 ("Never") to 5 ("Always"). An example item is "Thinking about the last week, how often did you give less priority to hobbies, leisure activities, and physical activity because of your work?". Cronbach's alpha was 0.79 in the TAS sample and 0.74 in the academic sample.

Work–family conflict was measured using the Italian adaptation (Colombo and Ghislieri 2008) of Netemeyer et al.'s (1996) scale, which consists of 5 items on a Likert scale ranging from 1 ("never") to 5 ("always"). An example item is "The amount of time my job requires makes it difficult for me to meet my family obligations." An item measuring conflict in the family to work direction was added to this scale. Cronbach's alpha was 0.86 in the TAS sample and 0.84 in the academic sample.

Recovery was measured using 12 items (Sonnentag and Fritz 2007) previously used in other Italian studies (Ghislieri et al. 2021b). Participants were asked to rate statements on a five-point Likert scale ranging from 1 ("strongly disagree") to 5 ("strongly agree"). Four dimensions define the factor structure of this scale: psychological detachment, relaxation, mastery, and control; each dimension was measured with three items, except for mastery, which included four items. Participants were asked to reflect on their after-work activities;

some sample items are "I forget about work" (psychological detachment), "I do relaxing activities" (relaxation), "I seek intellectual challenges" (mastery), and "I determine my own schedule" (control). Cronbach's alpha coefficients for TAS were 0.92 (detachment and relaxation), 0.84 (mastery), and 0.82 (control); for academics, they were 0.89 (detachment), 0.91 (relaxation), 0.77 (mastery), and 0.75 (control).

Remote work disadvantages were assessed using 12 ad hoc items on a 5-point Likert scale. Participants were asked to rate on a scale of 1 ("Not at all") to 5 ("Totally") how much some negative aspects of remote working affected their well-being and/or daily schedule. Cronbach's alpha was 0.89 in the staff sample and 0.88 in the academic sample.

Remote work advantages were assessed using 9 ad hoc items on a 5-point Likert scale. Participants were asked to rate on a scale of 1 ("Not at all") to 5 ("Totally") how much some positive aspects of remote working affected their well-being and/or daily schedule. Cronbach's alpha was 0.89 in both samples. Questions about the advantages and disadvantages were based on existing knowledge about remote work from before the pandemic and from the current situation (e.g., Kurland and Bailey 1999; Fonner and Roloff 2010; Cooper and Kurland 2002; Organisation for Economic Co-operation and Development 2021) and aimed to analyze aspects related to the home–work interface, work-related productivity, organization, quality of communication, and relationships with physically distant colleagues.

Emotional exhaustion was assessed using eight items from the Oldenburg Burnout Inventory (OLBI) (Demerouti et al. 2010) on a five-point Likert scale ranging from 1 ("Strongly disagree") to 5 ("Strongly agree"). Participants were asked to rate statements such as "during my work, I often feel emotionally drained". Cronbach's alpha was 0.82 in both samples.

3. Results

3.1. TAS Sample

Table 1 shows the means and standard deviations of the variables for the male and female TAS subsamples, followed by the ANOVA results. The only variables that did not show a significant difference between genders were detachment, off-TAJD, and remote work advantages. Women reported higher levels of work demands, workaholism, emotional exhaustion, and WFC, while reporting lower levels of recovery; finally, on average, women reported a slightly higher impact of remote work disadvantages.

Table 1. Means, standard deviations, and ANOVA for the TAS sample by gender.

	Women		**Men**			
	M	**SD**	**M**	**SD**	***F***	***p***
Workload	3.58	0.98	3.30	0.96	57.72	0.000
Cognitive demands	3.94	0.79	3.81	0.79	20.67	0.000
Off-TAJD	2.52	1.18	2.46	1.15	1.76	0.185
Workaholism	2.30	0.85	2.18	0.82	13.58	0.000
WFC	2.48	0.90	2.30	0.88	29.12	0.000
Detachment	2.81	1.16	2.85	1.15	1.33	0.250
Relaxation	3.22	1.13	3.60	0.99	91.76	0.000
Mastery	3.10	1.02	3.43	0.93	75.59	0.000
Control	3.16	1.05	3.27	1.05	8.30	0.004
Remote work disadvantages	2.68	0.95	2.53	0.88	18.92	0.000
Remote work advantages	3.61	0.97	3.63	0.92	0.09	0.764
Emotional exhaustion	2.82	0.76	2.64	0.75	44.11	0.000

Means, standard deviations, and ANOVA results for the different work areas are shown in Table 2, while the post-hoc tests are shown in Table 3. No significant differences were found for control, remote work advantages, and WFC in the ANOVA. Moreover, a post hoc test showed that there were no significant differences for workload and detachment either.

Table 2. Means, standard deviations, and ANOVA for the TAS sample by work areas.

	Human Resources		ICT		Logistics and Maintenance		Research		Educational Services		Internaz.		Finance		Administration		Legal Affairs			
	M	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**	***F***	***p***
Workload	3.55	0.96	3.39	0.96	3.47	1.06	3.46	0.97	3.52	0.99	3.68	0.90	3.70	0.98	3.44	0.98	3.75	0.97	2.58	0.008
Cognitive demands	3.91	0.76	3.99	0.78	3.77	0.86	3.98	0.78	3.84	0.81	3.88	0.78	4.17	0.72	3.87	0.80	4.28	0.71	5.45	0.000
Off-TAJD	2.24	1.13	2.51	1.10	2.95	1.10	2.74	1.13	2.44	1.16	2.15	1.10	2.43	1.20	2.37	1.16	2.60	1.16	9.45	0.000
Workaholism	2.16	0.87	2.07	0.75	2.36	0.75	2.31	0.81	2.30	0.87	2.29	0.85	2.37	0.89	2.28	0.86	2.28	0.65	3.13	0.002
WFC	2.36	0.94	2.31	0.85	2.52	0.81	2.46	0.83	2.44	0.91	2.33	0.94	2.54	0.99	2.39	0.92	2.51	0.87	1.70	0.000
Detachment	2.92	1.19	2.92	1.18	2.94	1.11	2.67	1.10	2.78	1.14	2.93	0.11	2.88	1.22	2.88	1.20	2.97	1.04	2.52	0.010
Relaxation	3.44	1.10	3.55	1.07	3.37	1.10	3.23	1.06	3.26	1.12	3.34	1.01	3.35	1.22	3.33	1.16	3.15	0.92	2.79	0.004
Mastery	3.28	0.95	3.34	0.99	3.25	0.94	3.15	1.01	3.09	1.00	3.37	0.94	3.15	1.14	3.15	1.04	3.39	0.76	3.06	0.002
Control	3.29	1.09	3.19	1.10	3.26	0.94	3.12	1.03	3.12	1.02	3.27	0.98	3.29	1.14	3.24	1.09	3.04	0.95	1.58	0.126
Remote work disadvantages	2.66	0.94	2.44	0.89	2.71	0.89	2.59	0.89	2.74	0.91	2.72	0.82	2.57	0.98	2.55	0.94	2.86	0.95	4.70	0.000
Remote work advantages	3.64	1.00	3.69	0.94	3.66	0.87	3.62	0.92	3.56	0.95	3.70	0.87	3.72	0.92	3.69	0.97	3.49	1.08	1.38	0.202
Emotional exhaustion	2.70	0.78	2.64	0.82	2.83	0.63	2.81	0.76	2.83	0.74	2.80	0.70	2.79	0.84	2.75	0.78	2.80	0.65	2.26	0.021

Table 3. ANOVA post hoc tests for the TAS sample by work areas.

			95% CI
Cognitive demands	Logistics and maintenance	Finance	−0.70, −0.09
		Legal affairs	−1.00, −0.02
	Educational services	Research	−0.28, −0.01
		Finance	−0.55, −0.12
		Legal affairs	−0.88, −0.00
	Finance	Administration	0.08, 0.53
		Human resources	0.01, 0.51
Off-TAJD	Logistics and maintenance	Human Resources	0.30, 1.11
		ICT	0.04, 0.84
		Educational services	0.15, 0.86
		Internationalization	0.34, 1.26
		Finance	0.07, 0.96
		Administration	0.21, 0.95
	Research	Human Resources	0.23, 0.78
		Educational services	0.11, 0.50
		Internationalization	0.25, 0.95
		Administration	0.16, 0.60
Workaholism	ICT	Logistics and maintenance	−0.55, −0.02
		Research	−0.41, −0.06
		Educational services	−0.39, −0.06
		Finance	−0.56, −0.04
		Administration	−0.39, −0.03
Relaxation	ICT	Research	0.08, 0.57
		Educational services	−0.22, 0.49
Mastery	Educational services	ICT	−0.46, −0.04
		Internationalization	−0.56, −0.00
Remote work disadvantages	Educational services	ICT	0.11, 0.50
		Administration	0.05, 0.35
Emotional exhaustion	Educational services	ICT	0.01, 0.36

Regarding cognitive demands, logistics and maintenance had the lowest scores, with significant differences from finance and legal affairs, the latter having the highest scores. Finance, legal affairs, and research also showed significantly higher scores than educational services; in addition, finance showed significant differences compared to administration and human resources.

ICT reported lower scores of workaholism compared to almost all other areas, with the exception of legal affairs and internationalization, for which there were no significant differences, likely due to the smaller size of the group.

For off-TAJD, logistics and maintenance reported higher levels than all other areas, with the exception of legal affairs and research, for which there were no significant differences; the latter reported an even higher level, significantly different from human resources, educational services, internationalization, and administration.

Looking at the two recovery experiences that showed significant differences, for relaxation, ICT had higher scores than any other group, with the only significant difference being with research and educational services, reporting the lowest levels; a similar scenario concerned mastery, where educational services reported the lowest scores, with significant differences compared to ICT and internationalization.

Finally, educational services showed higher scores of remote work advantages compared to ICT and administration, and higher scores of emotional exhaustion compared to ICT.

3.2. Academics Subsample

Table 4 shows the means and standard deviations of the variables for the male and female academic subsamples, as well as the results from ANOVA. Given the low scale reliability of cognitive demands, the results for this variable are not discussed. With the exception of the recovery experience of control, all variables showed statistically significant differences between women and men. Women reported lower scores for all recovery experiences and higher workload, while at the same time reporting higher scores for both the advantages and disadvantages of remote work. Regarding negative outcomes, women reported higher scores on workaholism, emotional exhaustion, and WFC.

Table 4. Means, standard deviations, and ANOVA for the academics sample by gender.

	Women		Men			
	M	**SD**	**M**	**SD**	***F***	***p***
Workload	3.79	0.95	3.62	0.98	15.85	0.000
Cognitive demands	4.32	0.68	4.18	0.69	24.07	0.000
Off-TAJD	3.92	0.88	3.68	0.93	39.01	0.000
Workaholism	2.77	0.79	2.56	0.79	38.82	0.000
WFC	2.89	0.85	2.68	0.84	31.11	0.000
Detachment	2.02	0.98	2.11	0.99	4.41	0.036
Relaxation	2.87	1.04	3.16	0.97	45.84	0.000
Mastery	2.86	0.94	3.05	0.86	24.27	0.000
Control	2.81	1.03	2.75	0.99	2.06	0.151
Remote work disadvantages	2.81	0.86	2.70	0.83	9.26	0.002
Remote work advantages	3.08	0.99	2.97	0.96	6.88	0.009
Emotional exhaustion	2.92	0.74	2.72	0.72	42.56	0.000

Means, standard deviations, and ANOVA results for academic levels are presented in Table 5, while post hoc tests are shown in Table 6. All differences between groups are statistically significant. RU showed lower scores of workload, but also higher scores of detachment.

Table 5. Means, standard deviations, and ANOVA for the academics sample by role.

	FP		AP		RU		RTD-B		RTD-A			
	M	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**	***F***	***p***
Workload	3.73	0.99	3.76	0.94	3.31	1.01	3.89	0.85	3.74	0.94	16.71	0.000
Cognitive demands	4.18	0.71	4.29	0.67	4.16	0.75	4.31	0.59	4.30	0.65	4.46	0.001
Off-TAJD	3.83	0.86	3.85	0.92	3.59	1.00	3.87	0.85	3.73	0.92	5.58	0.000
Workaholism	2.55	0.81	2.73	0.77	2.44	0.80	2.81	0.80	2.88	0.78	15.90	0.000
WFC	2.71	0.85	2.85	0.84	2.63	0.85	2.83	0.80	2.87	0.84	5.64	0.000
Detachment	2.05	0.97	2.05	1.02	2.30	1.04	1.90	0.82	2.03	0.92	6.46	0.000
Relaxation	3.14	1.01	2.95	1.01	3.16	1.05	2.86	1.01	2.98	0.97	5.72	0.000
Mastery	3.01	0.87	2.97	0.92	3.10	0.93	2.77	0.89	2.77	0.86	7.36	0.000
Control	2.90	1.06	2.73	1.02	2.90	1.01	2.62	0.86	2.68	0.90	5.39	0.000
Remote work disadvantages	2.64	0.85	2.83	0.84	2.66	0.89	2.81	0.80	2.83	0.80	5.87	0.000
Remote work advantages	2.89	0.99	3.01	0.98	3.09	0.99	3.16	0.96	3.19	0.92	5.34	0.000
Emotional exhaustion	2.68	0.76	2.86	0.73	2.82	0.73	2.81	0.73	2.81	0.73	7.21	0.000

FP and RU both reported significantly lower scores of workaholism only compared to other groups, but not between them; RU also showed the lowest scores of off-TAJD compared to all other groups, though the difference with RTD-A was not significant.

RTD-A reported the highest scores of WFC, significantly different from RU, which reported the lowest value; the other significant differences were found between both FP and RU and AP, which reported the second highest level of WFC

Table 6. ANOVA post hoc tests for the academics sample by role.

			95% CI
Workload	RU	FP	−0.62, −0.23
		AP	−0.63, −0.28
		RTD-B	−0.80, −0.37
		RTD-A	−0.68, −0.18
Cognitive demands	AP	FP	0.01, 0.22
		RU	0.00, 0.27
Off-TAJD	RU	FP	−0.43, −0.05
		AP	−0.44, −0.09
		RTD-B	−0.49, −0.06
Workaholism	FP	AP	−0.30, −0.06
		RTD-B	−0.43, −0.09
		RTD-A	−0.51, −0.15
	RU	AP	−0.42, −0.14
		RTD-B	−0.55, −0.18
		RTD-A	−0.63, −0.23
WFC	AP	FP	0.01, 0.27
		RU	0.07, 0.37
	RU	RTD-A	−0.45, −0.03
Detachment	RU	FP	0.06, 0.45
		AP	0.07, 0.44
		RTD-B	0.19, 0.62
		RTD-A	0.04, 0.52
Relaxation	FP	AP	0.03, 0.34
		RTD-B	0.06, 0.50
	RU	AP	0.021, 0.38
		RTD-B	0.06, 0.54
Mastery	RTD-B	FP	−0.44, −0.05
		AP	−0.38, −0.02
		RU	−0.55, −0.13
	RTD-A	FP	−0.45, −0.03
		RU	−0.56, −0.11
Control	FP	AP	0.01, 0.32
		RTD-B	0.08, 0.48
		RTD-A	0.00, 0.44
	RTD-B	RU	−0.50, −0.06
Remote work disadvantages	AP	FP	0.06, 0.32
		RU	0.02, 0.32
Remote work advantages	FP	RU	−0.39, −0.011
		RTD-B	−0.48, −0.06
		RTD-A	−0.52, −0.07
Emotional exhaustion	FP	AP	−0.29, −0.07
		RTD-A	−0.45, −0.11

Regarding relaxation, RU still showed the highest score, but with significant differences only for AP and TRB, which again both differed significantly from FP, which showed comparable scores of relaxation to RU. As for mastery, RTD-A and RTD-B showed the lowest scores, with significant differences from RU and FP, although only RTD-B showed significant differences from AP. Predictably, FP had a high score in control, which was significantly different from the scores of all other roles with the exception of RU, which reported an even higher score, but only significantly different from RTD-B.

FP reported a lower impact of remote work advantages compared to RU, RTD-A, and RTD-B, with no significant differences from AP, which also reported the second lowest impact, though we did not find significant differences from other groups. Conversely, AP reported a high impact of remote work disadvantages, which was significantly different from FP and RU, which reported the lowest scores.

Finally, regarding emotional exhaustion, FP reported the lowest values, significantly different only from AP and RTD-A; while RU reported the highest scores, no significant difference was found.

4. Discussion

The aim of this study was to describe the work in Italian universities for academic and technical and administrative staff during the second COVID-19 lockdown, using the framework of the Job Demands-Resources-Recovery model (Kinnunen et al. 2011) with reference to the process of health degradation and, in particular, emotional exhaustion. The study also addressed the advantages and disadvantages of emergency remote working. Starting from an exploratory perspective aimed at providing a general framework for further specific research, the study examined differences in gender and work area (in the TAS sample) and gender and role (in the academics sample).

As for TAS, the data showed a high level of work demands, but accompanied by recovery scores that were almost always above the middle point of the response scale: some difficulties emerged in terms of psychological detachment. The possibility of recovery should have allowed the restoration of resources spent at work (Sonnentag and Fritz 2007). Emotional exhaustion presented lower scores than the middle point of the scale and even lower scores for work–family conflict, although in both cases the scores are higher in the female subsample. The levels of workaholism and off-TAJD do not seem to be particularly critical, while in the general perception of remote work, the advantages outweigh the disadvantages, despite the overall critical situation.

The data on differences in relation to the TAS' work areas indicated that the measures used were able to identify the specificity of different work areas, which is an important element in studies of this type, while also providing useful insight into which areas seem to share similar characteristics in terms of job demands; in addition, it could prove useful in developing targeted measures for specific areas.

Compared to TAS, the mean scores of the variables in the academics subsample are more critical overall, with higher perceived levels of demands and especially more "additional" work demand through new technologies (off-TAJD); this high-demand work environment is associated with greater difficulty in recovery.

Thus, how can we explain the more critical scores in the female subsamples, in both TAS and academics samples? We can assume that women were simultaneously more engaged on the family front, considering the persistence of the traditional family model in Italy, with an unbalanced distribution of the care burden between men and women (Dolce et al. 2020; Saraceno 2013; Addabbo et al. 2012), especially in relation to childcare, which, globally, was particularly demanding during lockdowns (Fisher et al. 2020; Moreira da Silva 2019; Power 2020; Pozzan and Cattaneo 2020). More generally, other studies have documented more problematic outcomes for women during the pandemic (Gualano et al. 2020; Liu et al. 2020), but scholars had already shown gender differences in these indicators prior to the pandemic, which were associated with greater commitment to work–family balance and less chance of recovery (Purvanova and Muros 2010; Nolen-Hoeksema and Harrell 2002).

Our research confirms that these differences were strongly evident in Italian academia during the second lockdown. It is one of the first systematic studies to provide comprehensive evidence of these phenomena within universities, albeit in a particular situation such as remote work in an emergency situation. It also supports some of the assumptions about women's greater difficulties in their academic careers due to higher levels of family and academic domestic work (Heijstra et al. 2016, 2017). Mixed-method studies should investigate the nature and dynamics of this overload.

The differences we observe in terms of academic roles reveal more problematic experiences for the first stable academic career roles, which are still precarious positions, and for Associate Professors, i.e., roles that are still fully engaged in the dynamics of career confirmation, in a highly competitive context that more or less implicitly demands high levels of time and energy commitment even outside “typical” working hours, as evidenced by the reported high levels of off-TAJD. Indeed, the opportunity for professional affirmation is associated with a complexity of tasks and positive results in terms of research, teaching, public engagement, and participation in the functioning of the institution (Agasisti and Soncin 2021). These are also the academic positions in which we find women and men taking on childcare duties, when they are not simultaneously caring for their own children and their aging parents (the well-known phenomenon of the sandwich generation; Brenna 2021).

To understand the less problematic outcomes of Full Professors and RU, we can refer to both the academic career process and the characteristics of these roles. As is well known, the position of Full Professor in Italy is predominantly “male”, the average age is high, the domestic care duties are less, and the salary high; in most cases, there is a working group to support the various research and teaching activities. As mentioned in the description of academic positions in Italy, there have been no new RU hires since the reform. In recent years, a significant part of this population has gained access to the role of Associate Professor through dedicated selection procedures. Those who still remain in this role might experience academic competition with more detachment or resignation (Guidetti et al. 2020), with less activation and workload, which is also allowed by the reference legislation for this role (low commitment to teaching, less involvement in institutional roles). One piece of information we do not have concerns the possible choice of part-time employment, a condition that allows to perform other extra-university activities, which, combined with a lower workload, can have positive effects as an outcome of multi-tenure in a process of general enrichment of resources.

Limitations

Although this study includes a large sample and covers the entire national territory, it is not without limitations. First, it is a cross sectional and descriptive study, which limits the scope of our conclusions. The second limitation is the low response rate, which is unfortunately quite common in surveys carried out in universities, especially concerning academics. Third, as mentioned above, the indicators cannot be compared with previous descriptions, due to the lack of similar studies in Italian universities because of the exceptional and unprecedented nature of MWFH. Finally, we must consider the low reliability of the scale measuring cognitive demands, though only for the academic subsample. This could be due to the small numbers of items, a decision taken to ensure that the questionnaire was reasonably lean in order to maximize the expected low response rate.

5. Conclusions

This study starts from the observation that it is important to have systematic results on the variables considered in the present study, as a reference for the development of policies and interventions. The systematic conduct of such studies and their visibility is fundamental to build a system of interventions based on empirical evidence and to set in motion good practices of virtuous cycles between research and intervention.

Italian law requires companies (including universities) to assess stress but allows for different methods that leave much room for improvisation and do not allow for consideration at a general, national level. Even if the possibility to customize surveys on these topics is fundamental from the perspective of situated organizational analysis (Gorli et al. 2009), it is also important to have some general observatories that allow placing specific data in a broader frame of reference. Thus, it is a matter of promoting evaluation processes with mixed methods that use general, reliable, and valid measures, specific aspects, and qualitative findings.

Analyzing work dynamics in academia, taking into account gender differences, is a necessary prerequisite for defining action plans to promote well-being and gender equality. This analysis requires a situated approach that is able to take into account the specific field of study, i.e., science as a social institution (Picardi 2020) and, even more specifically, a particular university as a place with its own uniqueness, characterized by its own history, elements of the present, and perspectives that must be considered when designing interventions. While a particular university may share structural, procedural, regulatory, and cultural elements with other research institutions in the same country, it may also have its own unique characteristics that result from its history, successive governance structures, and perspectives that partly determine future trends.

In this sense, "research for action" approaches, such as the present, are fundamental. Starting from a general approach, they can later allow specific universities to carry out ad hoc studies capable of analyzing the phenomena in depth and thus proceed to the definition of actions. This approach can promote sustainable working conditions that can promote greater well-being and improved quality in higher education, consistent with Goal 3 and 4 of the 2030 Agenda (Gamage et al. 2022).

Even if they remain at a general level of analysis of the national situation, further studies are certainly necessary to understand the relationships between the variables studied, in all their complexity, and to integrate a qualitative evaluation of the results, possibly with the help of focus groups to discuss the main findings. It is not only important to understand the current dynamics, but also to evaluate the impact of the measures introduced and, even before, their actual use.

Finally, to be truly consistent with Sustainable Development Goal 5, it is essential to reiterate that there is still a large gap between theoretical considerations, empirical research, and the actual implementation of gender equality measures (Verloo 2013; De Vries and Brink 2016), in the illusion, unsupported by evidence, that the meritocracy constructed by reform processes is in and of itself gender neutral. Building adequate psychosocial research systems for the academy provides essential contextual data for developing gender equality plans, which are now mandatory to participate in Horizon calls and, along with gender budgeting, to access recovery and resilience funds for research. Moreover, they could serve as the basis for building and reporting strategic planning.

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Note

1 Although terms may differ between countries, for the sake of simplicity and convenience, in this paper we used "academics" for teaching and research staff and "TAS" for technical and administrative staff, i.e., non-academics.

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Article

Including Digital Connection in the United Nations Sustainable Development Goals: A Systems Thinking Approach for Achieving the SDGs

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Abstract: In the two decades since the establishment of the 2030 Agenda, the world has faced significant challenges to achieve the 17 Sustainable Development Goals (SDGs). Before COVID-19, the SDGs were not on track to be achieved, and disruptions in implementation resulting from the pandemic have had significant effects, turning back years of progress. The pandemic has highlighted the essential nature of digital technologies in advancing the SDGs, continuing education, including higher education, social, and commercial activities, as well as enabling people to participate in society, democracy, and the economy during crises. As humanity enters this new period and begins to reset after the 'great pause', it is imperative to reconsider how the digital revolution has affected progress, especially in realizing the SDGs. Digital inclusion and connectivity inform and are essential to achieve all of the Goals. This article builds on the Just Digital Ethical Framework conceptualized by the authors in O'Sullivan et al. published in *Nature Communications*, which argues that four strategic drivers (digital capabilities, technology, infrastructure, and governance) are imperative to complete all of the 17 SDGs. It takes the Just Digital Ethical Framework to the next critical step, in which there needs to be a new SDG dedicated to these four drivers. This article is an exploratory study that uses a systems thinking approach and presents an 18th SDG called Digital Connection. Digital Connection focuses on the equitable distribution of digital wealth guided by the drivers. Understanding the relationship between these drivers and how they operate, where they are used, the pace of change, and systems' ability to adapt are essential for sustainable development and to address the challenges that face society equitably and fairly.

Keywords: sustainable development; digital technologies; digital technologies in higher education; digital inclusion; United Nations; sustainable development goals

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1. Introduction

In the two decades since the establishment of the 2030 Agenda, the world has faced significant challenges to achieve the 17 Sustainable Development Goals (SDGs). Before COVID-19, progress in reaching the Goals was behind schedule, and the disruptions in implementation resulting from the pandemic have had significant effects. The pandemic emphasizes the essential nature of the digital sphere in advancing the SDGs, continuing education, including higher education, social, and commercial activities, as well as enabling people to participate in society, democracy, and the economy during crises. School and learning space closures exacerbated the existing education inequalities, making it more difficult for the most vulnerable to continue their education, especially for girls, those in rural areas, refugees, and forcibly displaced persons [1]. On this basis, the United Nations (UN) projects that 2.8 million young people and children are at risk of lacking access to education or dropping out in 2021, when learning about the losses that are likely to transcend this generation [1]. The situation has impacted all of the countries, but the most vulnerable and impoverished are experiencing it more profoundly. Before 2020, nearly half of the world could not access the essential technologies needed in the contemporary era, such as the internet [2]. The restrictions imposed by governments worldwide exacerbated these disparities, stressing the gap between those with and without access to the digital sphere.

Throughout the pandemic, digital wealth has become a determining factor in the ability of individuals and communities to engage in society. With regards to the Just Digital Ethical Framework conceptualized by the authors [3], 'digital wealth' is defined as the capacity to have adequate access to four critical digital drivers: Digital capabilities, commodities, infrastructure, and ethical governance. Technologies including supercomputers and advanced algorithms analyzed thousands of drug compounds to develop vaccines, e-commerce ensured access to medical supplies and infrastructure, and digitally-mediated good governance helped in facilitating these activities. However, inequities in the current system of digital wealth indicate that there is an unequal distribution both between and within nation-states. For example, digital skills and literacy predicted which sectors of education and business could continue during the pandemic. While the digitally wealthy could utilize technologies to 'survive' hardships, digitally deprived populations were marginalized. These populations often could not participate in the same activities or access equivalent goods and services, fostering an emerging class of poor—the digital poor.

If not addressed through ethical governance, the gap between the under-connected and the hyper-digitalized groups will worsen the existing inequalities [4]. This scenario has significant implications for the SDGs. Without proper development and implementation of the four drivers of digital wealth, the world will fail to achieve the 2030 Agenda [5]. As a result, it is imperative to reflect on how the digital sphere influences sustainable development, recognizing that the world is amidst a technological revolution, where participation in modern society depends on digital wealth. It is now time to consider developing a new SDG dedicated solely to digital wealth. Based on these observations and to progress the essential nature of the Just Digital Ethical framework [3], this article explores the possibility of establishing a new SDG, Digital Connection, using a systems thinking approach. To achieve this, the study addresses two primary research questions: (1) Is there a need for an 18th SDG focused on digital wealth?; (2) How can an SDG based on digital wealth and its four associated drivers (digital capabilities, commodities, infrastructure, and ethical governance) help in progressing the SDGs and the 2030 Agenda?

2. Rethinking Digital: The Just Digital Framework and an 18th SDG

Observing the historical patterns of how technologies ebb and flow from invention to mass adoption, society has now reached the point of the digital sphere, which is a systemically essential part of society. It is no longer siloed in the 'Information Technology' category, but is pervasive throughout people's working, learning, health, personal, political, and social lives. The technological revolution has followed the lines of all previous revolutions. It has been driven by 'creative destruction' and significant productivity leaps. While countless traditional jobs and skills may have become obsolete during this phase, this productive leap creates enough new wealth and opportunities to ignite innovation, new types of business models, and jobs, while redefining perspectives and assumptions. Critically, it is followed by a period of 'creative construction', in which society 'catches up.' When considering the impact of the technological revolution, it is clear that the world is at a moment where society needs to 'catch up' [6]. This is taken alongside the growing concerns that new technologies could lead to counterproductive impacts, setting back progress towards the SDGs rather than moving the 2030 Agenda forward [7]. The Just

Digital Ethical framework explores how an ethical way to ensure that creative construction incorporates all of the society's needs and values can be created [3]. Due to its holistic and imperative nature in achieving the SDGs, this framework provides a starting point to consider the development of an 18th SDG, responding to the advancements in technology and digitization. As observed by Perez et al., the period of creative construction is the ideal time for society to catch up with modern developments and utilize the revolution to ensure society is best served by its advancements [6].

There are efforts to address the issues arising from the growth and influence of the digital sphere globally, such as the UN Secretary-Generals Roadmap for Digital Cooperation [7]. However, these endeavors fail to have an integrated and universal approach that supports digital wealth, access, and inclusion. This research contributes to these ongoing debates by considering what this article argues as the next logical step, the 18th SDG. The proposed concepts in this article theorize that developing new and innovative ways to support digital access, wealth, and inclusion in this context is necessary. Digital Connection is this reformulation, and as an SDG, it can reduce inequalities, provide access to employment, education, and healthcare in remote areas, create opportunities for co-creation of policies, and enable the education of girls, women, and other marginalized groups. Moreover, it can help in building disadvantaged communities' resilience to climate change through the increasing capacity for innovation. Furthermore, it can enhance agricultural productivity and logistic systems and provide market access and financial services, such as mobile money.

With society reaching a digital tipping point, it is critical to re-evaluate the entire system alongside the interconnected drivers of the Just Digital Ethical Framework [3] to inform of a new SDG. Reconceptualizing the digital sphere into a framework that considers the inter-related nature of digital capabilities, commodities, infrastructure, and governance allows for a modern review of digital inclusion, poverty, and the SDGs. The value of this research and Digital Connection is in its potential to re-imagine the factors that support digital inclusion, which inform digital wealth, poverty, and the broader goal of sustainable development. This model shows that these core drivers enable digital inclusion, which is crucial in mitigating digital poverty. These four inter-related concepts play an essential role in developing a digitally connected society and achieving the SDGs, illustrating the need for Digital Connection as an 18th SDG.

The first part of this process looks at how the Digital Connection drivers work within the existing system to achieve the SDGs. Using the systems thinking approach previously undertaken by the authors in health [8], disability [9], and education [10], the following sections identify the specific points and places within the current system where these drivers can solve digital inequalities and support the achievement of the SDGs.

2.1. Digital Capabilities

Digital capabilities are the skills deemed essential for driving digital transformation, supporting digital wealth, and sustainable development. Digitally literate citizens can benefit from the digital economy through accessing quality and safer information, e-government services, commercial products, media, and engagement with the global community. Conversely, digitally illiterate citizens can be victims of the digital economy, experiencing financial fraud and physical or other forms of exploitation and abuse. Consequently, equality in digital skills is vital to shared prosperity in the digital economy [11].

The need for employers and educators to move 'online' during COVID-19 highlighted the realities of the digital economy in both developed and developing nations. The pandemic has increased global dependence on digital technologies, and with this, the requirement for digital skills to participate in social, economic, and democratic aspects of society. Even the most developed countries found it challenging to guarantee that people had adequate skills to continue engaging in work and school activities. The situation was worse in less developed countries. As demonstrated in 2020, fewer than one in five people in the Least Developed Countries (LDCs) had the digital skills to use the internet, compared to four out of five in developed countries [12].

The distribution of digital literacy varies between the global North, global South, and within and between countries. Lack of Information and Communication Technology (ICT) skills is a significant barrier to accessing the digital economy, which is predicted to reach USD 23 trillion by 2025 [13]. The Broadband Commission for Sustainable Development recognizes this challenge and has set targets to ensure that 60% of youth and adults have minimum proficiency levels in digital skills by 2025 [13]. Even with these goals, there are disparities in skills. In 2019, the International Telecommunications Union (ITU) reported that less than 50% of the population possessed basic computer skills, including sending emails with an attachment or copying a file. Less than 50% of people in 60 countries worldwide had 'standard' skills, such as using basic arithmetic formulae in a spreadsheet or downloading and installing new software. For advanced skills, only two countries reported that more than 15% of people had written a computer program using a specialized language in the last 3 months [14]. These statistics demonstrate the differences between those who have and those who do not have access to digital capabilities and the potential impact on achieving the SDGs. People who have digital capabilities are better served in modern society in terms of work (SDG 8) [15], health (SDG 3) [15], and education (SDG 4) [15], which reduces the risk of poverty (SDG 1) [14], and unequal access to society (SDG 5) [15].

Several OECD countries and some Latin American and Asian countries have guidelines for measuring digital skills and developing education and training courses. On the other hand, Africa does not have any of these frameworks. However, the World Bank's Digital Economy for Africa (DE4A) Initiative aims to make Africa digitally enabled by 2030 [11,16], recognizing that Africa's young people need to be digitally literate and have access to technology and markets. This access ensures that they can thrive in a world increasingly driven by the digitalized economy [16]. One of the most comprehensive and commonly used frameworks to measure general digital skills is the European Union's DigComp 2.0 and updated DigComp 2.1. These frameworks consist of 21 competencies within five areas: Information and data literacy, communication and collaboration, digital content creation, safety, and problem-solving. Each competency has eight proficiency levels [11,17].

Digital capabilities are essential, and there needs to be a more significant focus on increasing digital literacy alongside sustainable development. For example, innovation, reducing poverty, and decreasing inequalities depend on the employability of people. With the growth in automation of service roles and the expanding dependence on technology, it is necessary to provide all of society with access to basic and advanced digital skills. These include the capability to communicate effectively using technology, be represented in developing technologies, and stay connected to self and services with emerging technologies.

2.2. Digital Commodities

Digital commodities are the fundamental technologies and solutions which were the cornerstone to continuing normal activities during COVID-19 and are needed for full participation in society. These commodities are a means of increasing people's engagement in society, improving accountability and transparency, public service delivery, and inclusion. They include hardware, such as laptops, computers, mobile phones, and software, such as word processing applications, coding capabilities, and access to cloud computing. The pandemic necessitated integrating technological solutions to work, learning from home, and building and sharing medical support. The past 2 years have highlighted digital inequalities, in which there are clear socioeconomic and political divides in who has access to essential technology [2].

Digital commodities are central for employment, education, and innovation. Research shows that digital technologies facilitate financial inclusion, access to markets, mobile banking, microcredits, and remittances [18]. Specifically, ICTs contribute to poverty alleviation by highlighting the needs of vulnerable groups using real-time data and analytics and simultaneously enabling people to work in partnership and co-create solutions with diverse stakeholders. As it currently stands, there is no SDG dedicated to ICT, and only four ICT related indicators appear in four of the Goals (SDGs 4, 5, 9, 17). However, the 2030 Agenda emphasizes technologies' essential role in achieving all of the 17 Goals [19]. In addition, more recently, the introduction of the six SDG Transformations, one of which is dedicated to digital technologies, demonstrates the importance of providing a framework to consider how the SDGs are affected by access to digital commodities [20].

An example of how access to technologies impacts the SDGs is evident in the growth in innovations in digital finance, e-commerce, and e-governance. These are increasing access to information and services. In China, e-governance has been seen to reduce the rural-urban divide through access to health, education, and the rising non-agricultural income-generating opportunities for rural areas. Furthermore, millions can now access financial services through social networks and e-commerce platforms, enabling marginalized and impoverished populations to save, invest, and build credit scores. In Bangladesh, iFarmer, a digital crowdfunding platform, allows the investors to offer capital to rural women cattle farmers and the e-commerce platform ekShop Shoron helps Rohingya refugees create livelihoods in Cox Bazaar [19]. These growths in e-commerce must be seen as more than an opportunity to shift from a traditional retail trade model to a more sustainable one, but also as an opportunity to use digitalization to advance this goal [21]. Without access to technologies that support engagement in these activities, these innovations do not serve the marginalized.

Although these examples in China and Bangladesh show how digital commodities empower these populations, there is a growing divide between urban and rural access to technologies. In China, rural areas still disproportionately lack access to technologies. Moreover, the cost of devices, data plans, as well as the speed and quality of connectivity are additional exclusionary factors. More than 70% of urban households have internet access in Bhutan compared to 29% of rural households [19]. COVID-19 has threatened to push nearly 71 million people into severe poverty due to a lack of digital commodities, which will most likely increase these divisions [18,19]. Commodities, infrastructure, and affordable services are necessary to mitigate this impact.

2.3. Digital Infrastructure

Digital infrastructures and services are essential for achieving several of the SDGs. In less than two decades, commercial internet has moved from innovation to a requirement for full participation in society. Although it might seem that the digital economy is a system in itself, several actors have invested in capital and operating expenditures, research, and development to construct and sustain the 'digital ecosystem' that facilitates the digital economy. Some of these actors include Communication Service Providers (CPSs), digital service and content providers, and hardware and software manufacturers. Moreover, governments are highly involved and act as policymakers, regulators, owners, and distributors of mobile networks. Non-Profit Organizations (NGOs), industry groups, and multi-stakeholders, such as the United Nations (UN) agency ITU, are crucial players. Collectively, these stakeholders are responsible for fixed and mobile networks, data centers, internet protocols, and technological equipment. As the number of people and companies that use the internet increases, companies invent more ways to service these needs, such as the Cloud, machine-to-machine communications, and the Internet of Things. This phenomenon makes good, working, digital infrastructure networks necessary for successful engagement in contemporary society [22].

A new face of inequality emerges when considering who has meaningful access to the technology and its associated infrastructure. While technologies, such as Artificial Intelligence (AI) and blockchain provide unique opportunities to people, they pose numerous risks, including exclusion [23]. Deputy Secretary-General Amina Mohammed stated that 'almost half the world's population ... the majority of them women, and most in developing countries, are still offline' [23]. In 2016, more than 4 billion people in emerging economies did not have access to the internet, many living in rural or remote areas [24]. In India, a country with the second-largest online market, only 50% of the population has access to the internet [25]. Additionally, recent data demonstrate that 66% of Caucasians have access to high-speed internet at home compared to 49% of African Americans and 51% of Hispanics [24]. The rural versus urban divide also shows the increasing marginalization of communities living in rural or remote areas. Studies by large industries demonstrate that poor broadband is a significant obstacle to employment in rural areas. As underfunded national governments remain primarily responsible for these infrastructure systems, there has often been minimal progress in providing digital networks in rural areas [26].

Although there have been developments in promoting inclusive and sustainable industry, including investing in infrastructure and connectivity guided by SDG 9, industrialization in LDCs is still slow [15]. There is a substantial variance in levels of digital infrastructure in emerging markets. This is especially prevalent in Low-Income Countries (LICs), where there are frequently low levels of internet penetration and usage, gaps in coverage between rural and urban settings, and barriers in affordability, specifically for the mobile internet. The pandemic shows that digital connectivity is essential to business continuity and societal resilience. However, there is still limited data on the effect of COVID-19 on digital infrastructure in emerging markets. Most of the COVID-19 analysis concentrates on government interventions or infrastructure subsectors [27].

In emerging markets, digital infrastructure providers may see higher demand, in which a series of adverse shocks can counterbalance. These shocks can impact broadband operators and smaller companies, resulting in reduced competition, technological innovation, and availability of open-access broadband infrastructure. COVID-19 is causing a decrease in funding into emerging markets. As a result, significant support may be required from development finance institutions for financing of smaller or independent companies in the most impoverished economies to ensure competition, resilience, and the promotion of digital inclusion for the poorest [27].

Funding is also a challenge for universal digital inclusion. Many independent actors provide funding for these goals, but often do not work as a coordinated mechanism. Gaining access to this funding can require onerous processes that many governments and non-state actors lack the capacity to complete, such as feasibility studies. In some regions, there are high levels of investment for infrastructure. In others, funding is significantly lacking, especially in LDCs and countries afflicted by conflict, where connectivity could help decrease poverty. Although the private sector has access to finance, technology, and resources to fund digital connectivity and inclusion, there is a reluctance to invest in places that are considered to have associated risks, lack of collateral, and little short-term returns [2]. Access to working infrastructure in the form of internet connection, cloud computing, and operating systems that connect critical stakeholders at the country and local levels are fundamental to achieve a fair and equitable society for all. This relates to nearly all of the elements of the SDGs. Failure to consider who has access and how they access the digital world hinders the ability to ensure that everyone's basic needs are met, which allows them to flourish in a way they value.

2.4. Digital Governance

Ethical governance plays a significant role in ensuring specific protections in conjunction with digital inclusivity. The UN has stated that digital technologies are a primary supporter of sustainable development, making it even more essential for the ethical management of all things digital to create an ecosystem that supports the integration of digital technologies into people's daily lives in a fair and safe way [28]. This system must ethically promote social inclusion and ensure national policies protecting citizens' rights and confidentiality, while considering data infrastructure and ownership. One of the core challenges for digital transformation is the lack of coordination or mechanisms to create relevant policies supporting digital innovation and private enterprise [13].

Universally, digital wealth is inextricably linked to human rights. The strategies and policies to achieve this goal must reflect on human rights online and enhance capacities for cybersecurity. Alongside an acceleration in digital connection resulting from the pandemic, the human right protections, both online and offline, continue to deteriorate. There has been a decrease in internet freedom and increased internet shutdowns, as well as surveillance and privacy violations. These violations extend beyond government abuses, and if action is not taken, incidences of misinformation, hate speech, online violence, and sexual exploitation will continue to grow. However, the linkage between digital wealth and human rights is more than political rights. As COVID-19 illustrates, access to the digital sphere is crucial to accessing fundamental, economic, social, and cultural rights and critical to achieve the SDGs, such as access to education (SDG 4), employment (SDG 8), and health and wellbeing services (SDG 3) [2]. SDG 8 recognizes the right to work as a fundamental human right. Promoting decent work and economic opportunity through ensuring that everyone has access to digital commodities and capabilities is a cornerstone for success to SDG 8 and is critical to achieve progress in alleviating poverty (SDG 1) and in promoting health and wellbeing (SDG 3) [15].

While more attention is given to human rights in the digital sphere, there is a lack of cooperation and consensus around this topic, specifically among UN member states. The different approaches are challenges to digital security and safety, hindering a global approach to digital human right issues. The involvement of business and civil society groups to regulate online human right protections is also controversial [2].

Before the beginning of 2020, many governments tried to strengthen their strategic approach to digital transformation and focused on emerging digital technologies, such as AI, blockchain, and 5G infrastructure. In 2020, 34 OECD countries had a national digital strategy, and by mid-2020, 60 countries had a national AI strategy. Between 2017 and 2020, several OECD countries issued 5G strategies including, Australia, Austria, Colombia, France, Germany, Korea, Spain, the United Kingdom, and the United States. There is also increasing attention to blockchain and quantum computing strategies. Australia, the People's Republic of China, Germany, India, and Switzerland have policies, and France and Italy are developing them [29].

The ongoing cyclical relationship between digital innovation and digital transformation is crucial for new business strategies and markets, and digital technologies are playing a pivotal role in improving science and research systems that strongly influence countries' COVID-19 response and recovery. However, there is a growing awareness of how these technologies can challenge human-centred values, privacy, consumer protection, and security [30]. Countries need to respond to these issues when making policies. While these trends are encouraging, the pandemic shows that policymakers must adopt a whole government approach to digital transformation and governance [29]. Additionally, governments need to use metrics to measure digital inclusion within this system to produce evidence-based policymaking and to ensure that no one is left behind [7].

3. Methodology

3.1. Systems Thinking Approach

This research aims to use a systems thinking approach to explore the possibilities and potential need for an 18th SDG. This method allows for the understanding of reciprocal relationships, interactions, and differing perspectives of a system, including its boundaries [31]. In this article, a system is defined as a range of connected components forming a whole, showing properties that are a part of the whole rather than properties as individual elements [32]. This method uses four principal characteristics of a system: Emergence, hierarchy, communication, and control. Holistically, it aims to find solutions to problems by analyzing a system's framework where they occur [32].

An essential distinction in considering systems is whether the system is 'closed' or 'open.' Generally, closed systems function autonomously, independently from their environment, and are configured to be consistent, generating identical outcomes [8,33]. In contrast, open systems are rooted in, dependent on, and often designed to respond to their environment. Unlike closed systems, they may not be consistent, with their outcomes potentially requiring a change over time [8,33].

The systems thinking approach that guided the researchers' inquiry drew on four process steps as informed by Richmond (2000) and MacLachlan and Schere (2018) [8,34,35]. The first step focuses on identifying the problem using one of four 'thinking approaches': Dynamic thinking, system-as-cause thinking, forest thinking or loop thinking. Dynamic thinking demonstrates behavioral patterns over time or how these patterns are distinct in different contexts [8,34,35]. System-as-cause thinking concentrates on what can change in a system to solve the problem. This type of systems thinking can include changing the element's relationship to each other or introducing new components that may alter and impact the outcomes in other parts of the system that are not in direct contact with the changed elements [8,34,35]. Forest thinking seeks to understand the context in which the system exists and its interrelationships and defines its boundaries [34,35]. It emphasizes the significance of identifying the broader 'wooded area' from the individual trees and addressing the trees' relationship with one another [8]. Loop thinking focuses on the cause and effect and bi-directional relationships that are maintained in a continuous loop [8].

The second step is constructing a hypothesis or model using one of three methods of thinking: Operational thinking, closed-loop thinking or qualitative thinking. Operational thinking focuses on causality and behavioral patterns to understand the nature of the process. Closed-loop thinking seeks to understand feedback relationships between the different elements of the system, and quantitative thinking quantifies the core variables. The third step is testing the hypothesis or model. The fourth step is communicating, understanding or implementing changes [34,35].

This research used system-as-cause thinking and closed-loop thinking approaches to propose a way to solve the problem of inequality in digital access, wealth, and inclusion. This article is the starting point for advocating for Digital Connection as an SDG in order that the theory can be tested and holistic changes to the system can be implemented. This research hypothesizes that an 18th SDG dedicated to Digital Connection will help in progressing the 2030 Agenda, while promoting equality and access to goods and services, such as education, employment, and healthcare.

3.2. The Development of a Systems Thinking Diagram

Relationships in a system can be captured and represented in causal loop diagrams. These diagrams use reinforcing and balancing loops to produce system maps. Reinforcing loops represent feedback loops that accelerate change, and balancing loops depict ones that resist change. This approach assists in collecting data that can inform policy, feedback loops, and the negative impacts of policy change [31].

In this research, the systems thinking approach was used to evaluate the present global system that uses digital wealth as a determinant for full participation in society and is arguably a critical factor in achieving the SDGs. The systems diagram developed as part of this research illustrates the imperative nature of the four proposed drivers of digital wealth in the system and as an 18th SDG.

4. Results and Discussion

This paper explores the case for developing an 18th SDG based on digital wealth and its four associated drivers: Digital capabilities, commodities, infrastructure, and ethical governance. The relationship between digital technology and individual SDGs has been discussed extensively in recent years [2,19]. However, since the pandemic, there is a growing sense that the impact of technological innovation in society could be profound. The rate at which innovation grows is causing social and economic disruptions of which the consequences are not yet clear. While AI, robotics, and blockchain have become a driving force for change in modern society, the capacity for inclusion in this period of innovation is predicted by access to digital capabilities, commodities, and infrastructure. Furthermore, the policies and practices that ensure a safe and equitable use of invention need to be in place to steer innovation in order to ensure that all of the society benefits. As has been stated, digital wealth is often available only to those that can afford access, while excluding the most vulnerable in society if a proactive stance is not taken. With the SDGs' pledge to 'leave no one behind,' there is a considerable risk that will happen. Digital Connection not only analyzes the digital divide, but additionally focuses on the core commodities and capabilities essential for a meaningful engagement in society and achieving 'a good life'. The targets and associated indicators of Digital Connection are detailed in Table 1.

Table 1. Outlines the targets and indicators of the proposed SDG Digital Connection.

Goal	*Indicators*
Ensure everyone has equitable access to **Digital Connection**	
1.1 Digital Capabilities, Ensure all education systems provide everyone with the capacity to engage in the digital sphere	1.1.1 Proportion of population without access to education that teaching digital skills
1.2 Digital Commodities, Ensure everyone has access to the hardware required to engage in a basic standard of living	1.1.2 Proportion of population without access to required hardware
1.3 Digital Infrastructure, Ensure equal access to working communication systems that enable everyone to engage in work, school and daily life.	1.1.3 Proportion of population unable to access communication
1.4 Digital Governance, Ensure (and develop where needed) international standards to support the integration of digital technologies into everyone's daily lives	1.1.4 Proportion of population without access to digital technologies

Amartya Sen argues, 'poverty is not just a lack of money; it is not having the capability to realize one's full potential as a human being' [36]. Access to the commodities and capabilities that allow for the participation in society are fundamental to sustainable development. Reconsidering the digital sphere is a way of rethinking sustainable development in a broader sense. The capacity to gain employment, access services remotely, and have personal data represented in emerging technologies and algorithms are crucial factors that predict participation and encourage the equal distribution of digital wealth.

Using a system-as-cause thinking approach to understand the need of this SDG, the linkage between the four drivers and how they collectively inform the system can be determined. In Figure 1, a graphic system map illustrates how the four digital drivers in the system come together to enable (or undermine) sustainable development. This figure reflects how Digital Connection fosters sustainable development and allows for the full participation in society. It shows how the fulfilment of Digital Connection creates critical outcomes around the core dimensions of the 2030 Agenda, focusing specifically on the economic, social, and ecological aspects of sustainable development [37].

The system map demonstrates that digital drivers equally affect economic participation in terms of employment and commerce. This access allows for the society to take advantage of the technological revolution and employment. Furthermore, it enables democratic participation, whereby people can access information and use that information to participate in the democracy. The governance of digital data and information guarantees that democratic participation is fair and equal. In the social realm, access to digital capabilities, commodities, and infrastructure alongside an ethical governance structure allows for 'all things digital' to be used to support wellbeing. For example, understanding how screen time can affect mental health supports wellbeing. Without the commodities and capabilities to navigate all things digital, wellbeing can potentially be negatively affected.

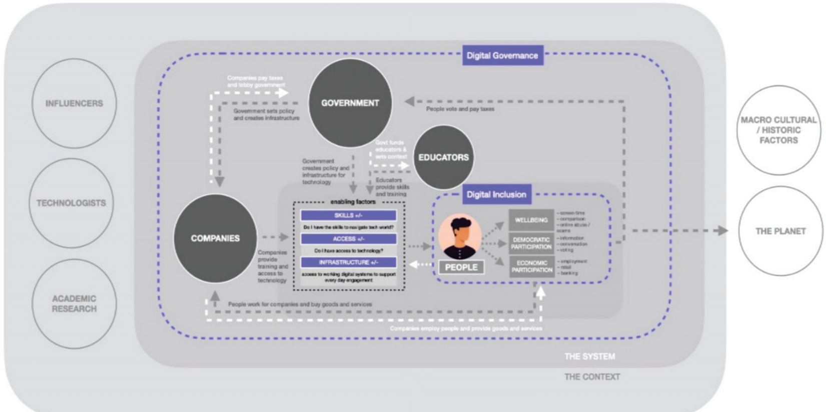

Figure 1. Figure 1 is a system map of Digital Connection, which explores how the four drivers interconnect and inform the whole system.

Another example is illustrated in how understanding internet frauds, fake news, and engaging with technological advances can also impact how individuals act, feel, and behave. Furthermore, representation in datasets that decide the future of service and innovation is a critical element of the social world. This representation depends on the digital capabilities, commodities infrastructure, and ethical governance of data in developing technologies. Moreover, it shows how the digital drivers affect the ecological and sustainability of the planet.

Creating a closed-loop feedback map shows how digital capabilities, commodities, infrastructure, and ethical governance are inter-related constructs that facilitate and enable inclusion. For instance, digital capabilities are required for full participation in education, yet these capabilities still depend on education systems that provide skill development. This is equally reliant on national and international policies that support and value digital capabilities and working infrastructure, as well as commodities that allow for skill development. Within this system, educators and companies play an essential role in developing Digital Connection and how individuals can build some skills themselves—only within a system that supports the process.

Highlighted within this system is the industry. For people to have the technology, they need to afford technology, indicating that companies must consider the cost and condition of use. Companies can make technology affordable and available, and they are an essential feature of the system. Notably, when looking at companies and industries, there is a strong need for ethical governance of who, how, and why they develop technologies and how they utilize data from technologies to develop technologies of the future and information systems. For technology to be usable and inclusive, companies need to design it well. If it is not designed well, it can be challenging to use and even exploitative or exclusionary. Therefore, the companies in the system, their ethics, the governance system, and their ambition are essential features facilitating digital wealth and ethical use of technology in modern society or acting as a barrier. Governments are a necessary feature of the system. They play a facilitatory role in developing the infrastructure that makes digital wealth possible and the policies that drive education and access. More importantly, they control the funding to run the system and potential legislation that ensures digital society is constructed ethically. The macro influencers in this system include technologists, academics, and researchers who set the context for Digital Connection and add insight and voice independent of the system players.

5. Limitations and Contributions

The researchers acknowledge that this study has certain limitations. Although a systems thinking approach can be advantageous, it also has limitations. In genuinely complex systems, minor variations in preceding periods of time significantly impact as time progresses, and the feedback loops are incomprehensible. These systems have an inherent complexity that systems thinking cannot penetrate. Systems thinking focuses on finding patterns in complexity in phenomena that look complex at the surface level, but have a more straightforward order below the surface. With this, systems thinking applies to instances where apparent complexity is high and inherent complexity is low [34,35]. Accounting for this limitation in the method, researchers conducted a preliminary research, which continued through the entire process to ensure that the case which is studied fits within the parameters of the systems thinking approach.

Beyond the methodological limitations, the study is limited in the understanding of the practical application of implementing the proposed SDG. This limitation elicits further research to be conducted on its practical application. Although there are limitations, this research contributes to the debates around progressing the 2030 Agenda and promoting global sustainable development. This article provides a framework from which to conduct these investigations into how this SDG would function and interact within the current SDG framework.

6. Conclusions

The pandemic has adversely affected the implementation of the SDGs. A significant factor is the increased global dependence on the digital realm. To address the study's research questions, the researchers analyzed specific variables that were predicted to help in mitigating these adverse effects and help in promoting sustainable development. In addition, the present article evaluated if adding an 18th SDG dedicated to Digital Connection with four underlying drivers (digital capabilities, technology, infrastructure, and governance) would effectively advance this desired outcome. By applying a systems thinking methodology, the study's objectives were met and the research questions were answered.

The primary finding derived from the discussion of the system map indicates that the four drivers of Digital Connection can effectively support and progress sustainable development. This outcome is sustained through the bi-directional relationships and proximal and distal factors of the four drivers. Each of these variables interconnects in a closed-loop system that stimulates responses that encourage the equitable distribution of digital wealth. In addition, with digital wealth as a determining factor in achieving the SDGs, as this article argues, it would be beneficial to include an SDG that concentrates on Digital Connection. As shown in the model, the critical outcomes related to digital wealth are health and wellbeing and economic and democratic participation at an individual and societal level, which eventually positively affects the planet. This system demonstrates the importance of Digital Connection in the contemporary era and how its reach is siginificantly important that it merits consideration as an SDG.

The conclusion of this article, alongside the secondary sources cited, elicit the need for further investigation to establish how Digital Connection can operate in symbiosis with the existing Goals and objective timelines and how it would function in practice. On a positive note, introducing this new SDG may facilitate and hasten the achievements of the other 17 SDGs by providing education, support, and infrastructure of digital technologies to create a more equitable and fair society. However, a risk assessment is also required to evaluate and ensure that the introduction of Digital Connection does not exclude non-technology based solutions. It is imperative to analyze the advantages of walling in digital solutions and the potential disadvantages of walling out other solutions that are a part of the holistic approach of the 2030 Agenda. Conversely, providing digital capabilities, technology, infrastructure, and governance will not ensure an equitable distribution of these drivers with a clear SDG objective in mind. Further research on governance is required, and it is crucial to safeguard the introduction of this goal, for example, to prevent companies from misinterpreting it as profiteering or greenwashing opportunities.

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Section 4—PUBLIC ENGAGEMENT

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Article

Coupling Coordination between University Scientific & Technological Innovation and Sustainable Economic Development in China

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Abstract: Coupling development between university science and technology (S&T) innovation and economy is an objective requirement for achieving sustainable economic and social development. The main goal of this paper is to explore the situation of the coupling coordination relationship between the two systems, i.e., university S&T innovation and sustainable economic development in China. It also hopes to provide a reference for promoting the coordinated development between the two. This paper constructs the evaluation index system of university S&T innovation and sustainable economic development separately and evaluates the indicators of university S&T innovation and sustainable economic development in 30 provincial regions in China from 2011 to 2020. On this basis, a coupling coordination degree model is constructed to evaluate the coupling coordination degree of university S&T innovation and sustainable economic development. Accordingly, this paper puts forward suggestions for promoting the coordinated development between university S&T innovation and sustainable economic development.

Keywords: university S&T innovation; sustainable economic development; coupling coordination

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1. Introduction

The growth pole theory put forward by Perroux points out that the main driving force of regional economic development is technological progress and innovation [1]. As an important force of original innovation in basic research and high-tech fields, universities provide powerful energy for the progress of S&T and the sustainable development of society [2]. Along with the in-depth development of the economy and society, promoting the deep integration of university S&T innovation and economy is not only a practical need based on sustainable development but also an important support to promote the high-quality development of society. Therefore, it is an urgent need to properly handle the coordination between the two systems, i.e., university S&T innovation and sustainable economic development, so as to promote the coordination between the two and then form a virtuous and coordinated cycle mechanism of S&T and economy.

Before improving the coordination between university S&T innovation and sustainable economic development, it is necessary to clarify the current situation of the coordination between the two systems. This paper focuses on the coordination relationship in Chinese provincial regions. What is the relationship between the two systems in reality? Are there any differences in coupling coordination between regions? This paper aims to clarify the situation of the coupling coordination relationship between the two systems in China from the perspective of time evolution and spatial pattern. It aims to provide a reference for promoting the coordinated development between the two systems.

2. Literature Reviewed

In recent years, scholars have conducted in-depth theoretical discussions and empirical studies on the impact between S&T innovation and economic development and achieved fruitful research results. Scholars mostly focused on the one-way effect of S&T innovation on economic development. Cheng et al. believed that S&T innovation is the core power of economic development and proved that various elements of S&T play a powerful role in promoting regional economic development through empirical analysis [3]. Salvatore verifies the contribution of S&T innovation to sustainable economic development based on the empirical data of UNESCO [4]. Sefer and Ercan proved the positive effect of S&T innovation on economic growth and competitiveness [5].

However, it is not comprehensive to consider the one-way effect of the S&T system on the economic system. Some scholars further researched the feedback or interaction of economic development on the S&T innovation system. Zanello et al. believed that the dynamic relationship between technological innovation and the local geographical environment, economic system, and political and legal system is the key condition for the success of regional economic development [6]. Maradana et al. investigated the long-term relationship between innovation and per capita economic growth in 19 European countries from 1989 to 2014 and found that there was a two-way causal relationship between innovation and per capita economic growth [7]. Liu and Xia established an indicator system with R&D investment, technological innovation and economic growth as research variables to discuss the two-way interaction between technological innovation and economic and social development [8].

As one of the three major S&T innovation forces [9], the impact of university S&T innovation on economic development has been given more prominence by scholars. Goldstein et al. analyzed the contribution of universities to regional economic development through empirical evidence and believed that university S&T innovation activities promote economic development by generating knowledge spillover effects [10]. Kruss et al. studied the impact of higher education on economic development and stressed the importance of considering the intersection of spatial dimensions [11]. Smith and Bagchi-Sen pointed out that the "aggregation" behavior between universities and regional enterprises plays an important influence, such as business training and innovation investment [12]. Wang et al. used the C-D production function model and entropy value method to measure the rate of S&T progress and the contribution of universities in Liaoning Province of China and concluded that the investment of university research funds plays an important role in regional economic development [13]. Li empirically studied the influence of university S&T innovation on regional economic development in 19 sub-provincial cities in China from 2008 to 2017 [14]. Wang et al. investigated the cross-regional flow of innovation capability factors of universities in China's coastal provinces and cities from 2005 to 2017 and proved the innovation ability of universities has an obvious spatial spillover positive effect on regional economic growth [15]. Cheng et al. studied the impact of the university-industry cooperation policy (UIC policy) on knowledge innovation and achievement transformation in universities and pointed out that cooperation between enterprise and universities can play an important role in economic transformation and development [16]. Li concluded that university S&T innovation could improve enterprise production efficiency, optimize the industrial structure, and promote energy saving and emission reduction [17]. In addition, Zhang et al. used a panel quantile spatial autoregressive model to empirically analyze the impact of S&T innovation in higher education institutions on regional economic development [18].

By ordering the existing research results, it can be found that the relevant research mostly focuses on the two-way relationship between S&T innovation and economic development at the macro level. In the existing literature with universities' S&T innovation as the research object, most of the existing research results focus on the effect of university S&T innovation in promoting economic development while ignoring the coupling coordination between the two. Few scholars research from the perspective of the two-way interaction between university S&T innovation and sustainable economic development, and few pay attention to the long-term changes between the two. Based on the existing research, with entropy value method, coupled coordination model and multiple regression, this paper analyses the time evolution and spatial pattern of coupling coordination between university S&T innovation and sustainable economic development in 30 provincial-level regions of China (excluding Tibet, Hong Kong, Macao and Taiwan) from 2011 to 2020.

3. Theoretical Analysis of the Coupling Mechanism

Coupling is originally a concept of physics, which refers to the phenomenon that two and more systems or forms of motion interact with each other in various forms and are closely related to each other [19]. Based on the premise that there is some form of association between various coupled subjects, coupling is used to analyze the dynamic relationship between multiple systems with connections [20]. University S&T innovation and sustainable economic development are closely related and have an interactive relationship, which can generate a positive synergistic amplification effect. University S&T innovation includes three parts: innovation inputs, innovation outputs and innovation environment. It affects sustainable economic development, which is specifically reflected in the impact on economic scale, economic structure, and economic quality. According to the two-way interaction relationship, the coupling mechanism diagram between university S&T innovation and sustainable economic development is constructed as shown in Figure 1.

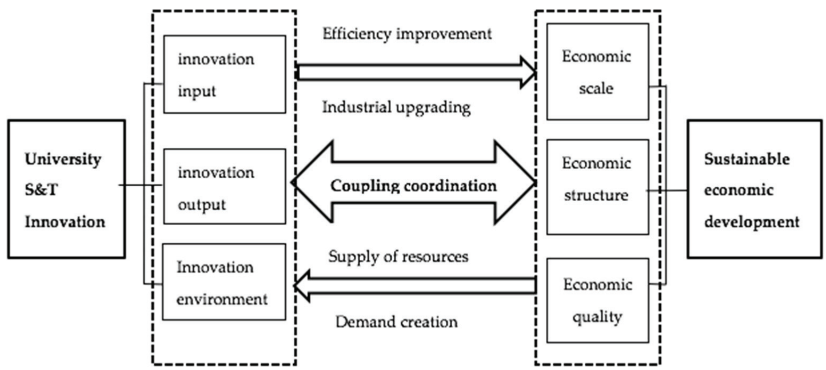

Figure 1. The coupling mechanism between university S&T innovation and sustainable economic development.

3.1. University S&T Innovation Promotes Sustainable Economic Development

The basic factors of sustainable economic growth are labor, capital, and scientific and technological progress. According to the Cobb-Douglas function that shows the dependency between capital input, labor input and output under certain production technology conditions, technology is an important factor that determines the level of economic growth [21]. In China, universities are an important part of the S&T system, and university scientific and technological innovation is also one of the important sources of economic growth. University S&T innovation acts on the optimization and upgrading of industries and the enhancement of economic benefits. Through the continuous diffusion of knowledge, information and technical resources, university S&T innovation has prompted corresponding changes in the human resource, production factors, production processes and production organization in the production field, and all factors in the production field will be recombined accordingly, further widening the space of production activities. Along with the generation and application of new technologies and new products, it accelerates the pace of innovation diffusion and promotes industrial innovation, which in turn changes the original factors of production, promotes the renewal of technology and realizes the transformation and upgrading of industry. Due to the continuous improvement of production factors, the efficiency of social labor productivity and resource allocation has been significantly improved, which not only increases the output of unit factors and the added value of resources but also changes the mode of economic growth, accelerates the transformation of economic growth from rough operation to intensive operation, and realizes the overall improvement of total factor productivity, labor productivity and the contribution rate of human capital.

3.2. Sustainable Economic Development Supports University S&T Innovation

The effective implementation of S&T innovation activities of universities is inseparable from the resource guarantee provided by sustainable economic development. In addition, sustainable economic development has produced a demand-pulling effect on the in-depth development of university S&T innovation and has also created a good innovation environment for innovation. Firstly, university S&T innovation needs to invest a lot of resources, especially financial support. The development of the economy means the increase of social wealth, which provides sufficient research funds for universities to carry out scientific and technological innovation activities. At the same time, the level of sustainable economic development directly affects the level of running and teaching quality of universities and thus enhances the level of scientific and technological innovation of universities, especially for new research universities, the importance of sufficient funds to strengthen the construction of basic disciplines and basic research is self-evident. Secondly, strong regional economic strength can attract all kinds of scientific and technological talents, thus optimizing the structure of the educational faculty and strengthening the scientific and technological talents in universities. Thirdly, the development of the economy will stimulate people's material and spiritual needs and expand market space, which will also stimulate university S&T personnel to carry out technical innovation and invention. Finally, sustainable economic development creates a good environment for scientific and technological innovation in universities. Sustainable economic development can promote the exchange of culture and the dissemination of knowledge, thus enhancing people's innovation consciousness and improving the comprehensive quality of the social groups to create a good operating environment for scientific and technological innovation in universities

4. Index System and Research Methods

4.1. The Construction of the Index System

The research on the coupling coordination of university S&T innovation and sustainable economic development must be based on the comprehensive evaluation of the two. According to the basic connotations and main ingredients, we followed the scientific, systematic principle of comparability and the availability of data in reference to the indicators designing of Xiao [22] and Liu [23], combined with the actual development situation in recent years in China, this study separately constructs the evaluation index system of university S&T innovation and sustainable economic development, as shown in Table 1. According to the evaluation system of university S&T innovation, this paper constructs 9 secondary indicators from 3 primary indicators: innovation inputs, innovation output and innovation environment. The evaluation index system of sustainable economic development includes 9 secondary indicators from 3 primary indicators: economic scale, economic structure and economic quality.

Table 1. Evaluation index system.

Subsystem	Primary Indicators	The Secondary Indicators	Index Attribute	Order Parameter
University S&T innovation	Innovation inputs	Research staff (person)	+	X_{11}
		S&T funds investment (1000 yuan)	+	X_{12}
		Full-time R&D staff (person year)	+	X_{13}
	Innovation outputs	Number of achievement applications and S&T service projects (items)	+	X_{14}
		Number of academic papers (articles)	+	X_{15}
		Number of patents granted (item)	+	X_{16}

Table 1. *Cont.*

Subsystem	Primary Indicators	The Secondary Indicators	Index Attribute	Order Parameter
University S&T innovation	innovation environment	Number of universities (units)	+	X_{17}
		Number of R&D institutions in universities (units)	+	X_{18}
		Proportion of illiterate population over 15 years (%)	-	X_{19}
Sustainable economic development	Economic scale	Gross Regional Product (100 million RMB yuan)	+	X_{21}
		Regional fiscal revenue (100 million RMB yuan)	+	X_{22}
		Total retail sales of consumer goods (100 million RMB yuan)	+	X_{23}
	Economic structure	Proportion of tertiary industry in GDP (%)	+	X_{24}
		Proportion of employees in the Tertiary Industry in the Employed Population (%)	+	X_{25}
		R&D investment intensity (%)	+	X_{26}
	Economic quality	Per capita gross regional product (RMB Yuan)	+	X_{27}
		Per capita disposable income of urban residents (RMB Yuan)	+	X_{28}
		Social labor productivity (10 thousand RMB yuan/person)	+	X_{29}

This paper takes 30 provincial regions (excluding Tibet, Hong Kong, Macao and Taiwan because of many missing data) from 2011 to 2020 as the research objects. Among them, the data are from "The Compilation of S&T Statistics of Institutions of Higher Learning," "China Education Statistical Yearbook," "China Science and Technology Statistical Yearbook," and "China Statistical Yearbook." It should be pointed out that the intensity of R&D investment is represented by the ratio of R&D investment to GDP, and the social labor productivity is represented by the ratio of regional GDP to the total number of employed people.

4.2. Research Methods

4.2.1. Entropy Value Method

As an objective weighting method, the entropy value method mainly obtains the weight coefficient by calculating the index of information entropy to judge the degree of data dispersion [24] and then realizes the comprehensive evaluation of the index system. The specific calculation steps are as follows:

(1) Standardize the original data

For positive indicators:

$$x'_{ij} = \left(x_{ij} - max\{x_{ij}\}\right) / \left(max\{x_{ij}\} - min\{x_{ij}\}\right) \quad (1)$$

For the negative indicators:

$$x'_{ij} = \left(max\{x_{ij}\} - x_{ij}\right) / \left(max\{x_{ij}\} - min\{x_{ij}\}\right) \quad (2)$$

x'_{ij}(i = 1, 2; j = 1, 2, 3 … 9) is the jth index of the i system.

Since the index will have no value after standardization processing, the logarithm of the entropy value cannot be taken in the calculation. Therefore, in order to ensure the rationality and usability of the data, the standardized value of each index was shifted by 0.01 units. Namely $x''_{ij} = x'_{ij} + 0.01$.

(2) The proportion P_{ij} of the *j*th index in subsystem *i* is calculated, and the formula is $p_{ij} = x_{ij} / \sum_{i=1}^{m} x_{ij}$, *m* is the number of evaluation samples, namely 30.
(3) The *j*th index entropy value, e_j, is calculated, and the formula [25] is

$$e_j = -\frac{1}{\ln(m)} \sum_{i=1}^{m} P_{ij} \ln(P_{ij}) \tag{3}$$

(4) To calculate the difference coefficient g_j of the *j*th index, the formula is

$$g_j = 1 - e_j \tag{4}$$

(5) Calculate the weight w_j of the *j*th index, whose formula is

$$w_j = g_j / \sum_{j=1}^{m} g_j \tag{5}$$

n is the number of secondary indicators of the subsystem.

(6) The composite index *U* of the 2 subsystems in each year from 2011 to 2020 is calculated, and the formula is

$$U = \sum_{i=1}^{n} w_j x''_{ij} \tag{6}$$

4.2.2. Coupling Coordination Model

According to the basic principle of coupling coordination and on the basis of the existing research [26], the coupling coordination degree model of university S&T innovation and sustainable economic development is constructed to measure the coordination degree of interaction coupling between the 2 subsystems.

The coupling degree *C* of the 2 subsystems is calculated, and the formula is:

$$C = 2\sqrt{\frac{U_1 \times U_2}{(U_1 + U_2)^2}} \tag{7}$$

In view of the staggered and unbalanced characteristics of university S&T innovation and sustainable economic development, the coupling degree *C* is difficult to fully reflect the true level of coupling coordination under some conditions. Therefore, the coupling coordination degree model is introduced:

$$D = \sqrt{C \times T} \tag{8}$$

$$T = \alpha U_1 + \beta U_2 \tag{9}$$

where *C* and *D* $\in$ [0, 1], the closer the values of *C* and *D* are to 1, the higher the coupling level and the better the coupling coordination between the 2 systems. *T* is the comprehensive coordination index of the two systems, which reflects the contribution of the overall level of university S&T innovation and sustainable economic development to the coupling coordination degree. α and β are undetermined coefficients, and $\alpha + \beta = 1$. In view of university S&T innovation and sustainable economic development are equally important, $\alpha = \beta = 0.5$.

According to the numerical value range of the coupling coordination degree and the existing research [27], the coupling coordination degree is divided into 5 grades, as shown in Table 2.

Table 2. Classification standard of coupling coordination degree.

Degree of Coupling Coordination	Grade
$0 \leq D \leq 0.2$	Severe maladjustment
$0.2 < D \leq 0.4$	On the verge of maladjustment
$0.4 < D \leq 0.6$	Primary coordination
$0.6 < D \leq 0.8$	Good coordination
$0.8 < D \leq 1$	High-quality coordination

5. Empirical Results and Analysis

5.1. Evaluation of University S&T Innovation and Sustainable Economic Development

The entropy value method is used to calculate the evaluation value of university S&T innovation and sustainable economic development of 30 provincial regions in China from 2011 to 2020. The evaluation values in most of the provinces indicate stability and slight increases. It is worth noting that the COVID-19 epidemic that occurred at the end of 2019 has caused a great impact on China's economic and social development. In 2020, the evaluation values of university S&T innovation and sustainable economic development decreased to varying degrees.

5.1.1. Evaluation of University S&T Innovation

According to the entropy method introduced in Section 4.2.1, the evaluation values (Figure 2) of university S&T innovation are calculated through Formulas (1)–(6). The values of Jiangsu, Beijing, and Shanghai ranked in the top three, reflecting the strong innovation ability of universities. In addition, Zhejiang, Shandong, Hubei, and other places have higher evaluation values and show an increasing trend. The reason is that the plentiful scientific and technological resources of universities and the perfect S&T innovation system in the regions have played an important role. For example, there are 31 "double first-class" universities in Beijing, 15 in Shanghai and 13 in Nanjing, far more than in other regions. Outstanding talents, innovation teams, and sufficient R&D funds provide continuous vitality for university S&T innovation. However, due to the constraints of geographical location and the weak scientific research foundation of universities in Qinghai, Ningxia, Xinjiang, and other places in the western region, the evaluation value is always at a lower level, which is significantly different from the developed coastal areas in the east. Meanwhile, the evaluation value in the northeast region has a decreasing trend, while Shanxi, Henan, Jiangxi, Hunan and etc., in the central region show a steadily increasing trend.

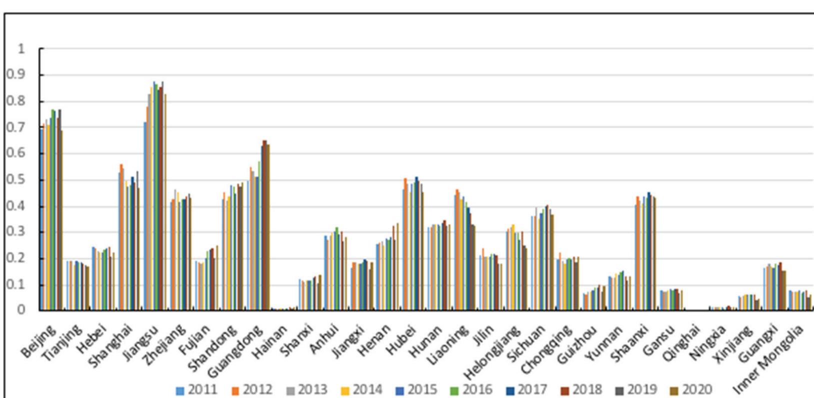

Figure 2. The evaluation value of university S&T innovation in provincial regions.

5.1.2. Evaluation of Sustainable Economic Development

According to the entropy method introduced in Section 4.2.1, the evaluation values (Figure 3) of sustainable economic development are calculated through Formulas (1)–(6). The evaluation value of Beijing, Shanghai, Jiangsu, Guangdong, and Zhejiang are at the forefront of the country. Most regions show stable development, which is in line with the driving force of development being shifted from investment to innovation. Under the guidance of the economic development strategy system such as Beijing-Tianjin-Hebei Cooperative Development, Yangtze River Economic Belt Development, Yangtze River Delta Economic Circle and the construction of the Chengdu-Chongqing Region Twin Cities Economic Circle, Chinese economic strength has continued to improve. Only Tianjin, Shanxi, Inner Mongolia, Guangxi, Ningxia, and Northeast China are affected by the extensive production mode and the relatively slow upgrading of industrial structure, which makes the evaluation value decline slightly, resulting in a relatively backward transformation and upgrading of economic structure. From the perspective of spatial layout, there is a wide gap between different regions, especially between the eastern coastal areas and the remote western areas. In addition, the evaluation value of the central region has shown a trend of the steady growth of sustainable economic development in recent years.

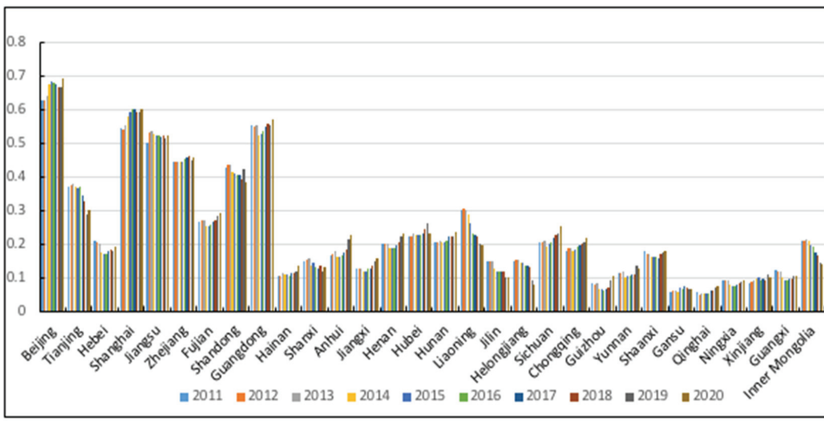

Figure 3. The evaluation value of sustainable economic development in provincial regions.

5.2. Evolution Characteristics of Coupling Coordination

Based on the evaluation value of university S&T innovation and sustainable economic development, the coupling coordination model, which is introduced in Section 4.2.2, is applied. The coupling coordination degree of the two subsystems of 30 provincial regions in China from 2011–2020 is measured through Formula (7)–(9). The results are shown in Table 3.

Table 3. Coupling coordination degree of university S&T innovation and sustainable economic development in provincial regions (2011–2020).

Province	Years										Average
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
The Eastern Region											
Beijing	0.814	0.820	0.827	0.832	0.843	0.850	0.849	0.838	0.848	0.831	0.835
Tianjin	0.517	0.517	0.521	0.506	0.515	0.512	0.504	0.492	0.475	0.476	0.504
Hebei	0.475	0.472	0.466	0.446	0.443	0.447	0.453	0.462	0.439	0.455	0.456
Shanghai	0.732	0.744	0.742	0.734	0.728	0.733	0.745	0.735	0.751	0.729	0.737
Jiangsu	0.776	0.803	0.817	0.819	0.824	0.821	0.815	0.819	0.819	0.813	0.813

Table 3. *Cont.*

Province	Years										Average
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
Zhejiang	0.656	0.659	0.675	0.669	0.657	0.664	0.666	0.672	0.671	0.669	0.666
Fujian	0.474	0.473	0.470	0.465	0.477	0.495	0.500	0.507	0.489	0.521	0.487
Shandong	0.655	0.666	0.654	0.652	0.666	0.663	0.653	0.664	0.670	0.659	0.660
Guangdong	0.725	0.742	0.739	0.719	0.721	0.744	0.767	0.776	0.777	0.776	0.749
Hainan	0.181	0.181	0.184	0.166	0.169	0.177	0.176	0.178	0.191	0.208	0.181
Average	0.601	0.608	0.609	0.601	0.604	0.611	0.613	0.614	0.613	0.614	0.609
The Central Region											
Shanxi	0.367	0.365	0.363	0.354	0.359	0.353	0.358	0.367	0.334	0.366	0.358
Anhui	0.469	0.466	0.477	0.467	0.472	0.482	0.476	0.486	0.488	0.504	0.479
Jiangxi	0.381	0.392	0.392	0.381	0.384	0.393	0.396	0.400	0.391	0.415	0.392
Henan	0.475	0.479	0.481	0.465	0.478	0.476	0.486	0.512	0.497	0.527	0.488
Hubei	0.568	0.582	0.578	0.566	0.577	0.580	0.588	0.585	0.597	0.571	0.579
Hunan	0.506	0.506	0.514	0.510	0.510	0.511	0.523	0.529	0.519	0.529	0.516
Average	0.461	0.465	0.467	0.457	0.463	0.466	0.471	0.480	0.471	0.485	0.469
The Northeastern Region											
Liaoning	0.605	0.613	0.609	0.595	0.581	0.557	0.547	0.537	0.507	0.503	0.565
Jilin	0.424	0.436	0.418	0.404	0.398	0.404	0.402	0.398	0.369	0.366	0.402
Heilongjiang	0.461	0.470	0.472	0.469	0.455	0.448	0.439	0.454	0.391	0.373	0.443
Average	0.496	0.506	0.500	0.489	0.478	0.470	0.463	0.463	0.422	0.414	0.470
The Western Region											
Sichuan	0.521	0.523	0.536	0.513	0.524	0.533	0.544	0.548	0.549	0.552	0.534
Chongqing	0.434	0.453	0.437	0.426	0.437	0.443	0.443	0.451	0.442	0.462	0.443
Guizhou	0.277	0.267	0.279	0.261	0.269	0.273	0.279	0.291	0.285	0.315	0.280
Yunnan	0.350	0.348	0.351	0.347	0.346	0.353	0.360	0.347	0.355	0.361	0.352
Shaanxi	0.518	0.524	0.519	0.508	0.515	0.513	0.519	0.519	0.527	0.527	0.519
Gansu	0.261	0.260	0.263	0.262	0.275	0.272	0.279	0.279	0.260	0.269	0.268
Qinghai	0.114	0.107	0.091	0.112	0.109	0.105	0.102	0.102	0.106	0.107	0.106
Ningxia	0.192	0.192	0.195	0.174	0.173	0.163	0.179	0.189	0.191	0.196	0.184
Sinkiang	0.261	0.262	0.273	0.278	0.280	0.278	0.278	0.279	0.259	0.266	0.272
Guangxi	0.377	0.377	0.382	0.363	0.353	0.359	0.361	0.367	0.354	0.357	0.365
Inner Mongol	0.356	0.355	0.352	0.352	0.351	0.339	0.340	0.334	0.295	0.309	0.338
Average	0.333	0.333	0.334	0.327	0.330	0.330	0.335	0.337	0.329	0.338	0.333

In general, the coupling coordination degree between university S&T innovation and sustainable economic development in most regions show a steady increase and gradually stabilize, but the growth rate is low. It indicates that university S&T innovation and sustainable economic development in China are developing in a more coordinated direction, but the speed of coordinated development is relatively slow, and the coupling coordination in most regions should be improved. The coupling coordination in the central region has the largest increase of the four regions, from 0.461 in 2011 to 0.485 in 2020. However, in Northeast China, the trend is downward.

5.3. Spatial Pattern Distribution of Coupling Coordination

ArcGIS10.2 software is used to visually display the average value of the coupling coordination degree from 2011 to 2020 in the form of a regional map, as shown in Figure 4. From the perspective of spatial layout, there are obvious regional differences in the degree of coupling and coordination in China. The overall unbalanced trend of "high coupling degree in the eastern and southern region, low coupling degree in the western and northern region" is shown, and the spatial stratification of coupling coordination degree gradually decreases from coastal to inland areas.

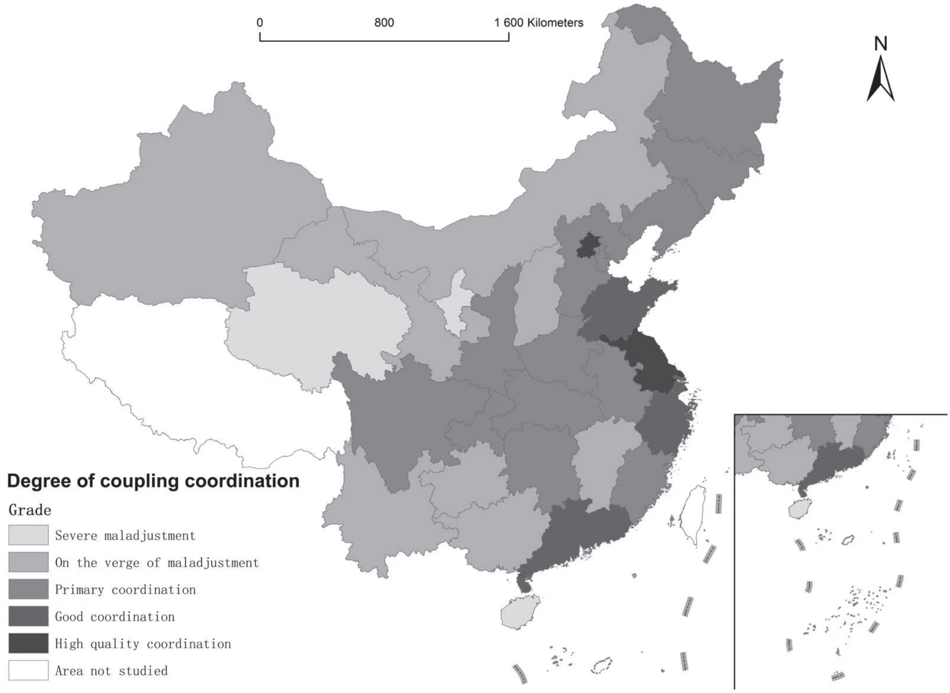

Figure 4. Spatial distribution pattern of the average coupling coordination degree in provinces of China from 2011 to 2020.

Taking the average value of each region from 2011 to 2020 as an example, the coupling coordination degree of Beijing, Jiangsu, Guangdong, and Shanghai ranks the top in the country, among which Beijing and Jiangsu are in the stage of high-quality coordination. Beijing, as the capital of China, is the national center of S&T innovation and the region with the densest scientific, educational, intellectual, and human resources in China. Relying on its unique geographical advantages, strong economic strength, and superior scientific and technological innovation foundations, the coupling coordination degree of Beijing has always ranked first in the country. With the dual advantages of real economic and industry research, Jiangsu has been committed to building a strong province in S&T and implementing various plans for sustainable development based on the in-depth implementation of the innovation-driven development strategy, and its coupling degree has been following that of Beijing. With the dual advantages of real economic and industry research, Guangdong, as a major economic province in China, has been strengthening the comprehensive strength of S&T in universities, and its coupling coordination degree has been in a good coordination stage and maintained a steady increase. Shanghai is the most economically developed region in China and also a region with concentrated higher education resources. In recent years, the construction of the S&T innovation system in universities has been accelerated, the S&T innovation capacity of universities has been enhanced continuously, and its coupling coordination degree has been maintained at a good coupling level. Besides, although the coupling coordination degree of Fujian, Hainan and other places in the eastern region is lower, it has been maintaining a good trend of a steady increase in the past 10 years.

The coupling coordination degree of the central region (except Shanxi) maintains an upward trend. Driven by the implementation of the strategy for the rise of the central region, the strength of science and education has been significantly enhanced, and the coordinated development of the central region is gaining momentum. Except for Shanxi, the coupling coordination degree of the central region in 2020 is above 0.4, and the situation of coordinated development between university S&T innovation and sustainable economic development is initially formed.

The average value of the coupling coordination degree of the three northeastern provinces in the past ten years is above 0.4, but the coupling degree of the northeastern region shows a decreasing trend year by year due to the growing institutional structural problems of the old industrial bases in the northeast, the weakening competitiveness of traditional pillar industries, and the influence of factors such as the transformation and upgrading of the heavy chemical value chain and the relatively slow development of university S&T innovation.

In addition to Sichuan, Chongqing, and Shaanxi, which have achieved primary coupling, the coupling coordination degree of other regions in the western region is relatively low. Due to the harsh natural environment and weak economic foundation, the average coupling and coordination degree of this region is the lowest among the four major regions of China, and there is a big gap with the eastern developed regions.

6. Discussion

On the basis of reviewing and sorting out the interaction mechanism between university S&T innovation and sustainable economic development, this paper establishes the evaluation index system from six dimensions of scientific and technological innovation input, output, environment, and the scale, structure and quality of sustainable economic development. Then, the entropy method and coupling coordination degree model are adopted. The temporal evolution and spatial pattern characteristics of coupling coordination degree in 30 provincial regions in China from 2011 to 2020 were analyzed. The following conclusions are drawn:

First, in terms of time, the coupling coordination degree between university S&T innovation and sustainable economic development in most regions of China showed a growth trend year by year, indicating that China's "innovation-driven development" strategy and sustainable economic development have achieved initial results. The coupling coordination degree of the central region is growing the fastest. However, except for the developed eastern coastal areas, the coupling coordination degree in other regions is relatively low, and the coupling coordination development should be improved. In addition, affected by the level of university S&T innovation and traditional industries, the degree of coupling coordination in some regions shows a declining trend. For example, in Northeast China, it is necessary to improve the output of university S&T innovation, the transformation of S&T achievements, industrial structure, and economic quality.

Second, in terms of space, the gap between the eastern coastal areas and the central and western regions is obvious, and the overall spatial layout is "high coupling degree in the eastern and southern China, low coupling degree in the western and northern China." Beijing and Jiangsu have reached a high level of high-quality coordination, and Shanghai, Zhejiang, Guangdong and Shandong are also in a good coordination stage. In the six central provinces, the degree of coupling coordination between Shanxi and Jiangxi is relatively low. In addition, in the western region, except for Sichuan, Chongqing and Shaanxi, other regions are on the verge of maladjustment, and Ningxia, Qinghai and other regions are even at the stage of severe maladjustment. The Bohai Rim region, the Yangtze River Delta region and the Pearl River Delta region are obviously superior to other regions, which to some extent indicates that the coordinated development of scientific and technological innovation and economy in colleges and universities needs to be further improved, which indicates the high level of coupling coordination in eastern coastal areas.

Due to the imbalance of the spatial distribution of coupling coordination degree in various regions and the limitation of economic and social development, it is urgent to narrow the gap between regions to improve the overall coupling degree. The multi-level, multi-organization, cross-regional internal and external linkage development mechanism should be constructed to consolidate the strength for the coordinated development of university S&T innovation and sustainable economic development. Firstly, it is to coordinate the university S&T innovation with economic development. For example, compared with the evaluation values of sustainable economic development, the evaluation values of university S&T innovation in Tianjin, Shanghai, and Hainan are relatively low. These provinces should focus on promoting the development of university S&T innovation to improve the coupling coordination. Instead, Jiangsu, Anhui, Hubei, and Shanxi should vigorously optimize the economic structure to promote sustainable economic development. Secondly, because industry-university research cooperation is conducive to the coordination of scientific and technological innovation and economic development [28], it is significant to encourage local governments, enterprises and institutions, as well as universities, to jointly build R&D institutions to form an innovation system with in-depth integration of industry, education and research, and give full play to the respective advantages of the three parties to achieve cross-field innovation cooperation. Thirdly, because the flow of R&D resources is conducive to stimulating the vitality of S&T innovation [29], it is meaningful to promote the rational flow of economic and scientific factors and the resources of university S&T innovation in various regions, and promote the transfer of capital, technology and talents from the eastern coastal regions to central and western regions, so as to enhance the radiating effect and driving role of coordinated regional development.

7. Conclusions

This paper constructs the evaluation index system of university S&T innovation and sustainable economic development separately. With the entropy value method, the evaluation values of university S&T innovation and sustainable economic development in 30 provincial regions in China from 2011 to 2020 are calculated. On this basis, a coupling coordination degree model is constructed to evaluate the coupling coordination degree of university S&T innovation and sustainable economic development. This study shows that the coupling coordination degree of university S&T innovation and sustainable economic development in most regions of China is increasing, but the overall coupling coordination level is low. The coupling coordination level is high in eastern and southern China and low in western and northern China. It is of great significance to improve the overall level of coupling coordination and reduce regional differences. From the perspective of time evolution and spatial pattern, this paper provides a reference for clarifying the reality of the coordination degree of university S&T innovation and sustainable economic development in China.

However, because the reasons for regional differences are very complex, this paper does not further analyze the reasons for regional disparities among China's provinces. Further research should concentrate on the related aspects of regional disparities, which may provide policymakers with a target for boosting the coupling coordination degree in low-performing provinces

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The Role of Community-Engaged Learning in Engineering Education for Sustainable Development

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Abstract: This paper presents the positive experience of facilitating over 300 community-engaged engineering projects at an Irish higher-education institution. The projects are framed by a research orientation, a commitment to civic engagement, and building university–community partnerships, city–university partnerships, and partnerships with other official agencies, so that community users can provide real learning problems and contexts for students and researchers and benefit from the results. The paper highlights how well the outlined approach fits with the ideas of engaged scholarship and civic professionalism, and facilitates sustainable development. Students recognise the long-term value of engaging with community partners, understanding their future role in the community as engineers, reinforcing the idea that their work can respond directly to real needs in the community, while promoting the sustainability agenda at the same time. The approach presented in this study will not only enable the development of future models for embedding sustainability in engineering programs, but will also equip future engineers with transferable skills to ensure that sustainable development goes beyond university courses and is practiced every day.

Keywords: community-engaged learning; sustainable development; engineering education

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1. Introduction

1.1. Sustainable Development and Engineering Education

Sustainable development is the overarching paradigm of the United Nations [1]. Sustainable development 'meets the needs of the present without compromising the ability of future generations to meet their own needs' [2]. The 2030 Agenda for Sustainable Development was adopted in 2015 by United Nations member states and provides a plan for action for people, planet, and prosperity, both now and into the future [3]. At the centre of the Agenda are 17 Sustainable Development Goals (SDGs) to eradicate poverty and hunger, improve health and education, reduce inequality, ensure peace and justice, and stimulate economic growth, while tackling the challenges of climate change and biodiversity loss.

In May 2019, the United Kingdom and the Republic of Ireland became the first two countries in the world to declare climate and biodiversity emergencies. Since then, 15 countries and the European Union have made climate-emergency declarations (as of July 2021) [4].

By declaring a climate emergency, these governments recognised human-induced climate change and the massive threat posed by the loss of biodiversity, and committed to an immediate and ambitious science-based action to limit global warming to 1.5 °C and avoid massive biodiversity loss [5].

Engineers play a significant role in shaping the world around us. Through their engineering education, application of knowledge, leadership, communication skills and ethical practice, engineers are:

- Specialists, who solve problems;
- Integrators, who operate and manage across boundaries and with different stakeholders;
- Change agents, who provide creativity, initiative, innovation and leadership.

The application of engineering in response to large-scale problems, such as those brought on by climate change requires a comprehensive and systematic approach [6]. Considering the impact of engineering achievements to date, it could be argued that engineering has had one of the biggest influences on the climate crisis, but also the biggest opportunity to help transition to a more resilient society [7]. Since the majority of greenhouse gas emissions come from industries that are enabled by engineers, Lawlor and Morley (2017) [8] called on professional engineering institutions to develop declarations for engineers addressing climate change.

Engineers Ireland is a professional body for engineers in Ireland, representing 25,500 members. In early 2020, Engineers Ireland added their voice to other professional engineering organisations around the world [9–11], by declaring a climate and biodiversity emergency and defining a sustainability framework [12]. Furthermore, engineering industry organisations are also recognising climate and biodiversity emergency by committing to changes in their practice [13].

Education and collaborative partnerships are central to the implementation of sustainable development. Quality education and Partnerships for the Goals form two of the SDGs (SDG 4 and 17), but relate to the entire sustainable development agenda. According to Malala Yousafzai, the education activist and Nobel Prize laureate, 'All the SDGs come down to education...' [14]. SDG 4 focuses on 'ensuring inclusive and equitable quality education and promoting lifelong learning opportunities for all' [15]. The core competencies required, alongside traditional learning outcomes, for achieving SDGs include [16]:

- Envisioning;
- Critical thinking and reflection;
- Systemic thinking;
- Building partnerships;
- Participation in decision-making;
- Ensuring that the engineering students who obtain these competencies contribute to a more sustainable future.

Higher-education institutions have been instrumental in transforming society by educating decision-makers, leaders, entrepreneurs and academics [17]. Universities are expected to produce graduates who can develop innovative and creative solutions to the world's most complex problems, and need to include sustainability concepts in their curricula [18].

Previous studies explored the principles and practices of sustainable development in university curricula [19–21], green campus initiatives [22], and university leadership and governance [23]. Moreover, the scientific output associated with the sustainable development goals and their integration with universities has also been mapped [24]. However, there are still many obstacles to the inclusion of sustainable development in universities, both through research and teaching curricula and though the holistic integration of sustainability in university systems [25].

Rampasso et al. [26] analysed the difficulties associated with the inclusion of sustainability in engineering education. The study showed that technical training in engineering education, with a focus on optimising solutions from an economic perspective, is not enough. Courses integrating sustainable development need to place more emphasis on the social aspects of sustainability [27]. Apart from their core engineering knowledge, students need integrated socio-contextual knowledge to evaluate designs for sustainability and demonstrate its positive social benefits [28]. Furthermore, engineering students must be better prepared in relation to the environmental aspects of sustainability [29], as it is imperative that professional engineers take into account the environmental impact of their designs, such as the proper use of water, materials and energy, the emission of polluting gases and the disposal of waste. According to Felgueiras et al. [30]: 'new engineering professionals need to have not only a set of deep capabilities in a specific area, but also more comprehensive proficiencies that allow them to understand how to integrate their particular system into a wider functional system'.

1.2. Community-Engaged Learning

As well as the need to integrate sustainable development into engineering degree programmes to provide them with the means to meet the challenges of the 21st century, there is a critical need to provide engineering students with a deeper understanding of the general concepts and principles of engineering [31–34]. The Royal Academy of Engineering [31] highlighted the need for 'university courses to provide more experience in applying theoretical understanding to real problems'. It was shown previously [27] that students can achieve better learning outcomes when more community-oriented and constructive-learning approaches are applied. These types of approaches also increase students' knowledge of sustainable development.

Several accrediting bodies for engineering qualifications have developed outcome-based criteria for evaluating programmes. Similarly, a number of engineering regulatory bodies have developed, or are in the process of developing, competency-based standards for registration. Educational and professional accords for the mutual recognition of qualifications and registration have developed statements of graduate attributes and professional competency profiles. These accords are the Washington, Sydney and Dublin Accords, which are the international agreements providing for the mutual recognition of programme-based accreditation for professional engineers, engineering technologists and engineering technicians, respectively. In relation to graduates understanding the role of engineering and technology in society [35]:

- The Washington Accord programme provides 'comprehension of the role of engineering in society and identified issues in engineering practice in the discipline: ethics and the professional responsibility of an engineer to public safety; the impacts of engineering activity: economic, social, cultural, environmental and sustainability'.
- The Sydney Accord programme provides 'comprehension of the role of technology in society and identified issues in applying engineering technology: ethics and impacts: economic, social, environmental and sustainability'.
- The Dublin Accord programme provides 'knowledge of issues and approaches in engineering technician practice: ethics, financial, cultural, environmental and sustainability impacts'.

Community-engaged learning and teaching are academic approaches that seek to engage and accredit students, within the curriculum, for working in partnership with civic and civil-society organisations to act on local societal challenges [36]. Working in collaboration with community organisations enables students to use and enhance skills, competencies and knowledge in a real-world capacity, which leads to an enlarged and more fulfilling educational experience [37]. Through community-engaged engineering projects, students can: (i) develop the ability to identify, formulate and solve engineering problems in their field of study in a real-world context; (ii) select and apply relevant methods from established engineering practice by critically using appropriate sources of information to pursue detailed investigations and research on technical issues in their field of study; (iii) recognise the importance of non-technical societal, health and safety, environmental and economic constraints; and (iv) develop the ability to effectively communicate information, ideas, problems and solutions with the engineering community and society at large. In fact, community-engaged engineering projects can help fulfil all seven of the programme outcomes required by Engineers Ireland, which is the education standard required for the registration of Chartered Engineers in Ireland [38]:

- Advanced knowledge and understanding of the mathematics, sciences, engineering sciences and technologies underpinning their branch of engineering.
- The ability to identify, formulate, analyse and solve complex engineering problems.
- The ability to perform the detailed design of a novel system, component or process using analysis and the interpretation of relevant data.
- The ability to design and conduct experiments and to apply a range of standard and specialised research (or equivalent) tools and techniques of enquiry.
- An understanding of the need for high ethical standards in the practice of engineering, including the responsibilities of the engineering profession towards people and the environment.
- The ability to work effectively as an individual, in teams and in multidisciplinary settings, together with the capacity to undertake lifelong learning.
- The ability to communicate effectively on complex engineering activities with the engineering community and with society at large.

Previous studies have shown the impact of project-based learning in engineering education [39], students' perceptions of the effectiveness of online-project-based learning in engineering [40] and the creation of communities of practice for industry-based projects [41]. However, more research is needed to establish the most effective way of embedding sustainability into undergraduate courses, including in engineering, and encourage authentic student engagement [18].

1.3. Community-Engaged Building Engineering Projects

The University of Galway formally committed to civic engagement in 2001, through the establishment of the Community Knowledge Initiative [42], to work on mainstreaming community engaged learning within the curriculum across the institution. To date, the majority of undergraduate and postgraduate degree programmes in the School of Engineering have embedded community-engaged learning, which allows students to work with and in local and international communities, as well as in multidisciplinary groups, as part of their academic courses [43]. Goggins [43] showed how community-engaged learning and teaching in engineering education at the University of Galway (formally known as the National University of Ireland Galway) can be intergraded at levels ranging from undergraduate to post-graduate modules, as well as how this can be a lens through which the global dimension of engineering is integrated into the curriculum.

Furthermore, the University of Galway recognises that the future of humanity is threatened by unsustainable interactions between society, the economy and the environment: 'Building on the work of the Community and University Sustainability Partnership and its approach to Learn-Live-Lead sustainability across the university mission, the University of Galway will embed sustainability in its culture, operational policies and governance structures and empower communities to be champions of sustainability' [44].

This paper presents findings and reflections from the authors' 12 years of experience of facilitating over 300 community-engaged building engineering projects for second-year undergraduate (Level 8) civil engineering students in Ireland. The projects are based around the student groups developing solutions for real-world problems identified by civic society organisations. The projects are framed by a research orientation, commitments to civic engagement, building university–community and city–university partnerships and partnerships with other official agencies. This framing means that community users can provide real learning problems for students and that community partners can benefit from the results.

The projects are designed based on the community of enquiry framework [45], which integrates the teacher's presence, cognitive presence and social presence to ensure that students discover, discuss and reflect upon their new learning. The module provides a platform for students, lecturers and community partners to engage, interact and collaborate, because the 'interaction between learners is of great importance to student success' [46]. This is aligned with Bloom's taxonomy [47] and enhances students' learning, particularly in terms of applying, analysing, evaluating and creating. The approach helps students' deep learning [48] and enables them to develop a wide range of graduate attributes, through [49]:

- Knowing—students utilise the knowledge they gain from other modules;
- Acting—students apply their theoretical knowledge to real-life projects;
- Being—students reflect on their work and engage with their learning.

Finally, the 'students as researchers' pedagogic approach [50] enables students to develop knowledge and understanding while also contributing to broader knowledge in their discipline. This approach allows students to learn from the published literature in engineering and gives them an opportunity to go beyond it by utilising their skills and knowledge to innovate.

Much of the engineering-related research and practice associated with societal responses to climate change falls under civil engineering and environmental engineering [6]. By applying knowledge from the physical sciences and engineering, these disciplines seek innovative ways to design, construct and operate built environments, to prevent and reduce the emission of greenhouse gases and deliver infrastructure that is resilient in the face of the changing climate. Thus, it is imperative that relevant threshold concepts [51] in engineering are considered and that future civil engineers are equipped with the right skills with which to develop innovative and creative solutions to the world's most complex problems, such as climate change. For instance, Pawley et al. [52] and Reed [53] investigated the incorporation of the sustainability and environmental concepts into an engineering curriculum.

Community-engaged building engineering projects develop the core competencies required for achieving the SDGs [16] through:

- Exploring how to achieve change, offering direction and inspiration to take action, taking ownership of visions, processes and outcomes;
- Providing new perspectives and promoting alternative ways of thinking;
- Understanding the nature of feedback;
- Building shared vision among a diverse range of stakeholders, motivating and adding values to initiatives, communicating and exchanging information;
- Decision-making and responsibility for outcomes, an enhanced sense of ownership and commitment, building capacity for self-reliance and self-organisation.

The paper highlights how well the outlined approach fits with the ideas of engaged scholarship [54] and civic professionalism [55]. Students recognise the long-term value of engaging with community partners, understanding their future role in the community as engineers, reinforcing the idea that their work can respond directly to real needs in the community. Furthermore, this paper shows how community-engaged building engineering projects enable a greater understanding of sustainable development among engineering students and partner community organisations. These projects facilitate the development of skills, lateral thinking and knowledge transfer to translate student research into real-life projects to improve quality of life, protect the environment and reduce inequalities (Figure 1).

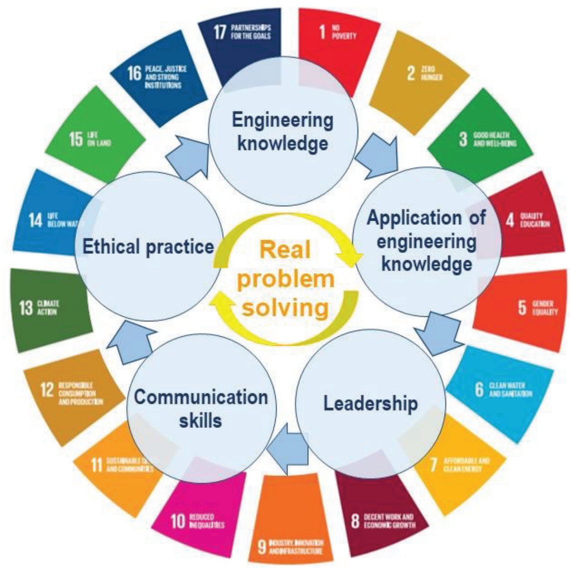

Figure 1. The development of core engineering competencies [38] through United Nations Sustainable Development Goals [15].

2. Methodology

2.1. Community-Engaged Building Engineering Projects

The community-engaged building engineering projects were allocated five European Credit Transfer and Accumulation System (ECTS) credits and started in academic year 2008/2009, as part of the second-year undergraduate 'Principles of Building' module. Since academic year 2020/2021, the 'Community Engaged Building Project' has been an autonomous module in second-year engineering. This module is compulsory for all students in Civil Engineering, Project and Construction Management and Energy Systems Engineering (approximately 60 students per academic year, but up to 120 students have completed projects in a given year). The general learning objectives for the projects include:

- Developing engineering skills through a self-directed project.
- Developing a sense of commitment to local communities by contributing time and expertise to an individual or community group.
- Learning how professional engineers make contributions to their communities.
- Applying the knowledge or skills learned in this module (and others) to a real-world context.
- Producing a technical engineering report.
- Delivering a high-quality oral presentation on a particular subject.

The projects are carried out following a step-by-step methodology that encourages students' engagement and self-evaluation (Figure 2).

At the start of the project, students (working in groups of two or three people) engage with community partners to identify a potential topic and scope for their engineering project. Community partners may include charity organisations, city and county councils, youth organisations, schools and universities, sport clubs, public organisations/offices, etc. Once the students identify a community partner and a project topic, they create learning outcomes of an individual nature for their project and complete and sign a learning agreement with the community partner. Identifying the project and its outcomes and completing and signing an agreement with the community partner increases the students' sense of ownership of their learning and gives them freedom to work on a topic of interest within the broader realm of the module. Many students appreciate the freedom that they are given to specify objectives for their project. However, outcomes of projects must fulfil a 'real' need of the community partner. In the recent feedback survey, the students stated (Student feedback, 2020):

- 'I liked being given a problem and looking for a solution interdependently, rather than being focused in on finding the correct way to bring about a solution that had already been formulated. Freedom.'
- '[The project] gives creative freedom to the students.'
- 'I liked the practicality of the project and the freedom of choice on which area we could choose to work on.'
- 'I enjoyed the group work and the ability to engage with a community partner in a real world engineering scenario.'

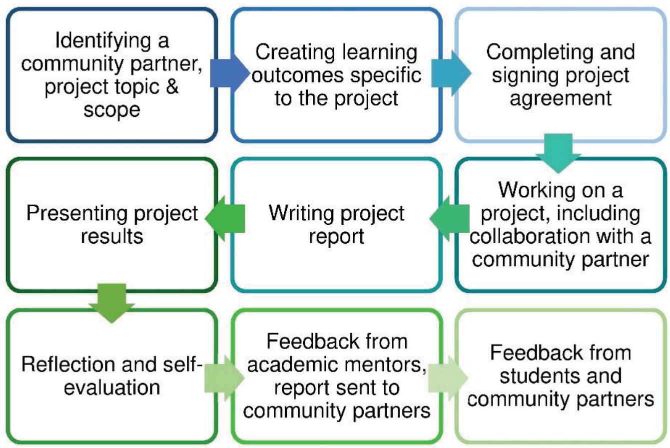

Figure 2. Community-engaged building engineering projects methodology.

Once the agreement with a community partner is signed, students have approximately 7 weeks to complete the project, which includes researching the topic, carrying out engineering design/evaluation and writing up an engineering report. During this time, students are encouraged to attend drop-in clinics run by teaching assistants, who can provide guidance on the project work and assess progress. Technical workshops on project stages, technical writing and presentation skills are also provided as part of the drop-in clinics.

When submitting a project report, students must complete a self-assessment form, where they reflect and assess their project work based on its knowledge base, relevance, impact on society, structure and presentation. Students later receive feedback (from their academic mentors) on their projects based on this self-assessment form. In this way, the students know what is expected of them and can compare their self-assessment of their project with that of the reviewers. This makes students aware of the characteristics of 'good work', encourages them to take responsibility for their own learning and helps them to reflect on themselves as learners [56].

Following the submission of a project report, students present their project results in the form of oral presentations in front of their peers, research students, engineers, a communication expert and community partners. Both the project reports and presentations are assessed based on their technical and presentation/communication merit. Thus, students learn not only how to carry out an engineering project, but also how to communicate it to various stakeholders.

Finally, students (and community partners) are asked to provide feedback on their experience with community-engaged learning.

Crucial elements of the community-engaged projects' set-up include:

- Detailed and structured guidance document for students;

- Structured learning agreement template that must be completed by the students and their community partners at the start of the project;
- Self-assessment form and marking sheet for reviewers;
- The return of marks to the students with feedback within two weeks of submission of the project and before the end of semester;
- Reports being sent to the community partners, who are asked to return feedback to the University.

2.2. Mapping Project Goals against the SDGs

In order to show relevance of the community-engaged building engineering projects to the 2030 Agenda for Sustainable Development, the projects carried out between 2014 and 2021 were mapped against the SDGs. Thirty different projects were undertaken by students in 2021, 30 projects were undertaken in 2020, 18 projects in 2019, 20 projects in 2018, 23 projects in 2017, 24 projects in 2015 and 19 projects in 2014. These projects were individually evaluated for their relevance to all SDGs. This evaluation generated a list of SDGs relating directly to each of the projects. Results of this analysis are presented in Section 3.1.

2.3. Evaluation Survey

Previous research [57] systematically reviewed literature on community engagement in undergraduate engineering education between 1980 and 2019. The study identified a need for additional research focusing on community partners' experience.

Thus, an important part of ensuring that the community-engaged building engineering projects meet the needs of students and community partners are feedback surveys. To date, seven online feedback surveys have been carried out among the community partners (2012, 2013, 2014, 2017, 2019, 2020 and 2021) and six feedback surveys have been carried out among students (2009 and 2011 in class; 2012, 2019, 2020 and 2021 online). This resulted in 62 community partners and 101 students providing qualitative feedback on the projects.

The community partner survey sought feedback on students' engagement with community partners, the usefulness of project report, any positive and negative aspects of the projects' set-up and suggestions for improvement.

The student survey included descriptive questions, such as:

- What did you like about the project and how it was set up?
- What do you gained from completing the project?
- What about how the project is run needs to be improved?
- What suggestions can you offer that would help make this project a more valuable learning experience for you?
- What suggestions can you offer that would help make this project a more valuable experience for your community partner?

3. Results

This section presents how the community-based building engineering projects, carried out in Civil Engineering at the University of Galway between 2014 and 2021, address the 2030 Agenda for Sustainable Development and their relevance to SDGs (content mapping). Furthermore, this section presents the results of surveys (qualitative analysis), carried out among the students and community partners between 2009 and 2021, which sought feedback from the participants on the set-up, structure and components of these engineering projects, invited suggestions for improvement and evaluated the quality of project partnerships and learning outcomes.

3.1. Mapping Project Goals against Sustainable Development

This section presents the results of the content mapping described in Section 2.2.

The community-engaged building engineering projects between 2014 and 2021 related to a number of the SDGs, as shown in Figure 3. Sustainable Cities and Communities

(SDG 11) was associated with the great majority of projects (96%), followed by Good Health and Wellbeing (SDG 3, 58%) and Affordable and Clean Energy (SDG 7, 46%). Industry Innovation and Infrastructure (SDG 9) and Reduced Inequalities (SDG 10) were each associated with approximately 10% of the projects, while Life on Land (SDG 15), Responsible Consumption and Production (SDG 12), Climate Action (SDG13) and No Poverty (SDG1) were directly related to 0.5–3% of the projects. The wide range of projects carried out between 2014 and 2021 included:

- The restoration of a historical mill wheel (2021, in partnership with local historical society)—directly relating to SDG 11, 3, 12;
- The renovation of a 1940s bungalow in order to transform it into a socially inclusive café (2021, in partnership with local social enterprise centre)—directly relating to SDG 11, 10, 7;
- A transitional refugee shelter focused on thermal performance (2021, in partnership with university buildings office)—directly relating to SDG 10, 1;
- The design of student accommodation made of recycled shipping containers (2020, in partnership with the university student union)—directly relating to SDG 11, 9, 3;
- The design of a ventilation strategy for new charity offices (2020, in partnership with the local charity group)—directly relating to SDG 11, 3;
- The design of a board-walk extension (2019, in partnership with the local chamber of commerce)—directly relating to SDG 15, 3;
- An energy and accessibility audit of a sports club (2019, in partnership with the local sports club)—directly relating to SDG 11, 7, 3, 10;
- Electric vehicle feasibility (2019, in partnership with the regional authority)—directly relating to SDG 7, 11;
- The development of a flood defence system in a city (2018, in partnership with the fire and rescue services)—directly relating to SDG 11, 9;
- The development of an awareness campaign for the search-and-rescue services (2018, in partnership with the National Lifeboat Institution)—directly relating to SDG 11, 3, 10;
- A light, heat and fire safety evaluation of a clubhouse (2017, in partnership with a local music band)—directly relating to SDG 11, 7, 3;
- The retrofitting of a charitable organisation's facilities (2017, in partnership with a local charity group)—directly relating to SDG 11, 9;
- The design, structural analysis and cost analysis of bridges in the proposed greenway project (2015, in partnership with the county council)—directly relating to SDG 11, 15, 3;
- An investigation and assessment of the accessibility and fire safety of a theatre (2014, in partnership with a city theatre company)—directly relating to SDG 11, 10, 3.

The community-engaged building engineering projects have been driven by Quality Education (SDG 4) and Partnerships for the Goals (SDG 17), as shown in Figure 4. 'Learning by doing' engineering education enhanced students' learning and engagement, as community partners/users could provide real learning problems and contexts for the students and benefit from the results. Furthermore, the partnerships between the engineering students and the community organisations set out the building blocks of engineering knowledge and skills and the underlying processes—from initial engagement with a community organisation, through communication and leadership, to project and partnership review. These building blocks were necessary to maximise the impact of the community-engaged projects and ensure that these partnerships led to positive changes related to the creation of a more sustainable society, planet and economy.

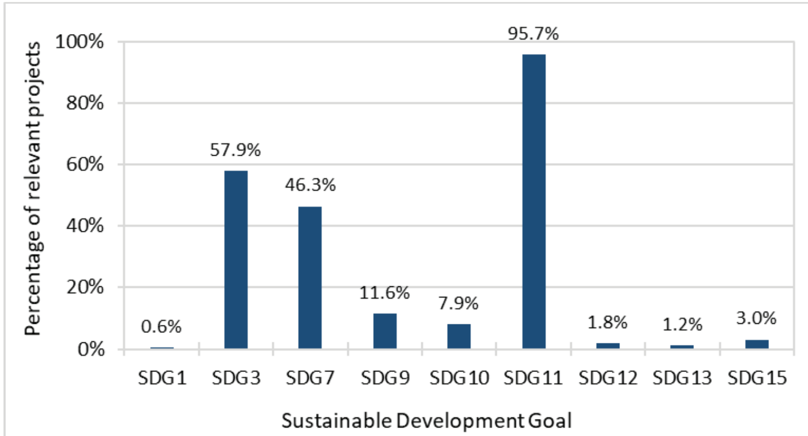

Figure 3. Relevance of community-engaged projects (2014–2021) to SDGs.

Figure 4. The gears of community-engaged building engineering projects.

3.2. Community Partner Feedback

The results of seven feedback surveys (qualitative analysis) carried out among community partners showed that the majority of the students' interactions, communication and cooperation were excellent (average 59%), with an average of 13% of partners expressing room for improvement in this aspect (Figure 5). No community partner felt that the students interacted, communicated or collaborated in a poor manner through the projects. Furthermore, the majority of the community partners found the students' reports very useful (average 54%) and stated that they would carry out the recommendations suggested in the reports (average 86%) (Figure 6).

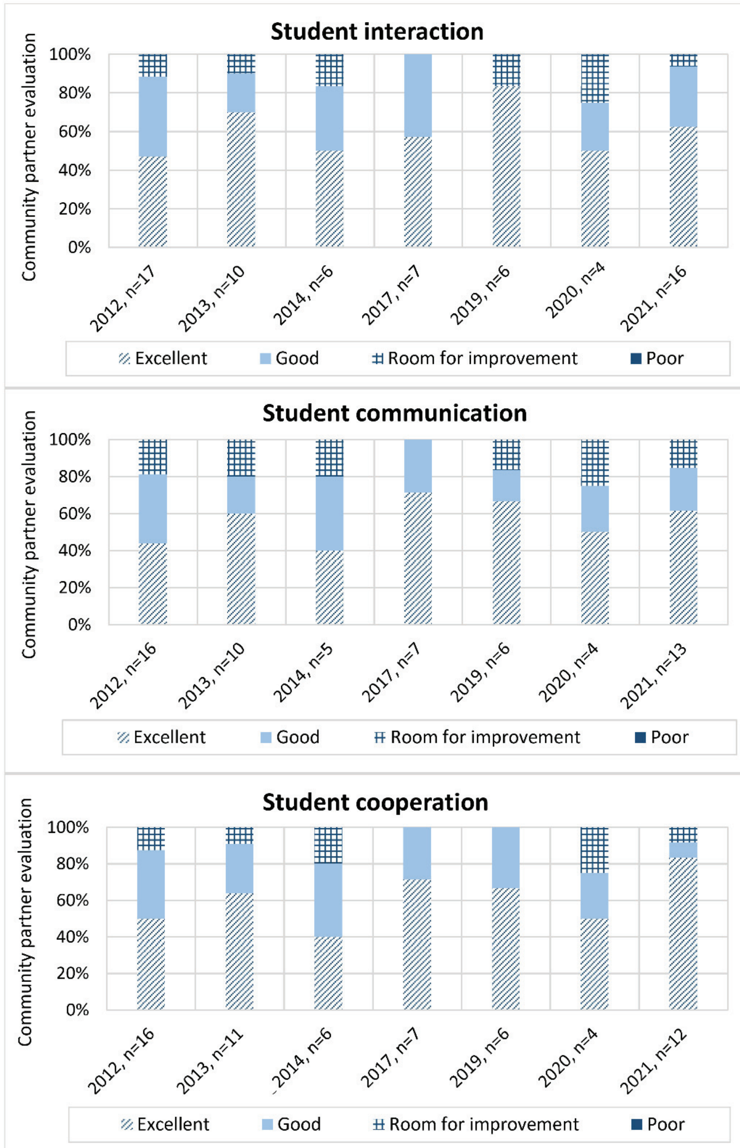

Figure 5. Evaluation by community partners of students' interactions, communication and cooperation.

In terms of the positive aspect of the project set-up, the community partners mentioned:

- 'In a time of economic hardship and challenging times for everyone, this [module] gives a great opportunity for students to get involved in real life projects that will make a difference to the service we provide' (community partner feedback, 2021).
- 'We now have concrete plans to develop our strategy. Being able to show stakeholders a building plan makes things very real, rather than just a concept. Given our limited budgets, we would not be this far advanced without your help' (community partner feedback, 2021).

- 'Fantastic to experience cross disciplinary work and I have the sense that the Engineering students benefitted from visiting and engaging with homeless services' (community partner feedback, 2014).
- 'Makes projects possible that could not be afforded otherwise' (community partner feedback, 2013).
- 'It's great that students can give something back to the community as part of their course, it's a boost for the project and vital real world learning experience for the students' (community partner feedback, 2012).
- 'It was rewarding to work with young people' (community partner feedback, 2012).

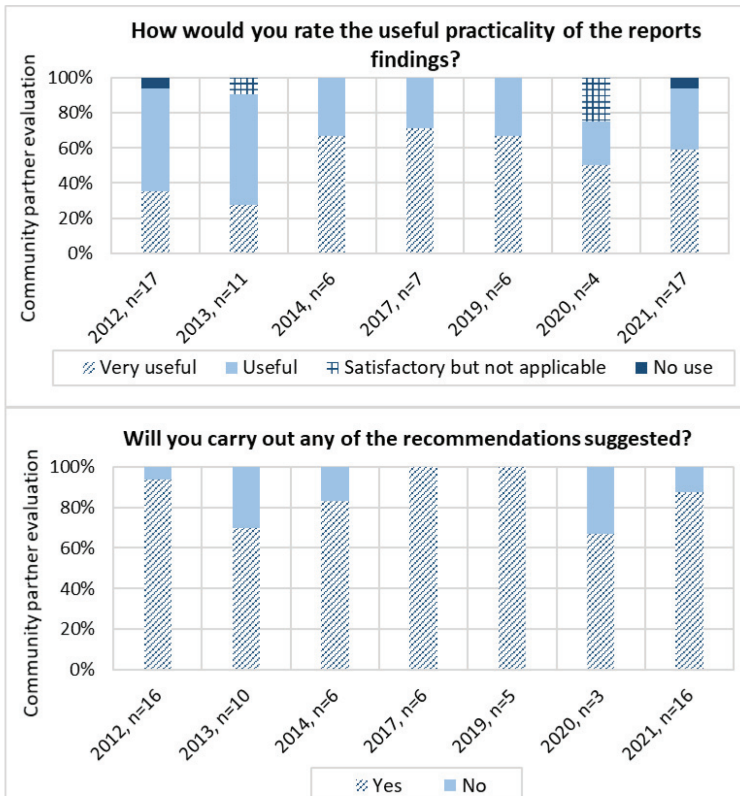

Figure 6. Evaluation by community partners of the usefulness of project reports.

When asked whether they would be interested in working with engineering students from the University of Galway again, as part of a community-engaged project, an average of 93% of community partners responded 'yes', while the remainder were undecided (Figure 7). No community partners claimed that they would not become involved in the projects again.

The community partners also made some suggestions for improvement, including extending the timeframe for the projects, incorporating the community-engaged projects into undergraduate and postgraduate research projects and disseminating and communicating the projects' results to the general public to show how engineering students contribute to the wider community.

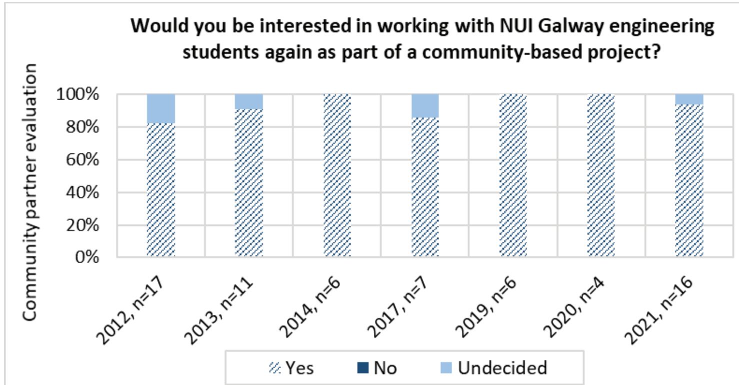

Figure 7. Community partners' interest in being involved in community-engaged projects again in the future.

3.3. Student Feedback

The feedback from the students was very important in the development of the community-engaged projects module in 2009 and has continued to help the module's improvement to date (e.g., inviting community partners to final presentations or increasing ECTS credits for the project from 2 ECTS to 5 ECTS).

In the first year (2009), the projects ran as a pilot, in which it was optional for the students to undertake a community engaged project. After analysing the feedback from the students, it was decided to make it mandatory for all the students in Civil Engineering and Project and Construction Management to complete a community-engaged project in the second year of their degree programme (Energy Systems Engineering students undertook the projects from 2011). In 2011, a grouped student evaluation was carried out, in which the students were asked to complete the survey in groups. Since 2012, the students have been asked to complete an online survey at the end of the module.

During the pilot run of the community-engaged projects, the students felt that they had received enough support from their lecturers and the community partners they worked with. Half of the students who completed the community-engaged projects felt that they had to spend more time working on their projects than if their project had not been community-engaged. It was apparent that the students who completed the community engaged projects were exposed to similar challenges to their professional counterparts. These included difficulties in organising meetings, learning to deal with deadlines and being responsible to clients (in this case, the community partners). It was interesting that feeling responsible to the community partner was described as negative by some students, since they felt under pressure and were forced to work harder in order to produce high-quality projects that met the needs of their community partners. It was, however, a valuable experience for the students for their future careers as engineers.

In the feedback surveys, the students described their experiences with community engaged-learning in the following terms:

- '[I feel I gained a lot] working as a team, looking into a project that we choose without much instruction' (student feedback, 2012).
- 'I feel that I gained more of a social experience from the project than engineering experience' (student feedback, 2012).
- '[I liked the] sense of freedom to an extent, chance to do meaningful work and explore an area of interest' (student feedback, 2019).
- 'I liked the hands-on nature of the project' (student feedback, 2019).
- 'I feel as if I have actually completed an engineering project that will be relevant to my future studies. The teamwork, engineering and presentation skills developed exceeded my expectations' (student feedback, 2019).

- 'I enjoyed getting a look at real world engineering practices. It was very beneficial to see how professionals operate in the real world (outside college). It was set up excellently; we had freedom to choose our own projects and had full control over the project. Letting us do the work ourselves allows both lecturers and community partners to see the quality of work which we are capable of doing' (student feedback, 2021).
- '[I gained] a real insight into the benefits by engaging with a community partner and working together to put a plan in place and execute it' (student feedback, 2021).

4. Discussion

Our society faces many challenges, such as poverty, inequality, climate and environmental degradation, lack of prosperity and insufficient peace and justice, which must be tackled at international, national and local levels to create a better and more sustainable future. Engineers play a significant role in tackling these challenges. Furthermore, considering climate change and biodiversity degradation, engineers are uniquely placed to utilise advanced methods and tools to reduce resource depletion by increasing the efficiency of infrastructure, products and systems during their full life cycle.

Engineering students are more motivated when they can see that their work has an impact on others [58,59]. Introducing community-engaged learning into an engineering degree programme is a very effective way to fulfil the Washington Accord programme requirement to provide a 'comprehension of the role of engineering in society and identified issues in engineering practice in the discipline: ethics and the professional responsibility of an engineer to public safety; the impacts of engineering activity: economic, social, cultural, environmental and sustainability' [35].

5. Conclusions

The evidence collected from 12 years of facilitating community-engaged building engineering projects has shown that, by creating community-engaged learning, students' enthusiasm can have a positive impact on communities. Students' energy and enthusiasm can be better utilised by setting assignments as real community projects. Through the projects discussed in this study, the students obtained a sense of pride and satisfaction from the knowledge that their work might have helped the communities. The projects increased the students' sense of ownership of their learning. Furthermore, the projects allowed the students to achieve all of the programme outcomes specified for an accredited engineering degree, while promoting the sustainability agenda at the same time. Finally, the students recognised the long-term value of engaging with community partners, understanding their future role as engineers, reinforcing the idea that their work responds directly to the real needs in the community.

Generally, the community partners found that their interactions and communication with the students was excellent. The technical reports delivered by the students were useful to the community partners, who were interested in carrying out the recommendations. Finally, the vast majority of the community partners were interested in being involved in the projects again in the future.

The qualitative feedback received over the past 12 years, from both the students and the community partners, was extremely valuable in shaping and improving these community-engaged engineering projects. The inclusion of feedback in the module's development led to tailor-made engagement between the lecturers, students and community partners, which enabled the education of engineers as change agents for a more sustainable future.

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Technological Innovation, Fiscal Decentralization, Green Development Efficiency: Based on Spatial Effect and Moderating Effect

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Abstract: Green development efficiency is an essential measure of China's economy turning into a stage of high-quality development in the new era. This paper establishes a spatial Durbin model based on the new geography economics. It empirically investigates the spatial effect of technological innovation on regional green development efficiency and the moderating effect of fiscal decentralization on the above mechanism using panel data of 29 provinces in China from 2010 to 2018. The results show that: from 2010 to 2018, both technological innovation and green development efficiency in Chinese provinces show significant spatial clustering effects; technological innovation not only has a significant role in promoting green development efficiency in the region but also leads to the improvement of green development efficiency in neighboring regions; and fiscal decentralization positively regulates the direct effect of technological innovation on green development efficiency in the region, and negatively regulates the spatial spillover effect of technological innovation on green development efficiency in neighboring regions.

Keywords: fiscal decentralization; technological innovation; green development efficiency; spatial effect; moderating effect

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1. Introduction

Since reform and opening up, China's industrialization and urbanization process has advanced rapidly, and China's economy has maintained a sustained and rapid growth, but the "high energy consumption, high emissions and high pollution" crude economic growth model has caused the growth of the total economic volume while consuming a large number of resources and causing serious resource and environmental problems, which has seriously restricted China's socio-economic high-quality development [1,2]. Compared with the traditional sloppy "black" development mode, green development promotes economic growth and environmental quality by improving energy utilization, reducing pollution emissions, and driving industrial transformation and upgrading, which is a "green" sustainable development mode. It has become an inevitable choice to escape from the dilemma of economic growth and ecological constraints and to achieve high-quality socio-economic development [3,4].

Green development emphasizes the coordination and unity of economic growth and environmental protection, and its focus is on the improvement of green development efficiency [4]. Green development efficiency is based on the efficiency of economic development, with more emphasis on resource input and environmental pollution, and is a crucial indicator of the level of regional green development [5]. Under the guidance of the new development concept, green development practices have been continuously promoted throughout China, but the overall level of green development in China still needs to be improved [6]. Therefore, exploring how to improve the efficiency of regional green development is a crucial step for China's economy to move towards the stage of high-quality development. Innovation is the primary driver of development, and regional governments are trying to break the "economic production at the expense of ecological governance" in the industrialization process through innovative behavior. Technological innovation, as the core of innovation-driven high-quality development, can not only improve economic growth performance [7–10] but also effectively enhance the level of regional green development efficiencies, such as reducing energy consumption intensity [11,12], improving energy efficiency [13], and realizing waste recycling and pollutant emission management [14], thus effectively reconciling the contradictions between economy, society, and environment. Therefore, technological innovation is an effective way to improve the efficiency level of regional green development [15,16]. However, the process of technological innovation is usually accompanied by high costs and risks. For example, knowledge creation spillover effects usually make technological innovation activities have positive externalities, and technological innovation results have specific public goods properties, making the market fail in allocating technological factors and assigning technological value to them, which means that technological innovation must rely more on appropriate subsidies and interventions from local governments to compensate for market failures through institutional reforms and optimization [17–20]. Generally speaking, the performance of local government responsibilities is mainly influenced by a fiscal system centered on fiscal decentralization, which directly affects the efficiency of the supply of innovative public goods and determines the effectiveness of government support for technological innovation activities [21]. Therefore, fiscal decentralization is highly likely to impact regional green development by affecting the level of technological innovation [22]. However, fiscal decentralization has two sides: it gives local governments relatively flexible spending power, and growth-incentivized local governments will support technological innovation to achieve economic growth; on the other hand, technological innovation outcomes are often characterized by long lead times, high risks, and uncertainty, and local governments may lack incentives to invest in technological innovation due to self-interested investment preferences [18]. Therefore, clarifying whether fiscal decentralization plays a facilitating or inhibiting role in the relationship between the impact of technological innovation on the efficiency of green development is of great practical significance in enhancing the essential pillar role of finance in national governance, improving technological innovation, reducing environmental pollution and achieving green economic development.

In summary, the main question we want to examine is, under the guidance of the new development concept, what should regions do to improve the efficiency of regional green development? Is technological innovation an effective way to improve the efficiency of regional green development? Does fiscal decentralization play a facilitating or inhibiting role in the relationship between the impact of technological innovation on regional green development efficiency? In order to address these questions, this study empirically investigates the spatial spillover effects of technological innovation on regional green development efficiency and the moderating effect of fiscal decentralization on the above mechanism by developing a spatial Durbin model. The second section of this paper presents a review of the relevant literature. The third section introduces the theoretical basis and research hypotheses. The fourth section introduces the model selection, indicator selection, and data sources. The fifth section presents the results of the empirical analysis, and the sixth section gives the conclusions and recommendations and presents the limitations of this study.

2. Literature Review

Many scholars have researched technological innovation, fiscal decentralization, and green development efficiency. This paper has combed through the relevant literature and found that most of the studies mainly focus on three aspects: (1) research on regional green development efficiency measurement. Scholars have mainly applied Data Envelopment Analysis (DEA) [23–25], the Slacks-Based Measure model (SBM model) [26–30], and the super-efficiency SBM model [4,5], which consider multiple inputs and outputs, to measure the green development efficiency of cities and provinces. Wu et al. constructed a DEA model to measure and analyze the green development efficiency of the Yangtze River Delta Urban Agglomerations and found that the green development gap between the three provinces and one city was narrowing year by year [23]; Zhou et al. measured the green development efficiency of Chinese cities based on the SBM model and found in their study that the green development of cities had a significant spillover effect [28]. In addition, since the DEA model does not take into account the slack variables, which may measure green development efficiency bias, and the SBM cannot rank multiple decision units with an efficiency value of 1, some scholars believe that it is more appropriate to use the super-efficient SBM model to measure green development efficiency [4,5]. (2) Regarding the research on the relationship between technological innovation and green development efficiency, there are two main opposing views: technological innovation can positively contribute to the efficiency of regional green development [3,16,30]. For example, Yuan et al. [3] combined the Directional Distance Function and SBM model to decompose the green development efficiency index into three parts: "change in technological innovation", "change in the technological gap", and "change in management efficiency". They found that technological innovation has a significant positive impact on green development through empirical analysis. Li et al. [2] used dynamic panel models and Systematic GMM methods. They found that energy-saving, emission reduction, and industrial upgrading effects were all effective transmission mechanisms for technological innovation to promote urban green development positively. The other view is that technological innovation may not be oriented towards green development and that there may be a 'rebound effect' [31,32]. In other words, technological innovation may stimulate economic growth and increase total energy demand, thus increasing resource consumption and pollution emissions in the production process, thus hindering the development of green transformation in the region. This "rebound effect" does not conflict with the energy-saving effect brought by technological innovation. Guo [33], when measuring the 'rebound effect' of energy consumption in China's industrial sector, points out that although the rebound effect of energy consumption in the industrial sector is much higher than that in developed countries, the overall improvement in energy efficiency in the industrial sector is still characterized by energy savings. (3) Regarding the relationship between fiscal decentralization and the efficiency of green development, scholars currently hold two main views: the theory of adverse effects. To achieve a GDP-focused promotion incentive assessment, local governments tend to focus more on short-term economic growth and neglect environmental management and resource conservation [17,34]. The fiscal decentralization systems induce the incentive for local governments to develop the economy at the expense of the environment, which will be detrimental to regional green development. Ran et al. [35] found through the spatial Durbin model that fiscal decentralization is not conducive to improving green development efficiency. Another view is the positive effect theory. For one, fiscal decentralization can improve the degrees of freedom of local governments in fiscal spending. For another, local governments can give full play to their information advantages and provide more appropriate innovative public goods and services according to local realities. These will be conducive to improving regional technological innovation and the efficiency of environmental governance. In addition, with the continuous socio-economic development, local governments have gradually changed from pursuing economic growth to pursuing synergistic development of economic growth and environmental protection, which further enhances the efficiency of regional green development [22,36]. Ren et al. [37] constructed a spatial econometric model with a panel data sample of 31 Chinese provinces from 2009–2018. They found a positive spatial spillover effect of fiscal decentralization on green economic development in the region.

Although the existing literature has laid a rich theoretical foundation for this study, there is still some room for expansion: firstly, the previous literature has mainly explored the impact of technological innovation on green development efficiency, the impact of fiscal decentralization on green development efficiency, and the impact of fiscal decentralization on technological innovation, and it is relatively rare to explore the impact of technological innovation on regional green development efficiency in the context of fiscal decentralization; secondly, there are few scholars who have taken the institutional factor of fiscal decentralization as a moderating variable from the perspective of spatial spillover to study the influencing relationship between technological innovation and regional green development efficiency, and only consider the direct effect and ignore the spatial correlation between regions, which may cause the bias of research results. According to Tobler's first law of geography: "Everything is related, and the closer things are, the stronger the correlation" [38]; the economic activities of a region not only affect the economic development of the region but also affect the economic development of the surrounding regions, i.e., presenting a spatial spillover effect. China's development varies greatly and unevenly between regions, and the level of green development in different regions may show spatial clustering due to differences in the level of technological innovation and government fiscal expenditure [28]. Therefore, while exploring the relationship between technological innovation and regional green development efficiency in fiscal decentralization, it is also necessary to consider the spatial correlation between the variables. This paper uses a spatial Durbin model based on panel data of 29 Chinese provinces from 2010 to 2018, with fiscal decentralization as the moderating variable, to explore the "local-neighborhood" relationship between technological innovation and the level of regional green development efficiency.

3. Theoretical Analysis and Research Hypotheses

3.1. Technological Innovation and Green Development Efficiency

Technological innovation promotes the green development of the regional economy mainly through two ways: (1) improving the efficiency of energy conservation and emission reduction and driving industrial transformation and upgrading. By optimizing traditional production processes, technologies, and operation modes, technological innovation can cultivate resource recycling technologies and production pollution control technologies, which are conducive to reducing pollutants, waste, and energy consumption emitted in the production process and improving the efficiency of resource and energy use, thereby effectively enhancing the efficiency level of regional green development. From the perspective of energy conservation, technological innovation can effectively reduce energy consumption while non-energy factors and output levels remain unchanged, thus significantly improving energy use efficiency and promoting green development. Wang et al. [39] argue that enterprises with high innovation capabilities can improve energy use efficiency by improving existing energy technologies or developing new energy technologies, thus promoting green development; Li et al. [2], in their study of the relationship between technological innovation, energy-saving and urban green development, point out that companies that favor technological innovation in energy technologies will spontaneously reduce their energy demand or find new alternative energy sources, thus reducing energy consumption and promoting urban green development. At the same time, it is essential to note that when energy efficiency is improved, technological innovation may also stimulate economic growth and lead to an increase in total energy demand [31,32]. In practice, however, this 'rebound' effect does not conflict with the energy-saving effect of technological innovation, as the improvement in energy efficiency in the industrial sector is still characterized by energy savings [33]. From the perspective of emission reduction, technological innovation can promote green development by improving energy consumption structure. According to Fan et al. [40], improvements in energy consumption structure are a direct determinant of reducing carbon emission intensity, which can effectively reduce pollutant emissions while playing a positive role in promoting urban green development. In addition, the use of technological innovation to restructure the energy industry, the innovative use of green energy materials, and the improvement of their efficiency can make energy production environmentally friendly and give energy companies a competitive advantage [41–43]. For example, Borowski's research [41] points out that by using green materials such as bamboo to produce energy through eco-innovation techniques, energy companies can not only improve their energy profile and reduce their dependence on non-renewable energy sources but also reduce their polluting emissions, thus achieving the goal of net-zero emissions. (2) Driving the transformation and upgrading of industries to "green." Technological innovation and its widespread application in social production are the technological basis for the green transformation of industries. Technological innovation promotes the development of traditional polluting industries into intelligent and green industries and helps to increase the proportion of low energy consumption, low pollution, and high value-added green industries in the industrial structure, and promotes the improvement of green development efficiency. Cha et al. [44] found that the optimization and upgrading of industrial structure can effectively improve carbon emission intensity, thus reducing overall pollution emissions and contributing to green economic development. In addition, everything is related, and the closer things are, the stronger the correlation. Technological innovation also has radiation diffusion and spatial spillover effects. For example, knowledge creation spillover effects usually make technological innovation activities, and technological innovation results have positive externalities. Based on the above analysis, this paper proposes Hypothesis 1 and Hypothesis 2:

Hypothesis 1. *From the direct effect, technological innovation in one region positively impacts the green development efficiency of the region.*

Hypothesis 2. *From the indirect effect, there is a positive spatial spillover effect of technological innovation in one region on the green development efficiency of neighboring regions.*

3.2. The Moderating Effect of Fiscal Decentralization

The fiscal decentralization system, which plays an essential function for local governments, plays an increasingly important role in innovation-driven development, and the constraints and incentives it constitutes have an essential impact on local technological innovation and green development [6]. In terms of incentives, as the pace of building an innovative country has accelerated in recent years, the central government has put forward some rigid requirements for local technological innovation, incorporating technological innovation performance into local government assessment indicators, so local governments are bound to promote economic growth through technological innovation in order to fulfil their assessment indicators, and local governments are more familiar with the development situation in their regions than the central government and are able to freely integrate resources within their jurisdictions according to the actual situation, making the allocation of resources in the innovation field more reasonable and effectively improving the efficiency of the use of resources, and ultimately realizing the growth of the local economy and the improvement of resource efficiency [17]. In their study on green R&D investment, fiscal decentralization, and regional carbon productivity, Li and Wang also point out that local governments with high fiscal decentralization also allocate sufficient funds to green R&D investment and environmental management for the sake of reputation evaluation [21]. Therefore, this paper argues that in the context of high fiscal decentralization, local governments will be more active in developing a green economy; in addition, when the degree of local fiscal decentralization increases, local government officials have the ability and incentive to pursue energy conservation, emission reduction, and industrial green transformation and development, and will set stricter local entry standards for enterprises, prompting enterprises in the region to move inefficient and energy-intensive production activities to neighboring regions. This phenomenon of "industrial relocation" will lead to an increase in pollutant emissions and a decrease in the efficiency of resource use in neighboring regions. At the same time, although the increase in local fiscal decentralization has led to increased support from local governments in the area of technological innovation, it will also lead to inter-regional competition for resources, making it more expensive for neighboring regions to obtain production resources, which is not conducive to green economic development in neighboring regions. Based on the above analysis, this paper proposes Hypothesis 3 and Hypothesis 4.

Hypothesis 3. *Fiscal decentralization positively moderates the direct effect of technological innovation on the efficiency of green development in adjacent areas.*

Hypothesis 4. *Fiscal decentralization negatively moderates the spatial spillover effects of technological innovation on the efficiency of green development in adjacent areas.*

4. Methodology and Materials

Previous studies have explored the relationship between technological innovation and green economic development, and fiscal decentralization and green economic development, respectively, from the perspective of spatial spillover effects. However, in the context of China's unique fiscal system, the relationship between the three is becoming closer and closer. It is vital to clarify the internal influence between the three. Therefore, to fully explore the impact of technological innovation on green economic development, this paper uses the moderated and spatial models to discuss the direct, indirect, and spatial spillover effects of technological innovation on green economic development and explores the critical role of fiscal decentralization. The specific research methods, index selection, data sources, and data processing methods are as follows.

4.1. Model Construction

According to Tobler [38]'s first law of geography, as mentioned earlier, the impact of technological innovation, fiscal decentralization, and green development efficiency may have spatial spillover effects. Hence, a spatial econometric model is necessary to analyze the impact of various variables on green development efficiency. By constructing a spatial econometric model, this paper explores the spatial correlation between technological innovation, fiscal decentralization, and regional green development efficiency. Elhorst [45] has proposed three types of spatial effect settings: spatial error model (SEM), spatial lag model (SLM), and spatial Durbin model (SDM). Among them, SLM refers to the inclusion of the spatial lag term of the explanatory variable in the general regression model, and SEM refers to the inclusion of the spatial lag term of the random error term in the general regression model. The SDM considers the spatial lag term of both the explanatory and explanatory variables and is the general form after combining SLM and SEM. Based on the research of Elhorst [45], this paper draws on the spatial panel model and constructs the SDM model as follows:

$$GDE_{it} = \alpha_0 + \rho WGDE_{it} + \beta_1 WTI_{it} + \beta_c WControl_{it} + \alpha_1 TI_{it} + \alpha_j WControl_{it} + u_i + \delta_t + \varepsilon_{it} \quad (1)$$

In Equation (1), $\mathrm{GDE_{it}}$ denotes the level of high-quality economic development in province *i* in period *t*, which indicates the level of digital economy development in province *i* in period t. The vector $Control_{it}$ denotes a set of control variables. u_i denotes the individual fixed effects of province *i* that do not vary over time, δ_t denotes the time-fixed effects, and ε_{it} denotes the random disturbance term.

In addition to the direct effect embodied in Equation (1), in order to further examine the moderating effect of fiscal decentralization on the relationship between technological innovation and green development efficiency, this paper constructs a model introducing the interaction term between fiscal decentralization and technological innovation based on model (2) above as follows:

$$\begin{aligned} GDE_{it} = \alpha_0 + \rho WGDE_{it} + \beta_1 WTI_{it} + \beta_2 WFD_{\ it} + \beta_3 W(TI * FD)_{\ it} + \beta_c WControl_{it} + \alpha_1 TI_{it} + \alpha_2 FD_{\ it} \\ + \alpha_3 (TI * FD)_{\ it} + \alpha_j WControl_{it} + u_i + \delta_t + \varepsilon_{it} \end{aligned} \quad (2)$$

In Equation (2), $FD_{\ it}$ denotes the level of fiscal decentralization in province *i* in period *t*, while $(TI * FD)_{\ it}$ denotes the cross-cutting items of fiscal decentralization and technological innovation in province *i* in period $t{\cdot}\rho$ denotes the spatial autocorrelation coefficient of green development efficiency, and when $\rho > 0$, it means that green development efficiency of neighboring regions shows spatial spillover effect; when $\rho < 0$, it means that there is a negative spatial effect between green development efficiency of neighboring regions. W denotes the spatial weight matrix.

The spatial weight matrix (W) is the key to performing the spatial correlation test. Due to space limitations, we chose a spatial distance matrix in this paper:

$$W_{ij} = \begin{cases} 1/d_{ij} \\ 0 \end{cases}, i \neq j \tag{3}$$

In Equation (3), d_{ij} denotes the linear distance between province i and the capital city of province j.

The empirical analysis in this paper needs to be conducted based on testing whether there is a spatial correlation between technological innovation and green development efficiency. Therefore, this paper uses the spatial auto-correlation index Moran's I index to test the regional correlation and spatial dependence of technological innovation and green development efficiency in 29 provinces in China from 2010 to 2018. The expression of Moran's I index is as follows:

$$\text{Moran's I} = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i - \overline{x})(x_j - \overline{x})}{S^2 \sum_{i=1}^{n}(x_i - \overline{x})^2} \tag{4}$$

In Equation (4), $\overline{x} = \frac{1}{n}\sum_{i=1}^{n}$, x_i and x_j denote the indicator values representing the provincial and provincial areas, n denotes the total number of provincial areas, and W_{ij} denotes the weight matrix, built based on different criteria, with a weight value of 1 if the two regions are adjacent or 0 if they are not.

$S^2 = \frac{\sum_{i=1}^{n}(x_i - x)^2}{n}$ denotes the sample variance. The value of Moran's I is between -1 and 1, which indicates a positive correlation of variables in adjacent regions when it is greater than 0, negative spatial correlation of variables when it is less than 0, and no spatial correlation between regions when it is equal to 0.

Unlike the classical regression model, the explanatory variables in the spatial Durbin model not only have a direct effect on the local green development efficiency but also have an indirect effect on the green development efficiency of adjacent regions. Therefore, a decomposition study of direct and indirect effects is needed. In this paper, drawing on the study of Pace and Lesage [46], the direct and indirect effects of the explanatory variables on green development efficiency in the spatial Durbin model are calculated through a partial differential approach as follows:

$$\left[\frac{\partial y}{\partial x_{1k}}, \frac{\partial y}{\partial x_{2k}}, \cdots, \frac{\partial y}{\partial x_{nk}}\right] = \begin{bmatrix} \frac{\partial y_1}{\partial x_{1k}} & \cdots & \frac{\partial y_1}{\partial x_{nk}} \\ \vdots & \vdots & \vdots \\ \frac{\partial y_n}{\partial x_{1k}} & \cdots & \frac{\partial y_n}{\partial x_{nk}} \end{bmatrix} = (I_n - \rho W)^{-1} \begin{bmatrix} \beta_k & w_{12}\theta_k & \cdots & w_{1n}\theta_k \\ w_{21}\theta_k & \beta_k & \cdots & w_{2n}\theta_k \\ \vdots & \vdots & \vdots & \vdots \\ w_{n1}\theta_k & w_{n2}\theta_k & \cdots & \beta_k \end{bmatrix} \tag{5}$$

In Equation (5), the mean of the diagonal elements' sum is the explanatory variable's direct effect on the explanatory variable. The mean of the sum of the non-diagonal elements is the indirect effect.

4.2. Measurement and Description of Variables

1. Explained variables: Green Development Efficiency

Green development efficiency is a measure of green development. The formula for measuring green development efficiency is shown below [2,47,48]. This paper uses the Super-SBM model containing non-desired outputs to construct evaluation indicators of green economic efficiency. Assuming K $(k = 1, \ldots, K)$ decision subjects, each using N $(n = 1, \ldots, N)$ inputs and producing M $(m = 1, \ldots, M)$ desired outputs and I $(i = 1,$

..., *I)* non-desired outputs with the jth in year t. The green economic efficiency (ρ_j^t) of the decision-maker is calculated as follows.

$$\rho_j^t = min\left[\frac{1-\frac{1}{N}\sum_{n=1}^{N}\frac{s_{nt}^x}{x_{nt}^j}}{1-\frac{1}{M+I}\left(\sum_{m=1}^{M}\frac{s_{mt}^y}{y_{mt}^j}+\sum_{i=1}^{I}\frac{s_{it}^b}{b_{it}^j}\right)}\right] \tag{6}$$

$$s.\ t.\ \sum_{k=1}^{K} z_k s_{nt}^m + s_{nt}^x = x_{nt}^j, n = 1, \ldots, N \tag{7}$$

$$\sum_{k=1}^{K} z_k y_{mt}^k - s_{mt}^y = y_{mt}^j, m = 1, \ldots, M \tag{8}$$

$$\sum_{k=1}^{K} z_k b_{it}^k + s_{it}^b = b_{it}^j, i = 1, \ldots, I \tag{9}$$

$$\sum_{k=1}^{K} z_k = 1 \tag{10}$$

$$z_k \geq 0,\ s_{nt}^x \geq 0,\ s_{mt}^y \geq 0,\ s_{it}^b \geq 0 \tag{11}$$

Green development efficiency reflects the input–output ratio in green development, which is the comprehensive utilization efficiency of the economy, resources, and ecological environment. It can represent the effectiveness of regional green development. In this paper, we adopt the Super-SBM model improved by Tone [49] and select provincial economic, environmental, and energy data to measure the green development efficiency of 29 provinces, setting capital stock, labor force and energy factor consumption as input variables, regional gross output value as desired output and industrial pollutant emission as the non-desired output. Among them, capital input is measured by capital stock, which is calculated by fixed asset formation according to the perpetual inventory method [50]. The depreciation rate is taken as 9.6%. The gross product of each province is obtained by deflating the actual value according to the consumer price index of each region, using 2010 as the base period. Table 1 shows the index system for measuring the efficiency of regional green development.

Table 1. Indicator system for measuring green development efficiency.

Indicators		Variables	Variable Definitions	Unit
Input indicators		Energy	Total energy consumption	per 10,000 tonnes of standard coal
		Labour	Number of people employed at the end of the year	per 10,000 people
		Capital	Capital stock	RMB per 100 million yuan
OutputsIndicators	Desired output	GDP	Real GDP	RMB per 100 million yuan
	Non-desired outputs	Environmental pollution	Industrial sulfur dioxide emissions	per million tons
			Industrial wastewater discharge	per 10,000 tons
			Industrial smoke (dust) emissions	per 10,000 tons

2. Explanatory variables: technological innovation

The core explanatory variable of this paper is technological innovation, which is measured by using R&D investment intensity by provinces and cities and is calculated by using R&D expenditure/GDP of industrial enterprises above the size of each province, drawing on Wu [51].

3. Moderating variables: fiscal decentralization

Government fiscal expenditure and its size are directly related to the level of science and technology and the degree of innovation and further influence the government functions in the regional innovation system. This paper draws on Qi Yu et al. [52] to measure fiscal decentralization using the ratio of provincial fiscal budget expenditures to major fiscal budget expenditures. The expression of fiscal decentralization is as follows:

$$FD = \frac{\text{Provincial fiscal budget expenditure}}{\text{Central fiscal budget expenditure}} \quad (12)$$

4. Control variables.

Considering that the efficiency of green development may also be affected by other variables, based on the existing literature, this paper adds gross domestic product per capita (GDP per capita), industrial structure level (IS), and energy consumption structure (ECS) as control variables in the above spatial econometric model, using the natural logarithm of real gross domestic product per capita, the ratio of secondary industry to GDP and coal consumption to total energy consumption, respectively.

4.3. Data Sources and Descriptive Statistics

In view of the continuity and availability of data, this paper is measured and analyzed with the panel data of 29 provinces in China's mainland from 2010 to 2018, except for Tibet and Hainan. The relevant data of the selected research variables are obtained from the China Statistical Yearbook, China Science and Technology Statistical Yearbook, China Energy Statistical Yearbook, China Industrial Statistical Yearbook, China Finance Yearbook, and the statistical yearbooks of each province in the relevant years. The descriptive statistical results of the relevant variables are shown in Table 2.

Table 2. Results of descriptive statistics for each variable.

Variable Name	Average Value	Standard Deviation	Maximum Value	Minimum Value	Number of Samples
Green Development Efficiency	0.8340	0.1443	1.2781	0.5241	261
Technological innovation	0.1624	0.1104	0.6170	0.0480	261
Financial decentralization	0.0280	0.0131	0.0740	0.0057	261
The logarithm of GDP per capita	2.4719	1.3318	6.6658	0.6915	261
Industrial structure	0.4911	0.0530	0.6148	0.3181	261
Energy consumption structure	4.1174	0.5029	5.0300	1.5900	261

5. Empirical Results of the Models

5.1. Analysis of Spatial Auto-Correlation Results

In this paper, the Moran's I indices of regional technological innovation and green development efficiency from 2010–2018 were calculated according to the above Moran's I index expressions, respectively. The results are shown in Table 3. As can be seen from Table 3, the Moran's I indices of technological innovation and green development efficiency from 2010–2018 are greater than zero and pass the 5% significance test, which indicates that technological innovation and green development efficiency have a significant positive spatial correlation in the spatial range and have a spatial agglomeration effect. Therefore, the spatial effect should be considered when constructing the impact model of technological innovation and green development efficiency to be consistent with the facts.

Table 3. Table of Moran's I indices of technological innovation and green development efficiency.

Variables	Year	2010	2011	2012	2013	2014	2015	2016	2017	2018
GDE	Moran's I	0.132	0.160	0.187	0.199	0.214	0.228	0.230	0.239	0.239
	Z-value	1.881	2.112	2.352	2.415	2.535	2.652	2.648	2.700	2.739
	p-value	0.030	0.017	0.009	0.008	0.006	0.004	0.004	0.003	0.003
TI	Moran's I	0.279	0.262	0.285	0.254	0.246	0.232	0.276	0.259	0.274
	Z-value	2.837	2.688	2.889	2.613	2.537	2.412	2.806	2.661	2.792
	p-value	0.002	0.004	0.002	0.004	0.006	0.008	0.003	0.004	0.003

5.2. Selection of Model and Estimation Methods

In order to correctly estimate the relationship between technological innovation, fiscal decentralization, and green development efficiency, this study needs to select the most appropriate spatial panel econometric model for parameter estimation. The specific selection process can be divided into two steps: (1) Using the LM test and robust LM test to judge the selection of SLM and SEM models, and if both are appropriate, the more general SDM model is introduced. (2) In order to judge whether the spatial Durbin model can be reduced to a spatial error model and a spatial lag model, it is estimated by LR test in this paper, and the results are shown in Table 4.

Table 4. LM, robust LM tests and likelihood ratio (LR) tests.

		LM Test		Robust LM Test		LR Test	
		Z-Value	***p*-Value**	**Z-Value**	***p*-Value**	**Z-Value**	***p*-Value**
Unregulated variables	SLM	7.417	0.006	10.885	0.001	25.670	0.000
	SEM	46.781	0.000	50.248	0.000	55.260	0.000
Adding moderating variables	SLM	92.204	0.000	2.713	0.100	29.460	0.000
	SEM	152.646	0.000	63.155	0.000	59.010	0.000

From the results of the LM test, robust LM test, and LR test in Table 4, it can be seen that the LM test and robust LM test of both SLM and SEM are significant at the 10% level when no moderating variables are added, which indicates that both control correlation terms and spatial error terms exist in the set models. Therefore, the SDM is the most appropriate model for estimating the relationship between technological innovation and green development efficiency. Therefore, the SDM is the most appropriate model to estimate the relationship between technological innovation and green development efficiency. In addition, the test results of this study with the addition of moderating variables are the same as above, so the SDM is also chosen in this paper to explore the effect of fiscal decentralization on the mechanism of technological innovation and green development efficiency.

5.3. Analysis of Regression Results

This paper regresses the model of technological innovation and green development efficiency to first explore the relationship between technological innovation and green development efficiency in the absence of moderating variables, and then introduces fiscal decentralization as a moderating variable to explore the impact of the interaction term between fiscal decentralization and technological innovation on green development efficiency. Before conducting the regression estimation, since it is necessary to determine whether to choose random effects or fixed effects as the basic model of this paper, the relationship between spatial effects and explanatory variables is analyzed by the Hausman test. The results show that the Hausman test is negative both when there are no moderating variables and when moderating variables are added, which indicates that the hypothesis that the disturbance term of the random effect is not correlated with the explanatory variables is not satisfied and the random effect is rejected, so the fixed effect model should be selected in both cases [53].

5.3.1. Technological Innovation and Green Development Efficiency

The regression results of the OLS model of technological innovation and green development efficiency and the regression results of the spatial Durbin model are shown in Table 5. As can be seen from Table 5: (1) The coefficient of W*GDE is significantly positive, which indicates that China's green development efficiency has a positive spatial spillover effect, and regions with high green development efficiency will lead to the improvement of green development efficiency in neighboring provinces. (2) The coefficient of technological innovation on green development efficiency is positive and significant at the 1% level, indicating that technological innovation has a significant role in promoting regional green development efficiency, which indicates that enhancing regional technological innovation capacity can improve energy use efficiency and pollution control capacity through intensive development and kinetic energy optimization, and finally improve regional green development efficiency. (3) Among the control variables, energy consumption structure (ECS) has a significant negative effect on green development efficiency. Thus, it can be seen that the coal-based energy consumption structure is detrimental to energy efficiency improvement and technological progress and brings about a sharp increase in pollutant emissions, which leads to the reduction in green development efficiency.

Table 5. Spatial Durbin model measurement results.

Variables	OLS	SDM
C	1.4322	0.48
TI	0.5701 ***	0.4862 ***
LnGDP per capita	−0.0245 ***	−0.0313 ***
IS	0.1225	−0.0877
ECS	−0.1679 ***	−0.1371 ***
W ∗ TI	–	0.3506 *
W ∗ LnGDP per capita	–	0.0102
W ∗ IS	–	0.1214
W ∗ ECS	–	−0.0302
W ∗ GDE	–	0.1299 *
R^2	0.6124	0.6984
log L	–	302.4783

Note: ***, **, * indicate the estimated coefficients are significant at the 1%, 5%, and 10% levels, respectively.

In order to further investigate the mechanism of action and spatial spillover effects between technological innovation and green development efficiency, this paper uses the spatial Durbin model and decomposes the spatial effects of the research subjects using the partial differential matrix method, and analyzes their direct, indirect and total effects. Table 6 shows the results of the decomposition of direct and indirect effects of the spatial Durbin model. From Table 6, it can be seen that the coefficients of both direct and indirect effects of technological innovation are significantly positive at the 1% level, which indicates that technological innovation can not only promote the green development efficiency of the region but also have a driving effect on the green development efficiency of neighboring regions. This phenomenon may arise due to the diffusion effect brought about by the improvement of technology level. The local production factors will spill over to the neighboring regions and have a radiating effect on the neighboring regions, which makes the neighboring regions continuously carry out technological innovation and optimize resource allocation to expand economic output, thus improving the green development efficiency of the neighboring regions, which is consistent with the conjecture of Hypothesis 1 and Hypothesis 2.

Table 6. Decomposition of effects for the spatial Durbin model.

Variables	Direct Effects	Indirect Effects	Total Effect
TI	0.5043 ***	0.4890 ***	0.9934 ***
LnGDP per capita	−0.0308 ***	0.0055	−0.2532
IS	−0.0879	0.1379	0.0499
ECS	−0.1385 ***	−0.6020 *	−0.19865 ***

Note: ***, **, * indicate the estimated coefficients are significant at the 1%, 5%, and 10% levels, respectively.

5.3.2. Relationship between Technological Innovation and Green Development Efficiency under Fiscal Decentralization

Table 7 shows the estimation results of the spatial Durbin model with fiscal decentralization as the moderating variable. It can be found that (1) the coefficient of the interaction term between technological innovation and fiscal decentralization is positive and significant at the 5% significance level, indicating that fiscal decentralization can significantly enhance the positive relationship between technological innovation and green development efficiency; (2) the coefficient of W*GDE is still significantly positive, which again proves that green development efficiency in China has a positive spatial spillover effect.

Table 7. Estimation results of the spatial Durbin model with fiscal decentralization as a moderating variable.

Variables	OLS	SDM
C	1.4089	–
TI	0.6388 ***	0.4982 ***
TI ∗ FD	−0.0213	0.3541 **
LnGDP per capita	−0.02727 ***	−0.3333 ***
IS	0.1159	−0.1145
ECS	−0.1621 ***	−0.4156 ***
W ∗ TI	–	0.2511
W ∗ TI ∗ FD	–	−1.0040 *
W ∗ LnGDP per capita	–	0.0241
W ∗ IS	–	−0.1974
W ∗ ECS	–	−0.0335 **
W ∗ GDE	–	0.1424 *
R^2	0.6207	0.6883
$\log L$	–	305.7194

Note: ***, **, * indicate the estimated coefficients are significant at the 1%, 5%, and 10% levels, respectively.

To further explore the moderating effect of fiscal decentralization, this paper decomposes it into direct and indirect effects, and the results are shown in Table 8. It can be found that: (1) the direct and indirect effects of technological innovation and green development efficiency are significantly positive at a 10% significance level. (2) The direct effect of the interaction term between fiscal decentralization and technological innovation is significantly positive, which indicates that fiscal decentralization can significantly enhance the role of intra-regional technological innovation in promoting regional green development efficiency. Therefore, Hypothesis 3 holds; that is, regional governments with high fiscal decentralization not only have more sufficient funds to support innovation development but also can freely integrate resources within their jurisdictions to improve technological innovation and energy utilization according to the actual situation, thus realizing the purpose of changing the local economic growth model and improving the regional environmental quality, and finally enhancing the efficiency of local green development. (3) The indirect effect of the interaction term between fiscal decentralization and technological innovation is significantly negative, indicating that fiscal decentralization has an inhibitory effect on local technological innovation leading to the improvement of green development efficiency in neighboring regions. It can be seen that Hypothesis 4 is valid; that is, higher local fiscal decentralization will lead to "industrial locational reset" and vicious competition for innovation resources, which will negatively impact the green development efficiency of neighboring regions.

Table 8. Direct and indirect effects of the spatial Durbin model with fiscal decentralization as a moderating variable.

Variables	Direct Effects	Indirect Effects	Total Effect
TI	0.5121 ***	0.3737 *	0.8858 ***
TI ∗ FD	0.3351 **	−0.4065 *	−0.0714
LnGDP per capita	−0.328 ***	0.02196	−0.0109
IS	−0.1118	−0.2420	−0.3538
ECS	−0.1369 ***	−0.0571	−0.1931 ***

Note: ***, **, * indicate the estimated coefficients are significant at the 1%, 5%, and 10% levels, respectively.

6. Conclusions and Policy Recommendations

This paper explores the relationship between fiscal decentralization, technological innovation, and green development efficiency by establishing a spatial Durbin model based on new geography economics. It is found that: (1) technological innovation and green development efficiency both show significant spatial agglomeration effects; technological innovation not only has a significant role in promoting green development efficiency in the region, but also leads to the improvement of green development efficiency in neighboring regions; (2) from the perspective of spatial spillover, this study investigates the regulation effect of fiscal decentralization on the relationship between technological innovation and green development efficiency, and finds that fiscal decentralization can positively moderate the effect of technological innovation on green development efficiency. (3) By studying the moderating effect of fiscal decentralization on the relationship between technological innovation and green development efficiency, this study finds that fiscal decentralization positively regulates the direct effect of technological innovation on green development efficiency in the region, while it negatively regulates the spatial spillover effect of technological innovation on green development efficiency in neighboring regions. Based on the above findings, this paper proposes the following countermeasures.

(1) In terms of technological innovation. ①Technological innovation is an effective driver of green development. In this regard, the government should establish and improve the innovation system, reduce the obstructive factors to enterprise innovation, increase the support to the innovation field, improve technology incubation, scientific and technological research and development and the market of technological achievements, and promote the economic structure to green and low-carbon development; meanwhile, the government should also formulate industrial policies to encourage innovation, drive the traditional polluting industries to intelligent and green development, and increase the share of low energy consumption, low pollution and high value-added green industries in the industry. At the same time, the government should also formulate industrial policies to encourage innovation and drive traditional polluting industries to develop in an intelligent and greenway, increase the proportion of low energy consumption, low pollution, and high value-added green industries in the industrial structure, and promote the efficiency of regional green development. ②In the process of implementing technological innovation to drive regional development efficiency, local governments should take into account the actual economic development status and innovation level of the region and implement differentiated policies. Suppose the eastern coastal region has a higher level of green development efficiency. In that case, the government should continuously stimulate the spillover effect of green development efficiency and improve the guiding demonstration role for the central and western regions. The central and western regions, on the other hand, need to strengthen the management mechanism of energy-intensive industries with low output, high energy consumption, and high pollution and also increase the support for technological innovation to promote the green transformation and upgrading of industries.

(2) In terms of fiscal decentralization, ① the fiscal decentralization system has a significant role in promoting the efficiency of green development. The central government should continue to decentralize part of its financial power, give localities a higher degree of financial autonomy, and make full use of the information advantages of local governments so as to optimize the efficiency of resource allocation. ②The central government needs to make appropriate adjustments to the performance appraisal methods of local governments in light of the actual situation. In the performance appraisal system of local governments, technological innovation and environmental quality should be added to the "GDP-only" appraisal method to motivate local governments to develop a green economy and technological innovation to promote the improvement of green development efficiency in China. ③ In order to reduce the negative impact of financial decentralization of neighboring regions on the green

development efficiency of the region, each region should take into full consideration its own resource advantages and endowments when formulating green development strategies, formulate policies suitable for the green development of the region in a targeted manner, promote the free circulation of green production factors among regions through fair competition and win–win cooperation among regions, and improve the level of technological innovation and green economic resource allocation to ensure the efficiency of the region. The green production factors are promoted to circulate freely among regions through reasonable competition and win–win cooperation among regions. The level of technological innovation and green economic resource allocation is improved to ensure the stability of green development in the region.

Green development efficiency also reflects the development of social systems. This study only considers the pursuit of economic benefits and environmental pollution control from two perspectives, ignoring that human social activities also generate social benefits and pollutants. In subsequent studies, the influence of social factors can be taken into account in the evaluation of green development efficiency by considering breaking the traditional "black box" model and dividing the provincial green development efficiency evaluation system into a two-stage, three-system network structure, and separat ely considering the green development efficiency of the economic and social benefit subsystems, so that the real root causes of inefficient green development can be found and have stronger practicality.

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