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Enhancing Transformative Learning and Innovation Skills Using Remote Learning for Sustainable Architecture Design

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Abstract: The currently used educational technology with artificial-intelligence-powered solutions, although rather instrumental, may lead to discontinuity in learning, as it lacks social and emotional value, which is an essential part of education for sustainable development and results in an immersive experience through which higher-order thinking skills can be adopted. This paper aims to explore transformative learning (TL) and innovation skill improvement accommodated by transactional distance theory in a 16-week remote sustainable architecture design course. The analysis identified the following: (a) significant progress in students' attitudes toward uncertainty and criticality while social support differs due to the influence of classmates, faculty staff, teamwork, writing and reading assignments, promoters from industry and extracurricular activities; (b) significant progress in TL achievement while innovation skill development differs significantly across the groups in which online collaborative learning was found as an influencer in creativity and motivation; (c) self-efficacy influenced by feedback in and on actions, such as essay and other writing assignments, verbal persuasions and positive social comparisons; (d) lack of development of situational awareness, continuity of learning and interactions/situations to empower teammates in handling conflicts to develop leadership ability; (e) decrease in risk-taking ability, especially in a group of students in which social support was limited due to the absence of challenging situations and tasks. The results support the use of remote intervention directed at prosocial motivations and action-focused group goals.

Keywords: remote learning; transactional distance theory; constructivist and critical pedagogy; sustainable architecture design; transformative learning; innovation skills

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1. Introduction

Nowadays, we are witnessing extreme digital transformation enabled by artificial intelligence in different sectors, such as the economy, production, education and society as a whole, in which interest in social innovations and the need to develop life competencies has increased markedly [1]; this has been further heightened by the COVID-19 pandemic of the last two years. In education, despite several incentives and projects designed in recent years to increase the effectiveness of information communication technology (ICT), the use of ICT [2] via different educational platforms and tools as the only possible solution for delivering lectures and organising courses has been rather forced and intuitive [3]. Thus, instead of adopting higher-order thinking skills that can be earned through immersive experiential learning such as creativity, reflection and critique, leadership, risk-taking skills, problem-posing and problem-solving skills and decision-making, educators and learners have instead indulged in the thrill of facilitated technology, as argued by Zhang and Zeng [4]. ICT used in such a situation has redefined the concept of learning, simplified the forms of learning and weakened the connotations of learning to better accommodate the educational technology revolution theory [4–6]. Many interventions designed to balance and focus ICT use are ineffective because they fail to inspire and empower individuals

to engage in pro-environmental behaviour (natural, economic and social environment included) and interact meaningfully with ICT [2,4,7,8]. Consequently, some bias might occur when student tasks and assignments are misinterpreted and, in turn, misevaluated. Thus, context-based negotiations of the use of ICT were omitted, which might call into question and lead to the rethinking of the entire concept of education for sustainable development (ESD) in an innovation-driven and knowledge-based economy [9], as defined by the United Nations (UN) [10].

The sudden pandemic has disrupted the rhythm of educational institutions around the world, bringing unprecedented challenges to teachers, students and managers who were used to face-to-face teaching models [4]. Education and training entirely shifted to the remote mode in which the different types of ICT were utilised for delivering courses. This task was not easy, as educational institutions had to face many ICT- and human-related challenges [3]. In order to exploit the potential of ICT, higher education institutions have redesigned existing teaching and learning methods in the direction of ICT-supported distance learning. Several institutions faced a dilemma over whether to retain or challenge the status quo in remote education settings. Moreover, the question of whether the hastily adopted ICT in remote settings can cover a wide range in terms of education is still unanswered. Thus, both the development of transformative competencies as defined by OECD [11] and the achievement of sustainable development goals (SDGs), as defined by the 2030 Agenda of the United Nations [10], have been put in jeopardy. The main challenge for several educational institutions is accomplishing a more integrated ICT-enhanced approach to sustainable development that encompasses new governance frameworks for enabling and managing systemic and social transformations [12,13] in which both sustainability and education are challenging process-oriented objectives [14,15]. Moreover, higher education institutions are investing much effort and money into enhancing personalised support for their students through artificial intelligence tools integrated into the training methods [2,16], which can also enable effective deployment of human-embodied capacity such as foresight, intuitive cognition, creativity, rationality and irrationality, empowerment, risk-taking, leadership, self-efficacy and self-awareness [4].

A need for holistic and transformational education that addresses sustainable development learning content, process and outcomes, pedagogy and learning environment for transforming society has also been noted in architecture education [17]. Students, more than ever, must have a higher level of transformative competencies to make informed decisions and responsible actions for environmental integrity and economic viability and to reconcile tensions and dilemmas in professional development for the good of society [17]. Meanwhile, personal, transformative changes occurring in participants as a result of their involvement in socially innovative interdisciplinary programs are often the most meaningful and powerful impact of innovation skills improvement, especially for social innovation [1]. Since skill development can be considered the most important factor in a knowledge-based economy-empowered nation [9], transformation for innovation competence development can be viewed through perspectives such as consciousness-raising, critical reflection, personal growth and individuation, which involves the discovery of new talents, a sense of empowerment and confidence, a deeper understanding of one's inner self and a greater sense of self-responsibility [1]. Therefore, exploring ways to systematically improve TL can be a rather straightforward and arguably more fruitful avenue to improve ICT-enhanced ESD, including the development of higher-order thinking skills.

1.1. ICT-Enhanced Teaching and Learning and Transactional Distance

When ICT-enhanced teaching and learning are done correctly, paired well with learning materials and methods, it has the potential to engage learners at multiple points through different strategies and should offer much flexibility, choice and assessments [16]. It seems that ICT-enhanced teaching and learning have been prioritised in the educational agenda and have become a common practice in higher education [18]. As argued by Zhang and Zeng [4], ICT always influences higher-order thinking through people and is

framed within a human–ICT structure [14]. Thus, for effective ICT-enhanced education, students need technical, communicative, socioemotional and cognitive competence, which enables them to negotiate and compromise on alternative ideas on how and what to learn and do [14,16,19,20].

ICT in education should not be seen as a factor that can independently make the change because, in the absence of knowledge, concepts and skills, ICT remains unused or misused [13]. Especially in distance education settings, pedagogy might play a crucial role and not the physical or temporal distances that separate students [15]. In those circumstances, the actual guiding principle and influential concept is transactional distance (TD), one of the major theories underlying distance teaching and learning [21]. As Moore [21] claimed, TD is a specific and relative concept, which can serve as an attribute of learning environments and be measured in various kinds of teaching-learning environments for comparing between such environments. TD is not an abstract understanding of distance but a specific, subjective, and personal distance, a byproduct of the explaining activity that takes place during the teaching-learning process [7] (p. 2). Literature also suggests that students trying to understand the learning material are influenced by the teaching activity [7,14,22]. Their effort, if unsuccessful, makes them feel a subjective distance, also perceived as a lack of mutual understanding or shared perception of ideas, feelings or situations [7,14].

Literature suggests [14,21,23,24] that TD is influenced by three interrelated factors: the structure of the program, the dialogue that exists between the teacher and the learner (and increasingly between learners) and the level of autonomy of the individual learner. These should be considered when designing both remote TL [16] and skill development [18] for turning the potential SDGs into reality. Social influence was recognised as a positive predictor in peer-learning, social learning and students' informal activity to support each other, but when interacting with ICT, privacy concerns and dysfunctional system performance have been connected with low trust, as argued by Raffaghelli et al. [25]. Thus, the type of dialogue that can occur in remote learning largely depends on the ICT type and method of use, as claimed by Moore [23]. To reduce TD, course designers must provide a flexible structure, which can be responsive to the learning needs of students [24]. When this is not possible, and dialogue is limited, the learner must exercise more autonomy [23]. Thus, a different self-regulation ability can manage reactions and behaviour towards different outcomes in remote learning success or failure [16]. It could be that online learners in the early years of a degree programme demonstrate low levels of autonomy and thus require, at a minimum, high levels of structure to limit TD, which should be considered at the time of course design. In this, students should be encouraged to engage in high levels of dialogue to support their learning and skill acquisition [24]. This can be easily addressed with a small group of students in a virtual classroom or design studio, while for larger groups and massive open online courses, some kind of blend is needed and not particularly to support each student [14,24,26]. Only by focusing on the experience of the object rather than indulging in the paradigm of ICT can learners successfully combine the knowledge and skills related to sustainable development [4] using TL theory [27].

1.2. Transformative Learning and Innovation Competence

Developing TL experience and improving innovation skills using online remote learning are difficult and complex tasks because innovative educational technologies might generate unreal expectations when supporting online learning [2,4,5,17,25]. More likely, rather than learning, a discontinuity in learning might occur, and learners may become lost and disoriented [28]. On the other hand, immersive experiences leading to the possibility of the irritation of doubt are necessary for changing our beliefs, as also argued by Zhang and Zeng [4] and English [28]. Moreover, complexity seeks to create learning activities that allow effective behaviour to emerge and evolve and ineffective ideas to be extinguished [14].

According to Mezirow [29], TL theory explores how individuals understand existing frames of reference and change their beliefs, and as it embodies Dewey's vision of active learning and pragmatism, it provides experiences that inspire critical thinking.

Thus, constructivist pedagogy is promoted through active student-centred experiential learning supported by the critical pedagogy of Freire [30]. Critical pedagogy seeks to rebalance the power between the student and teacher in the learning process towards one that is mutual and transformational [14,30], and it fits well with the TD theory where a learner's autonomy and teacher–student dialogue can be designed [7,14]. Moreover, when learning activities in architecture education are designed to promote extrarational processes (arts-based, dialogue, emotional and spiritual) and social critique processes (ideology critique, empowerment and unveiling oppression) as well, learners will more likely achieve TL outcomes, such as acting differently and having deeper self-awareness and open perspectives [2,19,27,31]. Thus, TL supported by critical pedagogy, constructivism and complexity theory involves a problem-posing and problem-solving paradigm that requires students to immerse themselves in the problem, critically appraise reality and propose interventions that promote social change [14,31]. This social change can be implemented in architecture education through design-based activities and socially innovative actions [1,32,33]. As such, constructive, aligned teaching can promote students' deep approach to learning, which is more likely to enhance deep understanding and lead to higher quality learning outcomes [34]. The course designer must carefully design learning outcomes, teaching-learning activities and assessment tasks [34], while the use of ICT must be purposive and aligned with the TD approach in which individual-oriented and socially shared metacognitive regulation during both asynchronous/synchronous ICT-supported collaborative learning must be enabled [14,16].

Much more than before, students' innovation competence should be well developed, as it is required in higher education to benefit learning, cope with current real-life problems and make a social impact [1,35–38]. To foster skill development outcomes, Romiszowski [39] proposed a theory that can also be applied in innovation skills improvement. The theory suggests that the innovation skill cycle involves more open responses in that environmental stimuli affect the decision-making and behaviour of the learner/performer [39]. Romiszowski [39] proposed several instructional design techniques for skill development, which were further integrated into our remote and online architecture design studio. Moreover, these techniques depend on situational characteristics, such as imparting essential information, providing practice, giving feedback and promoting transfer. As Romizowski [39] devoted more attention to the learner's inner self (the personality: intellect, feelings, beliefs and past experiences), which might have impacted the execution of the task, some gaps exist on how to elicit a learner's existing knowledge and how to address the level of skill, especially in a remote learning environment. Thus, Shawcross and Ridgman [40] argued that innovation skills and innovation capacity could be cultivated when course designers include the following in their courses: designing simulated relevant and authentic experiences, facilitating mastery and vicarious experiences, solving ambiguous problems and providing timely reflection tasks. These should take place in the learning environment or any place where learning occurs, including virtual and non-traditional spaces [14,36]. Moreover, Ovbiagbonhia et al. [36] identified several characteristics of constructivist learning environments that are relevant for promoting innovation competence, such as personal relevance, uncertainty and student negotiation. These characteristics can be used in designing remote online courses in which interactions can be defined by Bandura's social cognitive theory [41], which states that a well-designed online course should provide an active learning environment in which students are highly engaged in the learning process through interactions with peers, instructors and content [42]. Anderson [43] also suggested that meaningful learning can occur when at least one of the three forms of interaction is present at a high level, e.g., student–student, student–instructor and student–content, either asynchronously or synchronously. Thus, for effective learning and skills acquisition, students need integration into formal (academic performance) and informal (faculty/staff interactions) academic systems and formal (extracurricular activities) and informal (peer-group) social systems, as explained in Tinto's [44] social integration theory.

To focus on innovation skills, we must extract these skills from the wider contexts of innovation competence, which is understood as a synonym for a set of personal characteristics, knowledge, skills (or abilities) and attitudes that are connected to creating concretised and implemented novelties via collaboration in complex innovation processes [35]. Recently, Ovbiagbonhia et al. [36] identified in their literature review six interrelated components of innovation competence, which can be addressed in higher education: creativity, leadership, creative self-efficacy, energy, risk propensity and ambiguous problem-solving. Conversely, Hero et al. [35] provided a very extensive description for higher education students, including all the aforementioned, in which additional content knowledge, design thinking skills, psychomotor skills and social skills receive special attention [35]. Thus, any learning process, either face-to-face or distance, can be organised to address competency gaps concerning the desired problem-solving and future-oriented, innovative solutions [35].

1.3. Research Objectives

In this paper, we argue that using TD theory to design an online architecture design studio course, a TL towards SDGs occurs together with innovation skills development and that such development is best understood holistically as both an outcome and the process. Furthermore, we use TL theory to explore the TL process and outcomes in the architecture design studio and innovation competence. We aim to find new approaches to understanding the impact of TL, and we are also mindful that design-based online practices and meaningful interaction with ICT have different needs regarding impact assessment that must be addressed in this work.

Building upon the reviewed literature, this study was designed to answer the following research questions (RQs):

RQ1: What are students' perceptions of and experiences with the two different implications of the remote learning architecture design studio with respect to TL?

RQ2: Which factor influencing learning and development at the remote learning architecture design studio has a significant impact in enhancing TL?

RQ3: What are students' perceptions of and experiences with the two different implications of the remote learning architecture design studio with respect to innovation skills development?

RQ4: Which factor influencing learning and development at the remote learning architecture design studio has a significant impact on innovation skills development?

RQ5: What is the association between students' self-reported TL and the student's perception of their own innovation competence?

2. Materials and Methods

2.1. Research Design

This study used a quantitative research approach with a quasi-experimental pretest–posttest research design. This type of research design is most often utilised by behavioural researchers to determine the effect of a treatment or intervention on a given sample [45]. In pretest–posttest research designs, the effect of a treatment is determined by calculating the difference between the first assessment of the dependent variables and the second assessment of the dependent variables [45] using two questionnaires (Q1 and Q2). A visual representation of the research design used for this study is shown in Table 1. A remote conference platform, Zoom, was used.

Table 1. A visual representation of a quasi-experimental pretest–posttest research design.

Academic Year	Winter Semester	Survey (Q1, Q2)	Summer Semester	Survey (Q1, Q2)
2020/21	Intervention: No sustainable design principles applied to architecture design Task 1 and Task 2	Ex-post evaluation of winter semester intervention	Intervention: Sustainable design principles applied to architecture design Task 3 and Task 4	Ex-post evaluation of summer semester intervention
Modality	Online	Online	Online	Online
Form	Synchronous/Asynchronous	Synchronous	Synchro-nous/Asynchronous	Synchronous
Duration	120/120 periods *	30 min	120/120 periods *	30 min

* 1 class period is 45 min.

2.2. Online Teaching and Learning Context

Online teaching and learning were used in both experimental and reference groups for both semesters due to the restrictions imposed for the COVID-19 pandemic. We estimate that the proportion of synchronous learning was similar for all and that the teachers who delivered the online courses had varying levels of ICT skills and had taught entirely online since the pandemic outbreak in March 2020. Students were made to actively engage in all four tasks to achieve the learning objectives set by course designers. The course designers carefully followed the syllabus for an architectural design course, paying particular attention to the course characteristics taken from the official syllabus (Table 2) [46].

Table 2. Basic aims and goals of curriculum, learning outcomes and teaching and learning methods of the architecture design studio.

Aims and Goals of Curriculum	Learning Outcomes	Teaching and Learning Methods
Mastering the knowledge on the application of theory in design practice. Acquiring the ability to prepare a functional and spatial concept of a simple design task.	Knowledge: Knowledge of the application of theory in design practice (content knowledge, pedagogical content knowledge, technological knowledge). Skills: Ability to prepare a conceptual architectural and urban project of a small degree of complexity (personal characteristics, future orientation, creative thinking, project management, design thinking, critical thinking).	Design-based learning, inquiry-based learning, problem-based learning, experiential learning, discussion, work in groups, ICT-supported teaching/learning and presentations, consultation/discussion with tutor, reviews, test, reflective writings.
Acquiring the ability to prepare a project presentation using various tools, in the form of drawings, models and descriptions.	Skills: Ability to present a conceptual architectural and urban design by means of various tools (cognitive skills, ICT literacy skills).	
Begin acquiring project defence skills and participating in discussions.	Social competencies: The basic ability to defend the adopted project assumptions and participate in the discussion and teamwork (collaboration, networking and communication skills, social responsibility, having a deeper self-awareness, acting differently, having more open perspectives, experiencing a deep shift in worldview).	

In the first semester of remote education, the course designers carefully designed the tasks for the student (Table 3).

Table 3. Description of the architecture design studio Tasks 1 and 2 in the winter semester of academic year 2020/21.

Task 1: Form	**Task 2: Urban Composition**
Objectives: To teach students about the issues of shaping and the form of the spatial composition with reference to the human scale and the method of presenting the project in the form of a model and drawings. Individual study. Students chose to work on one of the two subjects mentioned below.	Objectives: To present the issues of spatial composition of an urban interior, correct use of "street furniture", material and texture choice, relationship between architecture and nature and functional and social meaning of public spaces in the city space. Teamwork.
Subject nb 1 of the task: The theme of the design task is the spatial composition in the urban interior, performing a function defined by the author, related to the human scale, linked to the base and constituting a symbol the hallmark of this place. Material: An area with dimensions that allow composing the whole project—the urban space floor or a fragment of the natural ground, which is an element of the composition, a rectangular plane in the initial form, dimensions: 6.0 m × 12.0 m, and an additional linear element/bar that can be repeated. Conditions: The ground should be shaped as an integral part of the composition; the plane can be shaped in various ways by cutting, incising, bending and perforating. If it is cut, all its elements must be used in the composition. After all changes, it must remain a noticeable plane structure; an additional linear element can be multiplied. It can also change its length proportionally; the texture can be varied both on the floor and on the surface, and an additional element of up to three colours can be used in the entire composition.	Subject of the task: The subject of the design task is the arrangement of a multifunctional urban interior as an example of a public space with a dominant pedestrian function supporting the function of neighbourly areas. There are three locations to choose from. All of them are based in Kraków in Kazimierz district: Nowy Square, Wolnica Square and Szeroka street/square. Part I of Task 2—Urban analysis A team of 2–3 students performs a joint task and presents results. Team works out the following: Urban analysis for the selected site with the conclusions, including functional analysis, compositional analysis, physiognomic analysis and the design guidelines for the area of elaboration. At least one representative from each team should visit the site and analyse it in situ. The process of analysis should be summarised, indicating the advantages and disadvantages and strengths and weaknesses of the site and the guidelines for further design work. The team presents the conclusion at the review and includes a brief of all the analyses completed in the final description of the project.
Subject nb 2 of the task: The theme of the design task is a spatial composition coexisting with the environment, adjusted to the human scale. The place where the composition will appear, the work of art that will be an inspiration for the project and principles of the transformation of the work of art must be specified by the student. Material: An area with dimensions that allow composing the whole project—the urban space floor or a fragment of the natural ground, which is an element of the composition; it is possible to use different materials with different textures. The dimensions should be adapted to the size of the ground. Conditions: The ground should be shaped as an integral part of the composition; the texture and colour of both the floor and other elements can vary.	Part II of Task 2—Project A team of 2–3 students performs the program-spatial concept of the selected site. The aim of the project: to formulate design assumptions, characterise the users, define the functional program and propose a clear compositional-functional concept for the selected urban interior.

In the second semester of the academic year 2020/21, students continued with the architecture design studio. This time, they worked on sustainable architecture principles included in the design project, using remote online learning (Table 4). Students used the AutoCAD and ArchiCAD software to develop and create designs and accomplish tasks. As a motivational aspect, different artworks were used, e.g., Klimt's Kiss and Korovin's A Sun-Drenched Garden (see Figures A3 and A4, respectively) [47], together with the real-life social component of the placement of the pavilion. These motivational means were chosen by each student independently according to their preferences, personal learning goal orientation and action-focused group goals when working in teams.

Table 4. Description of the sustainable architecture design studio Tasks 3 and 4 in the summer semester of the academic year 2020/21.

Task 3: Multifunctional Pavilion	**Task 4: Interior Design of the Pavilion**
Objectives: Introduction of the relations between architecture and nature, based on the principles of sustainable design. Individual study.	Objectives: Introduction to the interior design—proper functional arrangement, to teach the principles of architectural and aesthetical composition useful to achieve a specific character of the interior, to emphasise the relationship between theory and practice by using high-quality, contemporary design products available on the market to design unique space, to study and search for elements of the composition in line with modern technologies and leading trends and to teach the practical application of interior equipment.
Subject of the task: The subject of the design task is to design a pavilion-exhibition gallery/meeting space/working space in a particular landscape (on the square designed in Task 2) in a way that shows the relationship between architecture and nature using some elements of sustainable design. The pavilion should be at least two-level, adapted for people with disabilities (easy access to the ground floor and toilet for people with disabilities) and provide an area of 200–400 square meters. Students should specify the main function of the pavilion, the relationship between architecture and nature and/or the general environment and sustainable design principles applied in the design.	Subject of the task: The subject of the design task is to design the spatial and functional arrangement of the chosen part of the interior design of the pavilion (designed in Task 3) with particular emphasis on natural light. The interior function should be focused on exhibition and information and should activate the space surrounding the pavilion. The individual study terminated with a student competition at the end of the semester. In the appendices, some of the final students' projects are shown, namely in Figure A3, done by a domestic student and Figure A4, by an international student (Appendix A) [47].
Requirements of the design: to design the multifunctional pavilion on the urban square designed in Task 2 in the Kazimierz district in Kraków; compulsory program: reception/information desk + social space for the employees with toilet, coffee bar, toilets for users, technical rooms, at least three elements of sustainable design, at least two levels (underground + ground floor or ground floor + mezzanine or two floors) and between 200–400 square meters of area. In the appendices, some of the final students' projects are shown, namely in Figure A1, done by a domestic student and Figure A2, done by an international student (Appendix A).	Requirements for the design: to suggest interesting spatial arrangement; in case of each topic, pay special attention to the following aspects: correctness of the functional solutions, appropriate surface of the areas, size and dimensions of passages, distribution of sanitary equipment and furniture, proper placement of the ventilation and installation divisions, relations between interior and exterior space, the role of elements of the interior equipment, its lighting solutions and natural light availability, use of solutions proposed by sponsoring companies (furniture from Vitra offer, elements of glass walls, architectural glass from AGC offer and Rigips plasterboard walls/ceilings) and design of space inspired by art—to be inspired by a work of art.

Task 3 and Task 4 specifically targeted the development of innovation skills, which are well represented in Table 2 as key learning outcomes of the architecture studio curriculum designers. Innovation, as defined by Amabile [37] and Sawyer [38], requires new and creative ideas that can be produced and implemented in practice to reach an outcome [36]. Innovation skills improvement, whose process is often systematically organised as cross-disciplinary teamwork, and the personal characteristics of participants are arguably crucial [35,36]. Since innovation skills are an integrative part of the broader innovation competency, which is the ability to develop creative ideas that can be successfully implemented as products, services, processes, theories and strategies that are useful or meaningful to the intended audience [48], they, along with knowledge and attitudes, shape an innovative individual. Innovative students can be viewed as individuals who exhibit high levels of creative and leadership skills, persistence and task motivation, creative self-efficacy, a willingness to take calculated risks and a preference for working on ambiguous and complex architectural problems [36,49,50].

To develop innovation skills, we used design-based learning as a general pedagogical approach along with some other approaches (e.g., inquiry-based learning, problem solving, etc.). To engage in innovation, students were encouraged to pay attention to their thoughts, feelings and experiences while investigating a design task (multifunctional pavil-

ion and its interior design). The whole design process was embedded in three dimensions: empathy (user experience design), creativity (creative thinking techniques) and constraints (material used, dimensions, sustainable principles), which can also promote innovation learning. To develop students' creative potential and creative self-efficacy, different creative thinking techniques were used (e.g., SCAMPER, Synectic as direct and symbolic analogies, morphological matrix, etc.). Students created several conceptual variants, reflected on them, learned from the concepts and repeated design thinking to improve them (optimisation, rationalisation).

To transform creative ideas into strategies, capabilities, products and services, skills (ICT and digital skills, life cycle management skills, creative thinking skills, product manufacturing skills) were used as an important part of innovation capabilities together with attitudes towards technology and the environment (natural, economic and social) and their proactive behaviour. In order to develop self-efficacy as a very important innovation skill, students were also highly motivated with the help of some art-based motifs and the targeted use of ICT. They were encouraged by teachers, peers, job scouts and guest speakers by engaging students with structured, guided and open-ended inquiry at solution-driven designs that gave students enough freedom to work on the task. Students were guided to engage in self-regulated learning as they completed their tasks or assignments. Students used taxonomically selected ICT for problem solving or seeking and on specific levels of the SAMR model (modification and redefinition), considering not only the instrumental value of ICT, but also the emotional and social value.

Students were also taught to communicate with each other, with teachers and with content to develop very important social skills, such as the ability to collaborate, network and communicate in the creation and presentation of concepts, designs and final products. Building relationships and communication should further support innovation learning in the design studio. Design tasks and activities also allow students to develop some management skills, such as the ability to plan, make decisions, time management and project management, all of which are very important in developing leadership skills. All of the design tasks also emphasise risk assessment and risk-taking skills as an important aspect of developing innovation skills. Students faced constraints in terms of environmental impact, economic impact and social impact of their design concepts. In a sense, they acted as intrapreneurs at a certain point of design-based learning.

The innovation skills mentioned above can be very valuable in navigating changing, uncertain or complex situations in the architectural practise, and they are critical to both the long-term sustainability of an institution and to design. In addition, it may be that the innovation skills developed in our learning framework through the intentional use of ICT foster students' ability to respond creatively, adapt, transform and grow, as several literature findings suggest [1,27,36,50,51].

2.3. Sample

It should be noted that at the Faculty of Architecture of the Cracow University of Technology, an architectural design studio course has been taught in the English language for several years, and both domestic and foreign students can be enrolled in the course as a mixed group. The trend of enrolled students in the English language course in the last five years shows that the number of enrolled students fluctuates between 20–25 students per year [47]. In the 2020/21 academic year, we enrolled only ten out-of-state students in the design studio course. For the purposes of this study, some balance should be achieved between the groups of students in the randomisation process for the baseline conditions that serve as controls for the methodology. To avoid selection bias and protect against random bias, we used the stratified randomisation method. We carefully selected covariates such as gender, teacher influence, employment and reflective writing that might have an influence that would challenge the conclusions of the intervention study. First, we conducted a pretest to determine the baseline characteristics of all participants before the beginning of the intervention study (n = 51). Second, we balanced both groups in terms of gender

distribution, as male students were a minority in the overall sample. Third, based on the theoretical background, we assumed that the influence of teachers, job scouts and some of the reflective writing activities in previous courses might influence the intervention. Therefore, we identified ten domestic students who were not significantly different from the other subjects on the above covariates in the pre-test ($p > 0.05$) and then assigned them to the international student group. The group of international students consisted of 20 students, while the group of students taught in Polish consisted of 31 students in total.

The participants were undergraduate students from architecture education at the Cracow University of Technology, Poland, during the academic year 2020–2021. Exclusion criteria included cases of missing data, those who completed the study in under 10 min and those who failed an instructed response attention check. Two instructed-response attention check items were included in the survey to check for careless responses [52]. A total of 46 participants successfully completed the study and satisfied all inclusion criteria. The sample consisted of thirty domestic students who were taught in the Polish language and, as the second group, sixteen students who were engaged with and taught in the English language. The entire sample included more female (n = 37, 80.44%) than male participants (n = 9, 19.56%). Participants were, on average, 19.92 years old (SD = 0.96). The international group of students engaged in the English course—Bachelor Degree Studies in Architecture in English—represented 34.78%, while the thirty domestic students represented 65.22% of the entire sample. The international group of students served as a reference group because they were from different countries and cultures and were taught in English only, and they were mostly not affected by the real physical environment, which was the subject of Tasks 3 and 4. There was only a small number of students (one student from each working team) who visited the site. As a reference group, they all met in the environment virtually, while the domestic students in all groups met both physically and virtually.

This type of research design faces many threats to internal validity, which may lead to inaccurate conclusions regarding the effectiveness of an intervention. Some of the threats were related to the sample. To reduce the maturation threat, we limited the intervention to one semester (16 weeks); thus, significant mental and physical changes could not occur in this age group. The greater the time difference between the pre- and post-tests, the greater the potential effects due to maturation [45,53]. Next, the Hawthorne effect, a threat to internal validity, was reduced with the introduction of the survey as a part of reflection in and on action, as a part of learning. Thus, students did not pay special attention to the survey and did not put forth extra effort at the pre- and post-tests from the perspective of the evaluation of their performance [45]. From the same perspective, it seems that the pre-test did not influence participants' performances on the post-test. Instead, in both tests, students reflected on the treatment that they had received, and both instrument reactivity and instrumentation effect seem to have been reduced [45].

2.4. Measures and Instruments

Students' self-reported TL behaviour and innovation skills were measured. Their initial level of TL ability and innovation skills was checked before the remote design studio for the pre-tested sample. Sixteen weeks after the workshop, their TL ability and innovative skills were measured again for the entire sample engaged in remote learning. The survey instruments were created after a thorough review of the literature focused on transformative learning, transformative education and innovation learning. For this study, two questionnaires were used, namely the newly created Transformative Learning Survey (TLS) and revised Innovation Skills Measurement Tool (ISMT). When selecting, generating and adapting the instruments, some threats to internal validity due to research design were considered. To reduce the history effect, we included additional influencing variables in the survey to map external influencers as events, experiences or individuals that may impact the student between course participation and follow-up. It is important to note that the full survey was available for students in both English and Polish.

2.4.1. Transformative Learning

As several authors [27,33,54–56] argue, TL occurs inside three theoretical perspectives, e.g., rational, extrarational and emancipatory. Thus, the TLS should be associated with the aforementioned processes and should be able to assess the outcomes of TL, such as acting differently, having a deeper self-awareness, having more open perspectives and experiencing a deep shift in worldview [27]. As a foundation of TLS, two questionnaires were found useful, namely a recently developed Transformative Learning Outcomes and Processes Survey (TROPOS) [54] and King's LAS survey [57], but substantial revisions and adaptations in the Polish language and context were made by the authors of the present study. The TLS survey consists of three sections, namely process scale, outcome scale and learning influences scale. All items in the revised instrument asked for Likert scale-type responses for agreement from 1—strongly disagree to 6—strongly agree.

The first section includes TROPOS's three revised process scales: *Social Support*, *Attitude toward Uncertainty* and *Criticality.* The *Social Support* subscale was aimed at self-assessment of a learner's constructive engagement with a social group whose members exhibit mutual trust and respect, thereby facilitating a balance between support and constructive critique [54,58]. A subscale consists of eight items. The *Attitude towards Uncertainty* subscale is aimed at the self-assessment of a learner's attitude towards anticipating or experiencing a loss of certainty, typified by feeling stumped and confused or a sense of stepping outside one's comfort zone [54,58]. This subscale also consists of eight items. The *Criticality* subscale consists of nine items, which ask about a learner's beliefs of oneself and others (regardless of method), evaluating the validity of such beliefs and re-framing them [54,58]. In total, the first section consists of 25 items measured on a six-point Likert scale where the choices range from 1—strongly disagree to 6—strongly agree.

In revising and adapting the process scales, we did not include the TROPOS's scale of self-directed learning because the intervention in the architectural design studio at the faculty is more focused on a different level and intensity of guiding, facilitating and mediating the active learning in a remote online learning environment (the learning outcomes were set by the course designers and not by the students themselves). Since the original TROPOS was designed to assess TL in the study program, we downgraded the items toward an architectural design studio as a course in a remote online learning environment as a pedagogical framework. An example of an item from the revised *Social Support* subscale is, "When I was in the architecture studio, I usually felt safe expressing my opinion using ICT", or from the *Attitude toward Uncertainty* subscale, "I found that discomfort can be an important part of ICT-supported learning."

The second section as the outcome scale consists of three subscales with 21 items in total. One subscale was reworded from TROPOS [54,58] as *Perceptions of Change in Self and Others*, while two additional outcome subscales were added as reworded from King's [57] survey as *Considering and Making Changes in Thought and Action* and *Awareness of The Benefits of Change and Prediction of Future Behaviour*, already successfully validated in higher education settings by [59].

Perceptions of Change in Self and Others focuses on a learner's profound re-assessment of beliefs, typified by changed assumptions and a more inclusive, open perspective towards self and others [54,58]; it consists of seven items. An example of a revised item is: "This architectural design-based course, delivered with consideration of local environmental features, perspectives, views and values, has changed my life." *Considering and Making Changes in Thought and Action* as a subscale consists of five items, while *Awareness of the Benefits of Change and Prediction of Future Behaviour* consists of seven items. An example of a revised item from *Considering and Making Changes in Thought and Action* subscale reads, "As a result of an architectural design-based course, I have reconsidered past actions and behaviours." The items from the *Awareness of Benefits of Change and Prediction of Future Behaviours* subscale aim to assess the transferable value of the TL outcome, such as "As a result of an architectural design-based course that utilises local perspectives, I am able to contribute to society globally."

Each item was measured on an agreement scale, with 1 being strongly disagree and 6 being strongly agree.

As the research design was a one-group pre- and post-test that was sensitive to the history effect, we included in TLS the third section of the instrument (learning influences), which had 24 items taken from surveys of King [57] and of Madsen and Cook [59], to reduce it and then refined it for architecture education as a higher education discipline. Hence, the final TLS for this study was quite different from King's original instrument, which lacks construct validity [60]. For example, the majority of items in the original instrument were written to the participant to merely check off or yes/no. Due to the special nature of the architectural design studio, where different interactions and views are shared multiple times during the intervention, and the assessment of multi-faceted learning outcomes is based more on visual observation of progress in the design task, on the artistic and emotional value of the designs, we adapted the original scale to a Likert-type. All items in the revised instrument required responses on the Likert scale for agreement. Design Tasks 3 and 4 (Table 4), prepared by the course designers and embedded in the local environment, were based on critical thinking and collaboration. This allowed students to further foster their sensitivity to the diversity of ideas, beliefs and values of different influencers. The descriptive sentence introducing this section was, "When you think of your educational experiences in the course, how much influence has each of these groups of individuals, activities or experiences had on your learning and development?" *Influential Individuals* as a subscale consist of seven items measured on a six-point influence scale (from 1—no influence to 6—strong influence). The same scale was used for the *Learning Assignments and Activities* subscale (12 items) and *Out-of-College Influences* (five items). Learning influences also served as independent variables for this study.

The original questionnaires of Cox [54] and King [57] have a different question format, while we used a six-point Likert scale. We chose this scale because the ultimate purpose of the instrument was to track the development of metacognitive awareness for purposes of either self-assessment or research. Moreover, the six-point Likert scale, as it has an even number of ratings on the scale, makes it mandatory for respondents to choose the positive or negative end of the scale, resulting in better data. Furthermore, if at any point, neutral is desired, then the "slightly agree" and "slightly disagree" can be averaged together [61,62].

2.4.2. Innovation Skills

Innovation skills as a part of transformative competencies can be employed in creating new value, reconciling tensions and dilemmas and taking responsibility [11]. Creating new value requires critical thinking, creativity and leadership skills, risk propensity, motivation, communication, delegation, feedback and learning agility [11]. Moreover, Chell and Athayde [49] identified five generic skills that underpin innovative behaviours, which are the skills and attitudes that young people require if they are to become the innovators of tomorrow: (1) creativity, (2) leadership, (3) self-efficacy, (4) energy and (5) risk-propensity. Literature suggests that these generic skills, together with an advanced learning environment, can be a decisive factor in developing higher education towards learning for innovation [35,36,63,64]. Thus, as the foundation for this survey, we have decided to use the Chell and Athayde questionnaire, ISMT [49], which aims to identify and measure the innovative characteristics of young people. Since the original ISMT lacks reliability and validity at some subscales (*Energy, Risk propensity*) [51], substantial revisions and adaptation in Polish language and context were made by the authors of the present study. All items in the revised instrument asked for Likert scale-type responses for agreement, from 1—strongly disagree to 6—strongly agree, while an original ISMT has a seven-point Likert scale.

The revised and adapted ISMT questionnaire has two sections with 36 items in total. The first section with five items aims to self-assess students' future intentions with respect to innovative behaviour. The second section has five factors that present a student's generic innovation skills, namely perceptions about creative thinking skills (six items), leadership skills (six items), motivation and active engagement (seven items), self-efficacy (eight items),

and risk propensity (four items). The extensive revision of the *Energy* scale resulted in three greatly modified items, while the others were merely reworded from an original toward the Architectural Designer Studio domain. An example of a modified item is, "I am excited to engage in a real-world context with local values, norms, and economic perspectives." The other category, *Risk-propensity*, can be considered the most critical category in an original ISMT and resulted in a modification of all four items. First, we improved the readability of the items because the original items had greater average length of sentence and greater average number of syllables per word. Thus, original items had low readability scores. Second, the original items describing an assessment or exam were adapted to local conditions, as an exam in local conditions may not be considered a strong motivator for students. An example of an item is, "I like to try new approaches and methods in the architectural design studio, knowing that some of them will disappoint me."

2.5. Data Collection, Screening and Analysis

In this study, the target population was undergraduate students in an architecture education major. Data on TL ability and innovation skills were collected twice using the non-probability sampling of students in the design studio via online data collection. The first time, the students participated in the survey during the online distance design studio learning session at the end of the semester; that is, at the end of February 2021, while the second test was performed online at the end of the June 2021 summer semester. A high response rate was achieved because students participating in the study spent time responding to the questionnaires during their studio work. Ethical considerations and privacy protection were considered during data collection and analysis.

The data from the students who met all inclusion criteria (n = 46) were further analysed. First, we handled missing values that yielded similar outcomes if only a few points ($\leq$5%) in a large dataset were missing [65]. Missing values were predicted and replaced by the median of all nearby points. Second, outlier cases were detected using Mahalanobis distance [66] through the Social Sciences Statistical Package (SPSS) IBM (v.25) software. As the probability associated with the Mahalanobis distance in all subjects was greater than 0.001, no records of multivariate outliers were detected [66]. Thus, all student responses were subjected to further analysis.

Cronbach's alpha coefficient was used to support the reliability of the tests. Moreover, basic tools of descriptive statistics were used to present the students' basic information, the mean score and the standard deviations of the dependent variables.

As the pre- and post-test design is sensitive to threats to causal validity, such as regression to the mean (RTM), several measures were considered to reduce biases. To determine if the observed improvements in the outcome measures could be ascribed to the intervention in a causal relationship, we used the pre-test score as a covariate. Selection and randomisation of students to divide them into intact groups on a defined basis was not possible. Without random assignment, the groups could not be considered equivalent before the beginning of the study; however, the differences could be statistically controlled for, for a prior level of competency [67], ensuring that the groups' main effect could be more easily interpreted.

ANCOVA was used to examine whether the intervention was successful and if two different conditions in delivering tasks of sustainable architecture design interact with within-subject factor time. Hence, we explored the effects of the design studio instructional tools and modes on TL and innovation skills improvement.

Furthermore, when we found effects, we checked whether some influencing factors had affected them when we used the pre-test score as a covariate and the influencers as independent variables. ANCOVA was used to show which influencers played an important role in the increment of the dependent variable.

Correlation and regression analyses were conducted to answer RQ 5. In the regression analyses, the five self-perceived innovative competencies were used as dependent scales and the TL environment variables as the independent variables.

3. Results

3.1. Internal Validity Check

3.1.1. Common Method Bias

The potential problem of common method bias happens when variations in responses are caused by the instrument rather than the actual predispositions. The bias reflects the measurement error, which is compounded by the sociability of respondents who want to provide positive answers [68].

We performed validity checks on whether this study is a common bias-free method. This study employed two approaches, Harman's single factor test and variance inflation factor (VIF). Harman's single factor test was performed to determine whether a single variable appears for the greater part of the covariance between the measures using principal axis factoring with a single factor to extract [69]. The result indicated that a single factor solution accounted for less than 50% at both pre- and post-tests (39.12% and 41.73, respectively). This shows that the dataset was not contaminated by common method bias [69].

The VIF was further used based on the approach proposed by Kock [70] to assess and confirm the common method bias. The full collinearity factor was used in this study. When the VIF of each latent factor is greater than 3.3, the latent factor is considered to have pathological collinearity, which shows that the model is affected by bias. Table 5 shows that all latent factors in this study had a VIF value of less than 3.3, which indicates that the common method bias is not a pervasive issue in the present study.

Table 5. Full collinearity VIF values and reliability information: Cronbach's α at both pre- and post-test conditions.

Subscale	Pre-Test		Post-Test	
	VIF Value	*Cronbach's α*	*VIF Value*	*Cronbach's α*
Social support	2.01	0.77	1.81	0.89
Attitude towards uncertainty	2.21	0.76	2.23	0.74
Criticality	2.31	0.75	1.82	0.77
Perceptions of change in self and others	2.71	0.80	2.33	0.82
Considering and making changes in thought and action	2.25	0.82	2.44	0.83
Awareness of the benefits of change and prediction of future behaviour	3.12	0.87	2.98	0.92
Future intentions in respect innovative behaviour	2.81	0.77	1.85	0.82
Creativity	2.62	0.79	3.12	0.80
Leadership	1.62	0.90	1.71	0.91
Energy	3.09	0.83	3.21	0.79
Self-efficacy	1.97	0.85	2.68	0.82
Risk propensity	1.73	0.72	2.17	0.77

Cronbach's alphas were also computed for each subscale. This coefficient should normally reach a recommended threshold of 0.7 [71]. Therefore, both questionnaires were found to be reliable and valid instruments and appropriate for use in architecture education settings. In addition, we also provide evidence for the acceptable reliability of the *Energy* and *Risk propensity* subscales, as these two subscales did not reach the required threshold of 0.7 in the original study by Chell and Athayde [51].

3.1.2. Regression to the Mean (RTM)

RTM is a threat to the internal validity and is noted in pretest–posttest designs [45]. The RTM is a statistical phenomenon observed particularly in studies in which a researcher begins with participants who initially demonstrate extreme scores on the dependent variable [45]. If RTM is present, a negative correlation is observed between pre-test and change scores because participants with high pre-test scores would, on average, tend to have smaller gains than participants with low pre-test scores do. Considering the entire sample as one group and checking the correlation between pre-test and change scores, we

found the existence of RTM in all subjects or subscales of both questionnaires. Pearson's correlation coefficient ranges from −0.30 to −0.74 with significance at the level of $p < 0.05$.

By introducing a comparison group formed by non-random allocation of international students, we compared Pearson's correlation coefficient as an indicator of the RTM effect using Cocor (v. 1.1-3) [72]. We found that the differences in the correlation coefficient of each group were not significant ($p > 0.05$) at all subscales; thus, both groups can be comparable. Consequently, group differences in changes from pre- to post-tests can be appropriately ascribed to the intervention [73].

3.2. Descriptive Statistics

Table 6 presents the descriptive statistics considering the mean scores (*M*) and standard deviations (*SD*). Self-reported scores were obtained at both pre- and post-tests.

Table 6. Students' mean scores on TL and innovation skills, self-reported in the pre- and post-test by the participants.

Subscale	Pre-Test				Post-Test			
	Experimental Group		*Reference Group*		*Experimental Group*		*Reference Group*	
	M	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
Transformative learning								
Social support	5.00	0.67	5.13	0.35	5.18	0.67	4.84	0.66
Attitude towards uncertainty	3.67	0.69	3.92	0.776	4.33	0.55	4.21	0.67
Criticality	3.33	0.74	3.38	0.71	3.82	0.75	3.73	0.57
Perceptions of change in self and others	3.31	0.84	3.57	0.65	3.82	1.02	3.72	0.73
Considering and making changes in thought and action	3.70	0.99	4.25	0.82	4.53	0.76	4.38	0.88
Awareness of the benefits of change and prediction of future behaviour	4.08	0.94	4.45	0.79	4.65	0.91	4.53	0.89
Innovation skills								
Creativity	5.13	0.86	5.34	0.63	5.57	0.47	5.02	0.65
Leadership	3.54	1.02	4.20	0.97	3.90	1.02	3.61	1.09
Energy	4.81	0.83	4.67	0.51	5.33	0.44	4.79	0.63
Self-efficacy	4.98	0.80	5.03	0.44	5.27	0.57	4.70	0.74
Risk propensity	4.79	0.69	4.63	0.73	4.27	0.67	3.57	0.73

Visual inspection of Table 6 revealed that the sample mean was above the average on the scale with a midpoint of 3.5 in all subscales on the post-test in both groups, while *Criticality* as the TL process was self-evaluated as being under average in the pre-test in both groups. The worst assessed TL outcome was *Perceptions of Change in Self and Others*, which indicates a mean value close to average in both pre- and post-test conditions across both groups. Moreover, it seems that *Social Support* as a TL process and *Creativity* as the self-perceived ability for creative thinking appear to be the most developed process or skill.

As a part of the ISMT survey, students' future intentions towards innovation were mapped using self-evaluated scores expressed by mean (*M*) and standard deviation (*SD*) with a series of statements about pursuing five different innovative pathways: an inventor, a cultural innovator, a corporate innovator, an innovative entrepreneur and a social innovator (Table 7).

Table 7. Future intentions with respect to innovative behaviour.

Innovative Pathways	Pre-Test				Post-Test			
	Experimental Group		*Reference Group*		*Experimental Group*		*Reference Group*	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Inventor: I would like to invent something that is new to the world.	4.79	1.29	4.62	0.88	4.81	1.21	4.25	1.43
Innovative entrepreneur: My ambition is to set up a new company that offers something completely new.	4.20	1.34	3.75	1.07	5.03	0.85	4.43	1.03
Corporate innovator: I intend to get a job in a large company and apply my skills to develop new products or services.	4.33	1.12	3.37	1.34	4.20	1.46	3.18	1.04
Cultural innovator: I intend to design or create something new such as in music, software, buildings, dance, film, TV, digital production or fashion.	4.57	1.19	5.31	0.79	4.63	1.37	4.50	1.48
Social innovator: I would like to do something no one has ever thought of before that would bring about positive changes to society, the environment or politics.	4.83	1.14	4.43	1.03	5.00	1.17	4.62	1.20

The Shapiro–Wilk test for normality revealed a violation of normality assumption across the intervention groups ($p < 0.05$) at both pre- and post-test. It suggests the use of non-parametric tests.

The Kruskal–Wallis test was used to determine whether the differences between the innovative behaviour scores of the students according to class groups were statistically significant. In the case of the group of students, we found significant differences in the subscales of future intentions with respect to innovative behaviour, which is apparent in Table 7, although it must also be stated that an effect size ε^2 is calculated and interpreted as weak to moderate, as proposed by Tomczak and Tomczak [74].

At the pre-test, the students from the experimental group showed greater intention towards a career as corporate innovators ($p = 0.026$), while students from the reference group were more oriented towards innovations in culture ($p = 0.031$). After the remote TL of sustainable architecture design, the future innovative orientation of both groups was almost the same, while only the perceptions about a career in a large company as corporate innovators differed in favour of the experimental group of students ($p = 0.019$).

The prevailing and most stable innovator style in both groups seemed to be the social innovator. The Wilcoxon signed-rank test revealed significant changes in perception of the ambition to set up a new company that offers something completely new as an innovative entrepreneur style ($Z = 2994$, $p = 0.003$).

Before students started with the sustainable architecture design studio, we surveyed their perception of the different influencing factors they had during the first semester in the design studio. This insight might help course designers adjust some tasks and TL for effectively achieving learning outcomes. Students' mean scores on the subscale items were contrasted using Kruskal–Wallis, as shown in Figure 1.

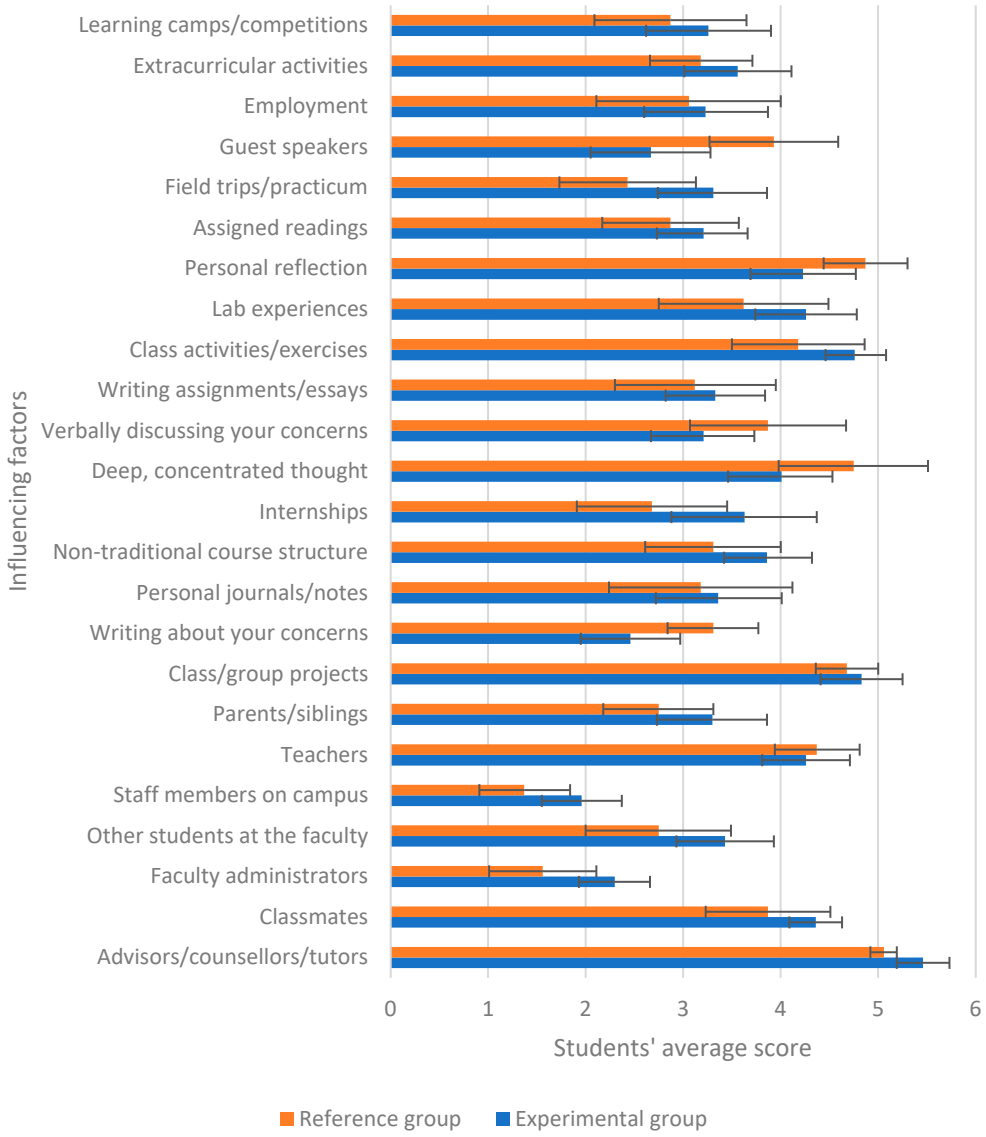

Figure 1. Influence of different individuals, activities and experiences on TL and innovation skills improvement at the remote architecture design studio with 95% confidence intervals.

It seems that domestic students received more support from specific individuals, such as tutors or advisors (p = 0.005), faculty administrators (p = 0.009) and staff members on campus (p = 0.038). On the other hand, international students did self-evaluation and written self-reflection tasks (p = 0.026). Moreover, international students also relied on some guest speakers to help them with tasks (p = 0.007).

After remote learning, we again mapped the factors influencing students in learning, and the average self-reported scores are shown in Figure 2.

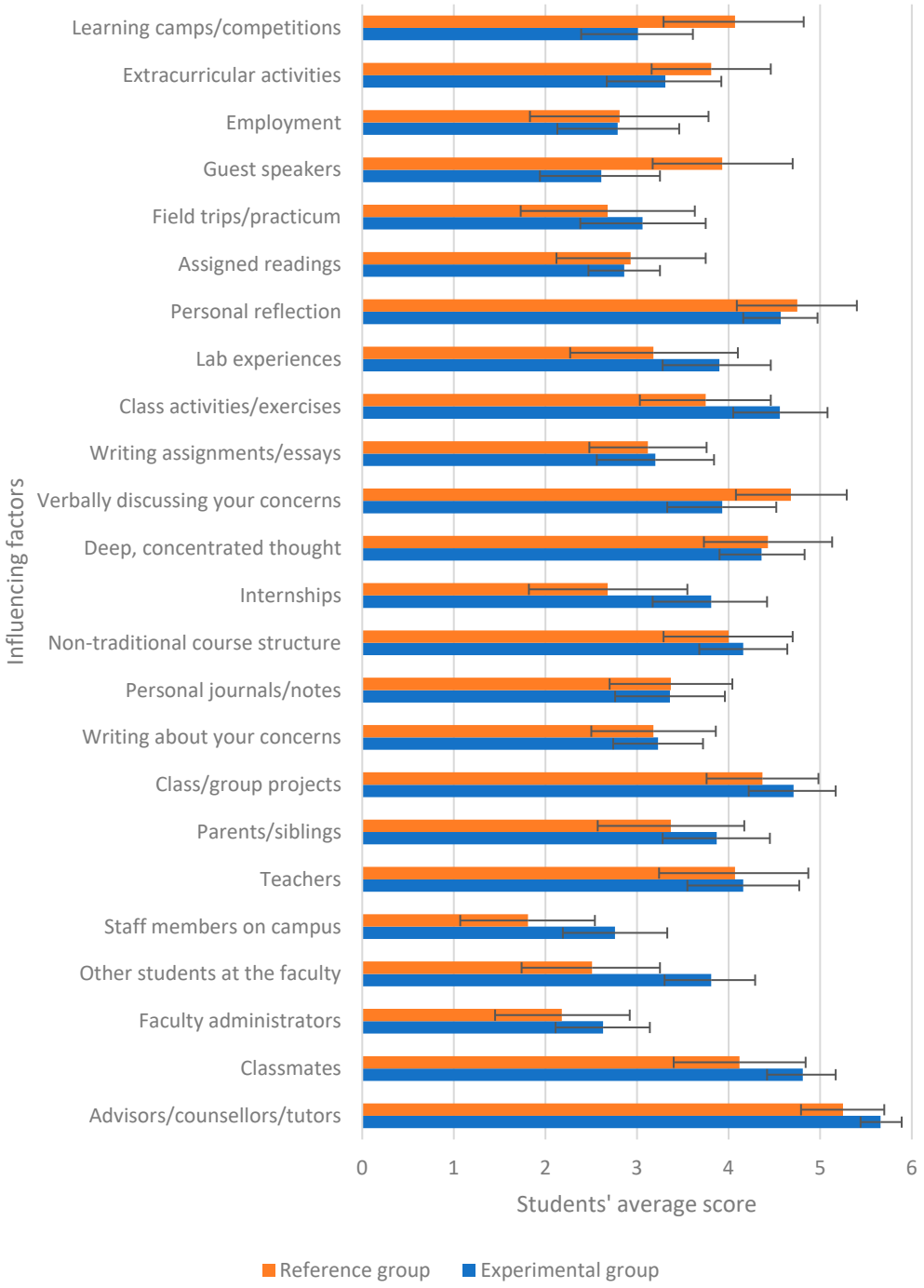

Figure 2. Influence of different individuals, activities and experiences on TL and innovation skills improvement at the remote sustainable architecture design studio with 95% confidence intervals.

During the intervention of remote sustainable architecture design, it seems that domestic students received a different level or amount of support from other students ($p = 0.007$) and staff members at the campus ($p = 0.029$), as their counterparts had. Still, this support was self-assessed as being under-average on the scale with a mid-point of 3.5. Moreover, it seems that groups differed regarding internship activity too, which was in favour of domestic students ($p = 0.041$), and collaborations/interactions with other classmates were more intensive ($p = 0.044$) than those of their counterparts.

Again, some guest speakers affected international students significantly different than they did the domestic students ($p = 0.015$), and it seems that international students

participated in other learning camps, webinars or competitions as out of college activities ($p = 0.034$).

Furthermore, in this study, we conducted the ANCOVA to determine whether the influencing factors during intervention have some role in the increment of TL and innovation skills.

3.3. Transformative Learning Effects

3.3.1. Transformative Learning Process

As we had a rather small sample size, determining the distribution of the dependent variables presenting TL processes and outcomes was important for choosing an appropriate statistical method. A Shapiro–Wilk test was performed and did not show evidence of non-normality in both pre- and post-tests ($p > 0.05$).

First, using the ANCOVA, we examined the TL process for whether a group of students engaged in different modes of remote learning advances and differed in learning. We found that both groups advanced in the TL process from pre- to post-test in the sustainable architecture design studio in *Attitude towards Uncertainty* and *Criticality*, while *Social Support* advanced only in the experimental group. The test of between-subject effects revealed significant differences between groups in *Social Support* ($F = 4.40$; $p = 0.04$, effect size partial $\eta^2 = 0.10$). It seems that sustainable architecture design activities evenly fostered student attitudes towards uncertainty and critical thinking in both groups ($p > 0.05$).

Second, we used the pre-test score as a covariate and analysed whether there was a difference in social support post-test between different influencing factors interacting with a group of students. Table 8 shows a summary of ANCOVA.

Table 8. Summary of ANCOVA for influential factors in social support process of TL with effect sizes.

Influencing Factors	*F*-Statistics	*p*-Value	Partial η^2
Influential individuals			
Advisors/counsellors/tutors	0.086	0.911	0.005
Classmates	4.967	**0.003**	0.369
Faculty administrators	2.506	0.060	0.228
Other students at the faculty	3.391	**0.019**	0.285
Staff members on campus	5.583	**0.001**	0.396
Teachers	0.309	0.904	0.045
Parents/siblings	5.831	**0.001**	0.469
Learning assignments and activities			
Class/group projects	3.296	**0.022**	0.274
Writing about your concerns	3.822	**0.011**	0.310
Personal journals/notes	0.572	0.685	0.063
Non-traditional course structure	1.714	0.182	0.128
Internships	3.078	0.029	0.266
Deep, concentrated thought	0.596	0.668	0.064
Verbally discussing your concerns	0.648	0.590	0.053
Writing assignments/essays	2.585	0.054	0.233
Class activities/exercises	0.419	1.529	0.216
Lab experiences	0.421	0.792	0.047
Personal reflection	0.791	0.539	0.083
Assigned readings	4.126	**0.008**	0.320
Out-of-college influences			
Field trips/practicum	4.092	**0.005**	0.383
Guest speakers	0.863	0.496	0.092
Employment	6.377	**0.001**	0.429
Extracurricular activities	4.605	**0.003**	0.411
Summer camps/competitions	0.487	0.783	0.069

Note. Significant *p*-value < 0.05 is in bold.

The results show that different influences have a significant impact ($p < 0.05$) on individuals in remote learning towards developing a social process, in which parents or

siblings appear to be the strongest influencers followed by staff members on the campus, while assigned readings and writings about concerns in learning might influence the increment in the social transformation process. Moreover, out-of-college influences can be found in employment promotion, followed by extracurricular activities and field trips ($p < 0.05$).

3.3.2. Transformative Learning Outcomes

We used ANCOVA to examine TL outcomes about whether a group of students engaged in different modes of remote learning advances and differs in learning. We found that both groups advanced evenly, and no differences were found ($p > 0.05$) across all TL outcomes. It seems that students from both groups perceived a change in themselves and others, which is focused on their profound re-assessment of beliefs, typified by changed assumptions and a more inclusive, open perspective towards self and others. Moreover, students perceived their acting and thinking differently after the workshop in which past actions or behaviour were considered. Students self-reported their awareness of the benefits of change, and the prediction of future behaviour seemed to be evenly enhanced during remote learning in both groups; no significant differences were found ($p > 0.05$). This might help students contribute to society, improve distal goals setting, make a future impact or difference and affect their choices and decisions.

3.4. Innovation Skills Improvement

A Shapiro-Wilk test was performed to check whether the variables of innovation skills follow a normal distribution. The test did not show any evidence of non-normality in both the pre- and post-test ($p > 0.05$) for the variable *Leadership*, while for other variables, e.g., *Creativity, Energy, Self-Efficacy* and *Risk Propensity,* the test showed departures from normality ($p < 0.05$) both in the pre- and post-test.

We used ANCOVA to examine *Leadership* ability regarding whether a group of students engaged in different modes of remote learning advances and differs in terms of skill acquisition. While controlling for the pre-test score, we obtained no significant difference ($p = 0.213 > 0.05$) in the post-test scores between groups of students. Moreover, it seems that both groups did not show significant ($p > 0.05$) progress in the improvement of their leadership ability as expected in online remote learning [16].

As the assumptions of parametric ANCOVA are not met for the dependent variables *Creativity, Energy, Self-Efficacy* and *Risk Propensity*, we used Quade's non-parametric ANCOVA. As the literature suggests, the non-parametric ANCOVA is more accurate, and it allows better control for the Type I error rates in cases when the variances are heterogeneous and in unbalanced designs, especially in cases when the sample size is small [75,76].

As shown in Table 9, groups significantly ($p < 0.05$) differ on the post-test in which prior levels of innovations skills were considered. It seems that domestic students outperformed their counterparts in all subscales of innovation skills. According to the Scheffe post-hoc test results of the method, the adjusted ranked post-test dependent variable value of international students was significantly lower than the adjusted dependent variable value of the domestic students ($p < 0.05$). The partial η^2 coefficient indicates a large effect size [77].

Table 9. Results of non-parametric ANCOVA (Quade's method) adjusting for differences in type of intervention group.

Innovation Skills	*F*-Statistics	*p*-Value	Partial η^2
Creativity	14.494	0.000	0.248
Energy	6.914	0.012	0.136
Self-efficacy	9.314	0.004	0.175
Risk propensity	7.385	0.009	0.144

Investigating the effects and/or efficacy of remote online learning is a very complex, multifaceted task. It is often very difficult to predict unbiased outcomes in which several

influencing factors may affect learning and skills acquisition in a remote online environment. In the next step of our investigation, we examined whether influencing factors such as influencing individuals, different assignments and learning activities and external events may contribute to the differences in the two groups of students. As the effect size was found to be large, it could be affected by influencers as well, not just attributed to intervention in the remote sustainable architecture design studio.

Using non-parametric ANCOVA, adjusted for differences in the type of group and different influencing factors and mapped for this study as influential individuals, learning assignments and activities and out-of-college related influences, we detected some influencing factors in innovation skills improvement on the following subscales:

- *Creativity*: It seems that other students at the faculty influenced skill improvement ($F = 3.030$, $p = 0.030$, partial $\eta^2 = 0.257$) together with activities organised as group projects ($F = 3.179$, $p = 0.025$, partial $\eta^2 = 0.261$).
- *Energy*: Students' enthusiasm, motivation, persistence, commitment and engagement in the design studio work was also influenced by classmates and other students at the faculty ($F = 2.674$, $p = 0.048$, partial $\eta^2 = 0.234$; $F = 5.411$, $p = 0.002$, partial $\eta^2 = 0.382$, respectively), while group projects of sustainable architecture significantly improved student's motivation and engagement in remote learning ($F = 3.779$, $p = 0.011$, partial $\eta^2 = 0.345$). It seems that meaningful use of ICT to provide continuous and goal-specific design feedback in a way that informs and supports individuals' behaviour was effective in energising students. Moreover, some guest speakers or employment scouts positively affected students' engagement in design work; especially domestic students were significantly differently encouraged ($F = 2.693$, $p = 0.047$, partial $\eta^2 = 0.235$) by their counterparts.
- *Self-efficacy*: Differences between groups of students in the post-test score can also be attributed to writing assignments or essays ($F = 4.217$, $p = 0.034$, partial $\eta^2 = 0.296$); especially domestic students benefited from this.
- *Risk propensity*: Risk-taking ability seemed to be less advanced in a remote learning environment (see Table 6). It seems that students at sustainable design activities were not given enough challenging and risky situations that offer new opportunities for skill improvement. Domestic students might be supported with some laboratory experiences ($F = 4.217$, $p = 0.034$, partial $\eta^2 = 0.296$), while international ones have not received such support.

3.5. Associations between Students' Self-reported TL and Their Perception of Their Own Innovation Competence

We used multiple regression analysis to investigate the relationships between the perceived TL process and outcome scales (social support, attitudes towards uncertainty, criticality, change in self and others, considering and making changes in thought and action and awareness of the benefits of change and prediction of future behaviour) and the self-perceived innovative competence scales (creativity, leadership, energy, self-efficacy and risk propensity).

First, we conducted a non-parametric Spearman's Rho test to measure the strength of the association between variables in which self-perceived innovative competence scales showed non-normality in distribution. The results of the correlation analysis are presented in Table 10.

Table 10. Bivariate correlation matrix for the TL processes (1–3) and TL outcomes (4–6) and innovation competence (7–11).

Scale	Correlations										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1. Social Support	1	0.360 *	0.232	0.142	0.148	0.479 **	0.611 **	0.257	0.604 **	0.613 **	0.228
2. Attitude towards Uncertainty		1	0.515 **	0.415 **	0.493 **	0.419 **	0.405 **	0.321 *	0.371 *	0.193	−0.060
3. Criticality			1	0.306 *	0.270	0.189	0.126	0.248	0.081	0.038	−0.256
4. Perceptions of Change in Self and Others				1	0.559 **	0.636 **	0.388 **	0.136	0.343 **	0.375 *	0.020
5. Considering and Making Changes in Thought and Action					1	0.566 **	0.321 *	0.395 **	0.308 *	0.382 **	−0.152
6. Awareness of The Benefits of Change and Prediction of Future Behaviour						1	0.601 **	0.351 *	0.509 **	0.592 **	0.010
7. Creativity							1	0.257	0.787 **	0.619 **	0.408 **
8. Leadership								1	0.420 **	0.343 *	0.127
9. Energy									1	0.702 **	0.446 *
10. Self-Efficacy										1	0.297 *
11. Risk Propensity											1

* Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).

As can be seen in Table 10, all TL outcomes and two TL process variables were positively and statistically significantly correlated with one or more of the five innovation competence variables. Only self-reported ability for criticism correlates with TL outcome *Perceptions of Change in Self and Others* and *Attitudes towards Uncertainty*.

To determine the joint predictive contribution of the TL variables to students' innovation competence by their individual components, five stepwise multiple regression analyses were conducted.

The first analysis indicated a significant relationship for TL, which accounted for 39% of the variance in creativity scores. Cohen's f^2 effect size was 0.64, which is regarded as large. According to Cohen's [78] guidelines, $f^2 \geq 0.02$, $f^2 \geq 0.15$ and $f^2 \geq 0.35$ represented small, medium and large effect sizes, respectively. Particularly, a significant effect ($p < 0.05$) was found for the main self-reported predictors of the creativity score, namely social support and awareness of the benefits of change and prediction of future behaviour.

Leadership as an innovative skill was largely predicted by TL, where 31% of the variance in leadership scores was explained by TL. The effect size of Cohen's $f^2 = 0.44$ was large. A significant positive predictor was found in considering and making changes in thought and action ($p = 0.03 < 0.05$).

The third analysis indicated a significant association for TL, which accounted for 41% of the variance in energy scores. The effect size of Cohen's $f^2 = 0.68$ was large where the social support TL process significantly ($p = 0.02 < 0.05$) predicted innovative competence.

The fourth analysis indicated a significant association for TL, which accounted for 42% of the variance in self-efficacy scores. The effect size of Cohen's $f^2 = 0.72$ was large, where the social support TL process significantly ($p = 0.02 < 0.05$) and positively predicted innovative competence. Moreover, the second positive significant ($p = 0.04$) predictor in self-efficacy scores was found in the perceived awareness of the benefits of change and prediction of future behaviour.

The fifth analysis indicated a significant association for TL, which accounted for 22% of the variance in risk propensity scores. The effect size of Cohen's $f^2 = 0.28$ was medium. Two strong predictors were found: the first was positive as social support ($p = 0.04$, beta weight = 0.35), while the second was negative as criticality ($p = 0.01$, beta weight = −0.41).

4. Discussion

The goal of this research study was to examine how remote learning in two different groups of students contributed to the perceived changes of TL and innovation skills via

the architecture design studio, where sustainability principles were applied in tasks and assignments. The aims of the sustainable architecture design course were as follows: (1) mastering the knowledge of the application of the theory of sustainability in design practice, (2) acquiring the ability to prepare a functional, spatial and sustainable concept of a simple architectural design task, (3) acquiring the ability to prepare a project presentation using various tools, in the form of drawings, models and descriptions and (4) beginning to acquire project defence skills and participate in discussions.

For measuring TL, the recently developed Cox's [54] TROPOS, which was revised and upgraded with King's [57] survey and named TLS, was used. Our study showed that the TLS is an appropriate instrument for measuring TL in higher education settings. Moreover, our study also yielded that the revised and adapted Chell and Athayde's [49] ISMT, which was used for measuring innovation skills, is also an appropriate instrument for measuring different self-reported characteristics and abilities that demonstrate innovative behaviour [36] in higher education settings, while the initially developed instrument was aimed at the measurement of the innovative characteristics of young people aged 14–19 [49].

The architecture design studio learning outcomes were also often considered to reflect institutional culture and goals. Therefore, various assessment tools and rubrics were used to evaluate the achievement of learning outcomes. As Goel et al. [79] noted, student learning outcome statements clearly state the expected knowledge, skills, attitudes, competencies and mindsets that students are expected to acquire at an institution. Thus, the use of different kinds of assessment activities is proposed to be consistent with the learning outcomes [79]. This study assessed course learning outcomes through a presentation, reflection journal, oral assessment, design projects, contribution/participation, checklist and e-portfolio. Students' attainment of the learning outcomes may be reflected in final grades for specific assignments (Tasks 3 and 4). The grading scale ranged from 2 to 5 as the maximum grade. For Task 3, the international group of students performed better than the domestic group of students ($M = 4.84$, $SD = 0.31$; $M = 4.64$, $SD = 0.39$, respectively), while for Task 4, the domestic students performed better than their counterparts ($M = 4.90$, $SD = 0.21$; $M = 4.68$, $SD = 0.51$, respectively). The differences found between the groups were not significant ($p > 0.05$). The results indicate that the learning approaches and methods used in distance education were perceived as beneficial.

The following are the answers to the research questions addressed in this study, together with the implications and limitations of the study and possible future works.

4.1. The Effect of the Sustainable Architecture Design Studio on TL

For research question 1, the result shows that the sustainable architecture design studio course benefits students because their TL is enhanced after an intervention. Overall, students perceived that the course assists them in advancing their ability to act differently, gaining deeper self-awareness and more open perspectives and experiencing a deep shift in worldview, considering cognitive, extrarational and social critique processes. It was expected that the deep transformational processes among the students and their perceived progress in TL would be detected because prosocial and proart motivational, experiential and action-oriented learning were applied, which confirms the findings of Legault et al. [8] and Reitter and Grossklags [80]. However, according to the TD theory, it seems that the prevailing interactions found in human-human interactions might be decisive, as argued by Weidlich and Bastiaens [26] and Croxton [42], especially in the social support process. Students' remote learning seems to extend beyond the borders of the traditional face-to-face learning environment, and it could be that different influencers from industry, local community or home environment reduce TD. Constructive alignment used in remote teaching accommodated well-intended TL outcomes, teaching-learning activities and assessment tasks along with teamwork and reflective writing on tasks in which the lecturers provided insufficient feedback for students, which affected students' behaviour towards TL [27]. Moreover, it seems that students adopted the deep approach across a range of learning environments, as already proposed by Hailikari et al. [34], and thus might provide new in-

sights into the predictive value of affective or irrational aspects towards cognitive learning gains, which was, till now, a shortcoming in distance learning [26].

To answer the second research question, we designed several items to map the factors enhancing remote TL. Our study revealed several influencers in the social support process, which were found to be not effective enough. On the study of influencers, we identified them as classmates, staff members on campus and parents or siblings, while the influencing learning assignments and activities seem to be group projects, reflective writings and assigned readings, which are a core competence for transformation, as also argued by Reitter and Grossklags [80]. Moreover, some out-of-college activities were found successful, such as field trips, visits from potential employers and other extracurricular activities. The sequence and content of the tasks designed in this paper demonstrate how teaching strategies informed by transformational pedagogies accommodated with TD theory in remote learning may provide a framework for both the TL process and the outcomes sought in architecture education by connecting the individual/group tasks to their underlying meaning, which confirms the findings of Peterson and Lundquist [31].

4.2. The Effect of the Sustainable Architecture Design Studio on Innovation Skills Improvement

A large majority of innovative behaviour characteristics have been advanced from pre- to post-test, while the remote learning implemented in this study had some shortcomings, especially in advancing leadership skills and risk propensity ability. As risk-taking becomes a core skill, it may interact with students' ability to act successfully in remote learning [81]. Thus, we discuss this personality trait in greater depth.

The use of ICT to develop innovation skills was purposeful and didactic, using the SAMR model to transform learning experiences to achieve higher levels of innovation skills. The model was mainly used at the advanced level of modification and redefinition according to the SAMR model [82]. A pedagogical wheel was used to think about teaching and learning at a distance and to connect considerations of the functions that ICTs provide with changing learning methods, increasing student motivation, improving cognitive development and distal goals of learning and education [83]. Progress in students' innovative skills can be observed in the 2nd semester (Tasks 3 and 4) when they are required to use ICT to prepare projects (all drawings, renderings, designs, models etc. are created using a variety of programs such as AutoCAD, ArchiCAD, Sketchup, V-ray, Lumion, Blender, Photoshop). These ICTs with solutions based on artificial intelligence allowed the creation of new sustainable architectural designs, previously unthinkable, and a significant transformation of tasks. It appears that the selection and use of ICT aimed at developing higher-order thinking skills, including all instrumental, social and emotional values, benefited the development of innovation capabilities in students in a variety of subscales of the ISMT.

As the basic communication, networking and collaboration workspace, MS Teams and Zoom were used along with the internet tools. To answer the third research question, first, we found the dominant innovative behaviour at both pre- and post-test, which was that of a social innovator. It seems that the course design's stress on constructive alignment and systems thinking enhanced social innovation action required the adoption of innovation skills and further developed them, as argued by Marini Govigli et al. [32]. Conversely, TL also had some impacts on innovation and skills development, at least from the perspective of consensus raising, critical reflection and individuation, as argued by Yee et al. [1]. It might be that innovative behaviour and TL develop social value and connect with the instrumental value of the ICT used in remote learning, as proposed by Zhang and Zeng [4]. Moreover, students' mastery goal orientation at design tasks and learning assignments might also play a decisive role in the increment of innovation skills, while students who felt less confident did not pursue self-determination; thus, they felt more TD, and being performance-oriented, they wanted just to compete with others or just to finish project/tasks using ICT as pure instrumental or technical value. Similar findings were revealed by Aldahdouh et al. [84], and these students might have deficits in creativity

improvement, motivation and engagement, self-efficacy and risk propensity, as argued by Hero et al. [35].

Analysing the factors influencing innovation skills improvement, indeed, we observed several important effects. Changes in creativity, which are also very important for learning and motivation [85], can be attributed to social factors and collaborative teamwork as well, in which group members share diverse perspectives. It seems that students use creative processes both internally and externally. Internally, students might assimilate social values and create a mindset and personality based on them, while when they communicate new ideas and designs externally, they are changing the culture around them, as also argued by Starko [85].

Guest speakers or employment scouts positively affected the students' engagement in design work. It seems that the acquainted students tended to regulate their remote sustainable architecture design behaviour as a function of personal interests and values, based on intrinsic motivation and autonomous forms of extrinsic motivation, as also argued by [8]. Moreover, it seems that students who received some sort of motivational intervention and were exposed to action-focused feedback advanced in innovation competence, which confirms Legault et al. [8]. In addition, inviting guest speakers or scouts from industry in a spirit of encouragement or collaboration could enhance innovation skills in students using problem-based, inquiry-based, design-based or any other active learning environment such as those used for the purpose of this study, which confirms the findings of Sinha [9].

According to Bandura's theory of self-efficacy [41], it seems that positive and negative self-statements such as verbal persuasion and positive social comparisons with other students were potential sources of self-efficacy, and might be influenced by teachers' judgement of their work and behaviour, as argued by Chell and Athayde [49]. Moreover, it appears that students who collaborate, examine together and share materials, as is often the case in architectural education, increase their willingness to self-learn, as noted by Arya et al. [86].

As leadership is a generic innovation skill and critical throughout the innovation process [49], we found no progress in its development due to forced remote learning, where social support from other people was limited due to the pandemic or the context of learning. Thus, some new learning pathways, such as targeting remote conference tools, should be designed and used to reduce TD and make learning more effective, as argued by Fujs et al. [3]. Moreover, we propose here to use a buddy system as an approach to improve student leadership in remote settings where much attention should be paid to building relationships, developing agility and adaptability and decision making, as also argued by Arya et al. [86].

A decrease in the level of risk-taking ability was detected. It might be that risk avoidance can result in a person being reluctant to innovate, as argued by West [87] and Ovbiagbonhia et al. [36]. It seems that the students of sustainable design activities were not given enough challenging and risky situations that offer new opportunities for skill improvement. Additionally, domestic students might be supported with some contextually riskier laboratory experiences. Risk-taking ability and TL might be related directly (as openness and extraversion) or inversely (as agreeableness and conscientiousness), as argued by Nicholson et al. [88].

As we can see from Table 10, risk propensity is correlated with self-perceived creativity, motivation and self-efficacy, which points to the redesign of current activities towards more cross-environmental tasks in which all, mindset, empathy and hands-on approaches can be enabled in a collaborative student-centred design studio. Several types of digital feedback that point to the learning pathway should be enabled, which might capitalise on motivation and goal setting [8].

In answer to the fifth research question, we found a significant correlation between TL and innovation skills. Moreover, it was found that TL has strong predictive value in creativity, leadership, motivation and engagement in remote learning, and self-efficacy, while for the prediction of risk propensity, TL was found to be a moderate predictor.

As developing risk propensity and TL are inversely related in certain places, negative prediction of criticality towards risk propensity was also found. It seems that students who were more questioning of their and others' beliefs, and evaluated the validity of such beliefs to a greater extent, felt that their risk-taking ability had decreased, which confirms the results of Migliorini and Lieblein [81]. It could be that risk propensity is more characteristic of an individual than their situation, which confirms the findings of Nicholson et al. [88]. It seems that criticisms of not challenging situations or tasks are rather harmful to risk propensity development.

4.3. Limitations and Implications of the Study and Future Works

Despite its contributions, the present study is not free from limitations. First, the quasi-experimental pre- and post-test design limited the ability to confirm causal relationships because the reference group was not the typical control group where different activities could be conducted. The reference groups differed regarding the language in which the lectures were delivered, and the background and prior knowledge of the international students were unknown. Future research using a Solomon four-group experimental design could prove our claims.

A second limitation of this study was the adaptation of the instruments to the Polish language and the context of the subject of study. We may not have covered the full range of measured variables, but we provided acceptable reliability coefficients of the revised and adapted subscales that are comparable to previous studies. In addition, we were able to demonstrate accepted reliability for all subscales of the revised ISMT, whereas for the original ISMT, two subscales did not meet the threshold. Thus, for further studies, very detailed construct validation research of the revised and adapted instruments should be conducted.

A third limitation of the study was the use of self-reporting questionnaires to measure the variables. A subsequent study will use a test for measuring TL and innovation skills, which is under construction now, and will be validated in a parallel study that has already been initiated. Moreover, we focused on addressing the characteristics of individual innovativeness; meanwhile, to prove the real value of innovativeness, the consequences of the innovative process have also been examined thoroughly, and our future research could measure these consequences.

The next limitation was the sample size and randomisation. Because recruitment of study participants is often a limiting factor in studies and there is an unpredictable, fixed number of specific groups of students, unequal randomisation can very often be used. However, with a fixed sample size, unequal randomisation of 2:1 can be used without serious loss of power, as argued by Dumville et al. [89]. With research budgets and resources under emergency and pressure, as in the case of COVID-19 pandemics, unequal allocation could be used more frequently to reduce the cost of the study. The statistical power and sample size will be increased in future studies in which students from the first to fourth years of study will be enrolled with gradually changed project tasks, especially solution- and problem-driven design tasks.

Finally, investigating prosocial remote learning design also requires qualitative approaches to understand the frustrations or motivations of interacting with this type of system.

Despite the limitations outlined above, the current study contributes unique insights to the growing research on social innovations and the advanced use of ICT in education towards reducing TD in the remote learning environment. The model of remote sustainable architecture design, as presented in this study, should prove useful in expanding our understanding of the factors influencing both individual TL and innovativeness. This points to the need for extra measures when developing 21st-century skills in the virtual or real classroom. This study yielded results that are of value to the academic, scientific, industrial and social communities interested in developing high-level thinking skills using contemporary ICT on artificial-intelligence-powered solutions.

5. Conclusions

Educational institutions are currently striving to develop and adapt the use of ICT towards social and emotional values aligned with SDGs. The educational technologies used nowadays are exploited at the level of understanding and technical application. On the other hand, particularly, using artificial-intelligence-powered solutions for the analysis, evaluation and creation of new knowledge, acquiring skills and developing attitudes is seldom effective, especially in remote-learning environments.

Architecture education, by its nature, is intricately entwined with the natural, economic and social environments, and as it is, may provide good evidence on how to develop TL in students in physical and distance or remote education using different ICTs. Moreover, our results suggest that the introduction of a course on experiential and action-oriented remote learning can support the development of both TL processes and outcomes and innovation skills towards SDGs. By creating a prosocial and proartistic motivational remote learning environment, we showed a way to balance the instrumental and social value of educational technology based on artificial intelligence-powered solutions. Another interesting finding is that TL and risk propensity, as a core capability of an innovative person, can be mutually exclusive in some aspects. This work, therefore, offers promising evidence of the potential for personal transformative interventions to reliably improve innovation skills using a remote sustainable architecture design studio. We believe that this can give rise to recommendations and insights for the innovative and balanced use of educational technology in other learning environments in higher education for quality education and to be systematically prepared for crises.

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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 on request from the corresponding author. The data are not publicly available due to privacy issues.

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Appendix A

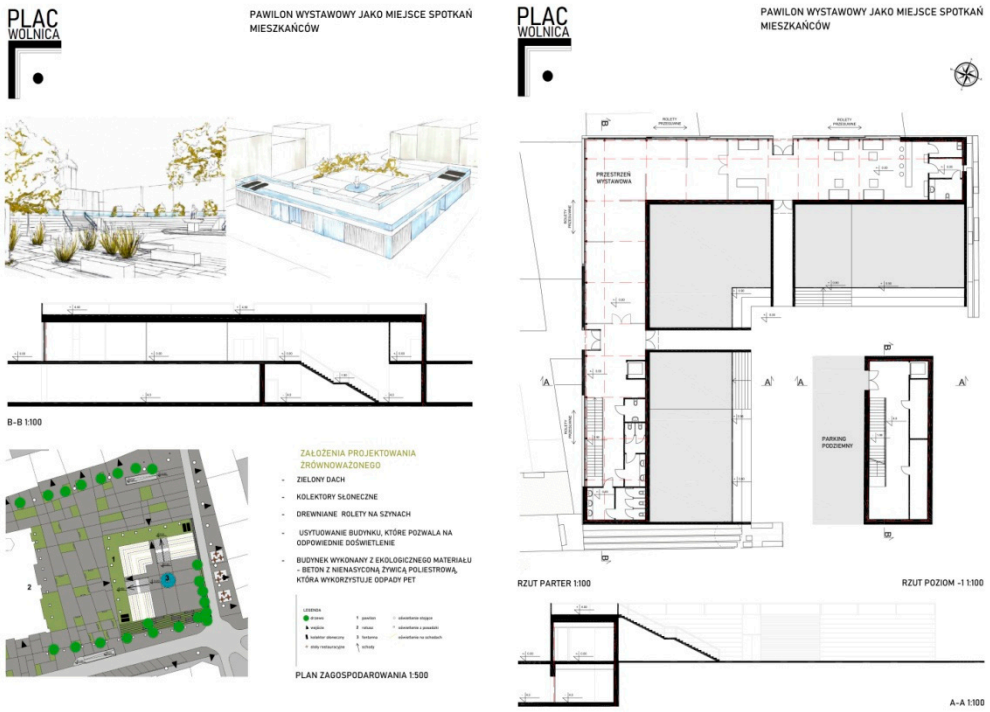

Figure A1. Course Bachelor Degree in Architecture in Polish. TASK 3. Exhibition Pavilion on Wolnica Square. proj. Diana Przybysz—author's archive.

Figure A2. Course Bachelor Degree in Architecture in English. TASK 3. Szeroka Street Pavilion. proj. Klaudia Możdżeń—author's archive.

Figure A3. Course Bachelor Degree in Architecture in Polish. TASK 4. Interior of the Exhibition Pavilion. proj. Szymon Popowski [47].

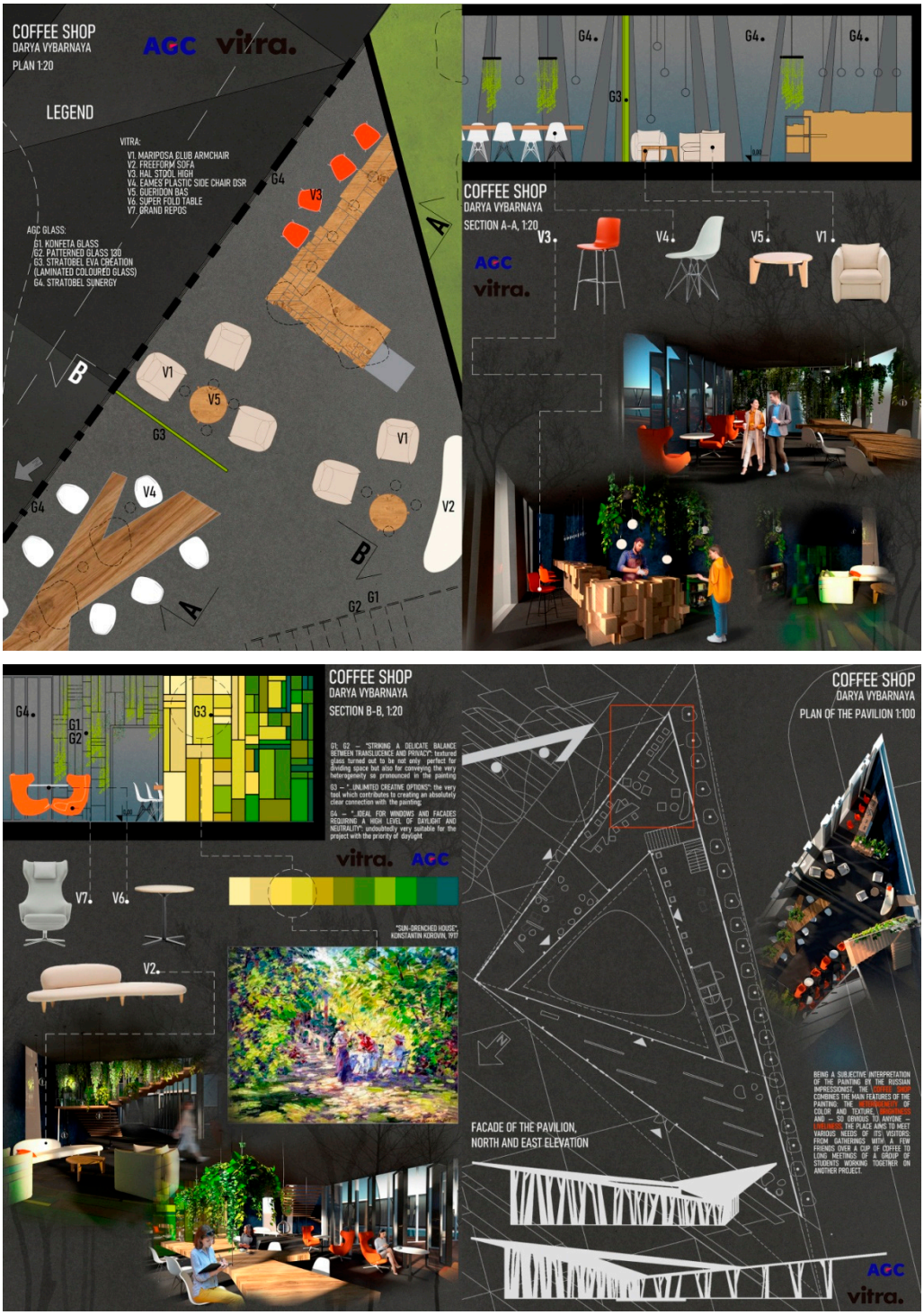

Figure A4. Course Bachelor Degree in Architecture in English. TASK 4. Coffee Shop. Interior of the Pavilion. proj. Darya Vybarnaya [47].

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