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Alfonso Chaves-Montero

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Cover image courtesy of Alfonso Chaves-Montero

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About the Editor

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My research interests are: teleworking, social services, COVID-19, quality of working life, job satisfaction, Twitter, citizen interactions, political discourse and network analysis.

Article

Social Services and Twitter: Analysis of Socio-Political Discourse in Spain from 2015 to 2019

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Abstract: The fundamental role of social networks in all areas of our lives and of social and political interactions is also very important in this new digital environment. The study focused on the analysis of tweets related to social-service issues published on Twitter during the different electoral campaigns in Spain from 2015 to 2019. The sample is 6728 tweets generated between 2015 and 2019 on the topic "social services" for quantitative analysis. In this analysis, we use the Gephi tool to observe how these messages flow on Twitter. The aim was to understand the socio-political discourse of different actors on social services in order to identify priority topics and networks for active Twitter profiles. The results show that users use Twitter for informal communication during the election period, focusing on messages, condemnation and positive evaluation to increase their visibility and influence.

Keywords: Twitter; social services; social participation; social networking; socio-political discourse; election periods

1. Introduction

Social networks are the most widely used and expanded digital media due to the potential they offer for communication between users and participation in the public sphere, and stands out for the possibility for unmediated communication between users and participation in the public sphere [1]. In this public sphere, a "unitary digital agora" [2] is produced, in which citizens and public institutions participate on equal terms.

Political actors and entities use this new environment for social interaction, due to its dissemination, propagation of messages and instantaneousness. In the words of [3], in most cases they opt to maintain a unidirectional communication strategy, seeking only a greater reach for their messages.

A presence on social networks in the era of online communication has become more used and important during the development of electoral campaigns; in this electoral period, political parties and candidates disseminate their slogans and messages to attract potential voters and undecided voters. Social networks, especially Twitter, have become a means of disseminating political propaganda and Twitter is a benchmark social network for participating and interacting in politics, where citizens can access information and send their messages instantaneously [4].

Throughout the years, each temporary space has been related to a traditional means of communication and the political class and, in particular, candidates have taken advantage of and used the media's influence on voters by making regular use of social networks during the development of electoral campaigns [5]. The development of marketing and political communication has been directly linked to the evolution and progress of mass media, and cannot be understood without them [6]. Every era has been marked by a media and the political class has always known how to take advantage of the media's influence and impact on voters, making extensive use of the media in election campaigns [7]. In the 1920s, print media predominated, and in the 1950s, television was the most widely used medium [8].

Today, we are in the Internet era, which marks a milestone in communication, with digital media and social networks dominating the ways in which politicians interact with citizens [5,9–11].

The so-called information society involves a transformation of all areas of life, and, therefore, social services are not immune to it. On this level, social services are undergoing transformations that affect the activity, strategies and tactics of social work, making it necessary to study the influence of the Internet and social networks on their structure and social processes [12]. In this information society, we are constantly interacting with the Internet and social networks, and this interaction is both human and non-human, leaving a trace of this interaction in the form of data, which are given voluntarily. From the processing of this data by means of analysis techniques, data on population interest, emotions, and interests, etc., can be extracted quite reliably.

One of the sources of data for this Big-Data processing is the messages posted on social networks such as Twitter, where users provide useful information applicable to different fields. In this sense, [13] points out that Big Data has the capacity to reveal information that is in the subconscious, and of which we are not aware.

Currently, the application of Big Data in the business sector is wide [14] and it is beginning to be used in politics. Today's social services do not have, among their approaches, the use of Big Data [15], although there is currently a call for full immersion in the digital era and for this discipline to be at the forefront of innovation [16]. In the 1980s, the ideology of "management" was imposed, also known as managerial ideologies, ideologies derived from economic neoliberalism, where the company and its management is the epicentre of everything [17]. According to this ideology, the system of accountability is imposed in social work [18], where the social-services professional is obliged to justify and explain the actions undertaken, with computer systems implemented as a mechanism to streamline and standardise processes [19]. However, these systems are aimed at measuring the efficiency and performance of the objectives imposed in order to be able to assess whether public funds have been used correctly [20]. "This managerialist view of social work causes a displacement of the relationship with users in favour of a managerialist approach based on data collection and bureaucratic completion" [21].

Although the managerial ideology is being progressively abandoned in the practice of social services, in favour of a more relationship-based system in which the bureaucratic burden has been lowered, it has not disappeared completely. To achieve this end, a step has been taken towards systems based on people's digital participation, designing intelligent systems that manage to lower the bureaucracy in the practice of social services, and also allowing citizens to relate digitally [22]. This is achieved thanks to the fact that citizens are gradually becoming more capable of using digital technologies, which means that the data that used to be entered by social workers into management systems are now entered by users, freeing professionals from this process.

In the words of [15], "this bureaucratic work of the social services professional, as well as the use of social networks, generates a huge amount of data that is currently wasted".

This use of ICT (information and communication technologies) in social services ranges from the level of intervention (implementation of social policies, social-justice issues, administration of organisations and communities, etc.), to the level of education and research (online courses and seminars, participation in online work, interacting with other social workers, etc.). In short, it can be said that ICTs are continuously redefining the boundaries of the profession, and in the face of these challenges, social work, both as a profession and as a scientific discipline, cannot remain on the sidelines of the digital transformation of society [23]. Just as ICTs are redefining society in all their fields of action, in social work they are redefining it in three dimensions: (1) in the social context in which it intervenes; (2) in the tools used for professional practice; and (3) in the competences and skills required.

Social networks and ICTs can impact or change social practice and offer new opportunities for social-service professionals in the coming years. Digital and social technologies provide older people with better social care solutions to improve their quality of life and

well-being. Evolutions in web and digital technologies will continue to have a significant impact on all aspects of life and social care. However, this technological change and its impact on society is also accompanied by new ways of caring, sharing and being. This brings with it both opportunities and ethical, practical and human challenges. It is, therefore, essential that social services and social-care professionals can enhance their digital professionalism and their ability to support, guide and protect a digital citizenry of children, adults and families in an increasingly mediatised digital world where individual privacy is invaded [24].

Social networks are digital platforms where users generate content, messages and share them publicly or privately [5]. Messages can be both written and audio-visual [25]. In today's society, in which we live on screens and social networks, interaction between political parties, candidates and users present on digital platforms is possible [26].

In this way, social networks have become the central node of political communication flows [27], a space in which, in the case of Twitter, numerous sources compete for the establishment of the political, economic and social agenda [28]. The traditional actors of political communication, media or partisan, coexist with many other emerging actors who, like citizens themselves, try to influence the digital public space from the same level [29,30].

Messages can be both written and audio-visual. In today's society in which we live on screens and social networks, interaction between political parties, candidates and users present on digital platforms is possible [31]. In this decade, some strategies are already being developed to bring the political class closer to the citizenry using the Internet. During election campaigns, political parties have created web pages to support their candidates and have even included spaces for debate, such as forums or live chats [32–34].

From 2002 onwards, candidates started to use social networks, such as blogs, for their election campaigns, due to the potential they offer [35]. The Internet and social media introduced new possibilities for political communication, changed politics itself and redefined the relationship between politics and the media [36,37]. These new opportunities for interaction and communication have moved political activity online. Political professionals are increasingly aware of the need to have a presence on the networks and the importance of generating relevant and useful content that interests users [38].

This has meant that social networks have become an essential tool among the instruments that candidates use to interact with citizens through their messaging [39]. For this reason, we can no longer speak of political communication planning without the use of Web 3.0 and social networks [40]. Due to the advances of the current society in which we live, the mass media are no longer the only means of communication to reach potential voters. Today, we increasingly see political institutions informing citizens through social networks, and vice versa [41].

This highlights the growing use of Twitter by the general population to stay connected with their political leaders. As pointed out by the CIS (Sociological Research Centre) post-election studies of the 2015, 2016 and 2019 general elections, more than 50% of those surveyed acknowledged having followed information on the aforementioned elections via this social network. It can be stated that Twitter is a primordial social network for political analysis and study which has more than 200 million users around the world, and gives rise to the two-way communication of messages every day. Twitter is a microblogging network, as its messages are condensed into a maximum of characters; in a few words, you have to communicate the message briefly [42].

Twitter also stands out for speed in the emission and reception of its messages, which facilitates interaction between users. Twitter favours communication, direct contact and dialogue, and, since its creation, it has shown its growing importance in the political context [43,44]. From Obama's US election campaign in 2008 to Trump and Clinton's last one in 2017, Twitter has been the social network most used by candidates. As a result, studies on Twitter in campaigning have been incorporated into the broad field of study of electoral campaigns in various regional, national and extra-regional contexts [45].

Twitter users are opinion leaders in their environments. Of all the social networks that exist in the ICT world, Twitter stands out for its remarkable rise as an electoral tool [46].

Achieving a greater number of followers on Twitter or any other social network, gaining an advantage in digital polls, ensuring that any idea favourable to the electoral campaign reaches the top positions in terms of the most commented topics on the network or having the support of users who disseminate a good image of the party or candidate, quantitatively determine the probability of achieving an electoral victory [47–49].

This study aims to examine the discourse surrounding social services on Twitter in Spain, focusing on the perspectives and perceptions of different agents who participate on the platform. It differs from previous studies by not only analysing political campaigns, but also the periods between campaigns and over a longer time frame. The study will specifically focus on analysing discourse about community and specialized social services. The goal is to understand the ideologies and priorities surrounding social services as perceived by active Twitter users, with a special focus on political discourse and the use of social media to highlight the reality of social services in the national sphere.

2. Materials and Methods

Thus, this research takes as its starting point the socio-political discourse on social services of the different agents on Twitter, in order to define the priority themes of the profiles that actively participated during the elections held in Spain from 2015 to 2019.

During these years, the political landscape in Spain at a national level was involved in different events, which have marked a destabilisation of the traditional two-party system in favour of a multi-party system [50], which has led to repeated electoral due to a lack of clear majorities. In this research, only the messages posted on social networks during election-campaign periods were extracted.

Gephi is an open-source software for visualizing and analysing complex networks. It is a tool that allows users to explore and understand large and complex data sets, such as social networks, biological networks, and transportation networks, among others. With Gephi, users can import and visualize data, apply various layout algorithms, and perform various types of analysis, such as community detection, centrality measures, and statistical analysis. It also allows users to apply different types of visualizations and customizations to the network graph, making it a powerful tool for data exploration and understanding. Gephi is widely used in fields such as social-network analysis, data visualization, and digital humanities, among others. Gephi employs the CSV (comma-separated values) file format, which is a plain-text format which allows data to be stored in a table where each row represents a record and each column represents a variable. The data can be imported into Gephi through the menu File → Open or File → Import. Once the file is imported, the data can be visualised in Gephi using different network-analysis algorithms. These algorithms are used to calculate the relationships between nodes and to generate a visual representation of the network. The most common algorithms used in Gephi are the Force Atlas 2 algorithm, the Fruchterman–Reingold algorithm and the Yifan Hu algorithm [51].

Additionally, different research methods and tools can be used for data collection and analysis, such as text mining or sentiment analysis. It is also possible to use different algorithms or approaches, such as natural language processing or machine learning, to analyse the data. Mentioning these related studies can provide context and perspective on the current study and highlight the unique contributions of the current research [51].

The result of the search enabled the configuration of the database that will be the subject of analysis in this article, with a total sample of 6728 tweets collected. Gephi is a software tool for visualizing and analysing network data. To collect data in Gephi, you can use a variety of methods, such as:

1. Importing data from a file: Gephi can import data from a variety of file formats, including CSV, GEXF, GDF, and GraphML. This is useful if you have data that you have collected previously and want to visualize in Gephi.
2. Scraping data from the web: Gephi has a built-in web scraping tool which allows you to collect data from websites. This can be useful if you want to collect data from social-media platforms, such as Twitter or Facebook.

3. Using APIs: Gephi can also connect to various APIs to collect data. For example, you can use the Twitter API to collect tweets related to a specific topic or hashtag.

4. Manual data entry: You can also manually enter data into Gephi, which can be useful if you have a small dataset or if you are testing a visualization.

Once you have collected the data, you can use Gephi to visualize and analyse it. Gephi has a variety of tools and features which allow you to manipulate and explore the data, such as layout algorithms, filtering, and statistics.

The methodological process followed was based on a quantitative analysis using the Gephi network-analysis tool to see how the information flows in the messages that are emitted. Twitter user accounts with which there is interaction and two-way communication were analysed:

The methodological process for collecting data in Gephi depends on the type of data you want to analyse and the analysis approach you want to use. In general, the following steps can be followed:

(a) Data collection: data is collected from the desired social network or source, either through automated extraction or manual collection.

(b) Data cleaning and pre-processing: the data is cleaned of any noise or unwanted information and prepared for analysis.

(c) Import data into Gephi: data is imported into Gephi in a compatible format, such as a CSV or GEXF file.

(d) Exploratory analysis: visualisation tools are used in Gephi to explore and analyse the data, such as network-analysis tools, centrality measures, and clustering.

(e) Analysis and interpretation of the results: the results of the analysis are interpreted and conclusions and recommendations are drawn.

(f) Creation of visualisations: Gephi allows you to create attractive and easy-to-understand visualisations of the analysed data, allowing a better understanding and presentation of the results obtained [51].

3. Results

The results of the research using the free Gephi software 0.10.0 provided a glimpse of information from the set of tools that connect the network of actors (individuals, politicians, and social organisations, etc.) with the emerging social structures that result from the relationships that actors establish. A first observation will be made concerning the way in which the relationships of the accounts are formed, as well as the positions of their components in the social network of the territory and the intensity of the relationships.

The study of the sample made it possible to obtain an X-ray of the discourse on Twitter during the electoral periods analysed. The discourse of politicians, political parties, citizens, and organisations, etc., dealt with the dissemination of information from different perspectives, including complaints and positive assessments, but always from the perspective of improving social services in the broadest sense of the term.

In an exhaustive analysis of the networks of words used in the tweets and how they are related, we can observe in graph 3 the existence of certain words that have a high centrality in the network and that connect the different clusters, serving as a bridge; these are "reform" and "families". Thus, there is cluster 1 (green) which is made up of terms related to budget issues, Europe, accounts, emergency. In addition, cluster 2 (red) is made up of terms such as protection, support, and participation, etc. In other words, most of the tweets on social services are about families and the reforms needed to help them achieve a better level of protection in terms of budget, as shown in Figure 1.
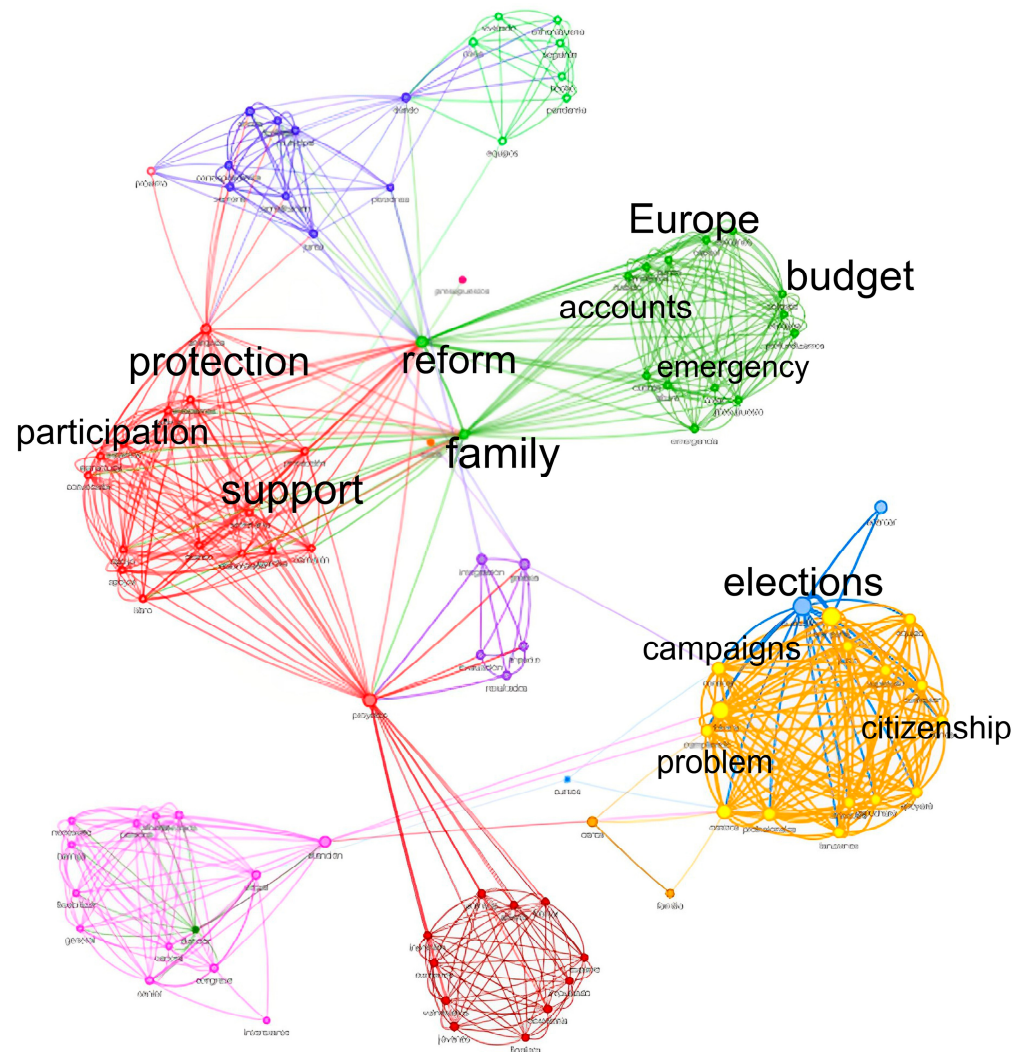
Figure 1. Keyword network of tweets.

On the other hand, there are clusters of words that are weakly connected to the two main clusters seen above (1 and 2). Cluster 3 (orange) is made up of words such as citizenship, campaigns, elections, and issues, etc., as shown in Figure 1.

In this quantitative study, we are going to focus on the issues addressed in the candidates' messages. The purpose of this quantitative study is to answer the question of whether the candidates' discourse is adapted to the concerns of citizens.

- Study variables: For this study, we took as a reference value the issues that most concern Spaniards from the CIS study no. 3121 Barómetro of December 2015, specifically in the question asked: "What do you consider to be the main problem that currently exists in Spain?" On the other hand, we considered the topics that politicians talked about on social networks, using the data in Table 1 (topics of the messages).
- Methodological design: For the quantitative study, a bivariate correlation was used, and since the variables have a normal distribution, according to the Shapiro–Wilk statistical tests, the Pearson's correlation coefficient was used [51].
- Variables to be studied: The variables to be investigated are those shown below; the data are expressed as percentages of the total set of CIS interviews, with the "Don't know" responses being omitted, coding them as missing values. In addition, the candidate variables are also shown as percentages of the total number of messages. Table 1 shows these values.

Table 1. Quantifier of the topics discussed.

CIS	%
Unemployment	63.6
Corruption	13.3
Politics	6.8
The economy	3.8
Independence	3.2
Education and teaching	2.3
Health	2.3
Social inequality	0.5
Immigration	0.4
Drugs and alcohol	0.3
Public safety	0.3
Housing	0.2
Islamic terrorism	0.2
Other	2.8

4. Discussion

From the study carried out with the open-source network-analysis software Gephi on the data extracted from Twitter, we can highlight that: in the series analysed from 2015 to 2019, there are increases in the emission of tweets coinciding with the periods of electoral campaigns, and decreases after them [4].

With regard to the interaction between Twitter users, it is observed that the accounts related to political parties and the associations and social entities that participate do not interact with other users, being mainly of a self-propagandistic nature. On the other hand, interaction and conversations between users can be observed, especially in the defence of ideological positions on social services in general, their coverage or funding.

Personalisation and negativism are important factors in election campaigning in Spain, and can influence the way voters perceive and receive information [52].

Personalisation refers to the tendency of political parties and candidates to focus on themselves and their leadership rather than on issues or policies. This can lead voters to base their decisions on the candidate's image or personality rather than on their policy platform.

On the other hand, negativism refers to the tendency of political parties and candidates to attack or criticise their opponents rather than promote their own views. This can lead voters to receive biased or inaccurate information about different candidates and their policy proposals [53].

It is important for voters to inform themselves critically and seek reliable sources of information in order to make informed choices in elections.

5. Conclusions

In order to perform this study, one of the main problems encountered was the time-frame, as there are a large number of variables that make up an in-depth study of digital communication and, on the other hand, there is a large amount of data produced by this communication on social networks, even considering the short timeframe for data collection in the study, such as the electoral campaigns.

The social-services system has been one of the most neglected in recent years in terms of public services, both in terms of investment and in terms of social and public attention. This social crisis has made visible the importance of its services, especially to the most vulnerable groups and as a guarantor of basic needs.

On the other hand, when we process a large amount of data like we are dealing with in this research, it is necessary to have powerful computer equipment. This issue slowed down the performance of some analyses in Gephi, given the large amount of information that the programme had to process.

In the election campaign in Spain, social services are an important issue as they are essential to ensure a good quality of life for citizens. Social services include services such as health care, education, housing, social assistance and care for the elderly and disabled.

Political parties and candidates often propose policies to improve social services in the country. This may include increasing the budget for social services, improving the quality of services and increasing access to services for those most in need [54].

For example, some political parties propose increasing the budget for health care to improve the quality of, and access, to health services, while others propose improving education through increased investment in education and teacher training.

Immigration is another important issue in Spain's election campaign, as the country has experienced a large influx of immigrants in recent decades. Political parties and candidates often propose policies to manage immigration, including asylum and integration policies [55].

Other political parties propose policies to improve housing, such as building social housing and improving accessibility to housing services, for people with fewer resources.

In terms of social assistance, some political parties propose increasing benefits and services for the elderly and disabled, while others propose measures to combat poverty and reduce economic inequality.

Each election has its own issues and dynamics; it is important to keep up with current news and information to know what the main issues are and how the parties and candidates are addressing them. In short, social services are an important issue in election campaigns in Spain, as they are essential to guarantee a good quality of life for citizens. Political parties and candidates propose policies to improve social services in the country, with the aim of improving the quality of life of the population.

One of the future lines of research, due to time constraints, would be to study all the variables that influence digital-communication models and to continue to deepen this analysis over the next few years to see how the discourse on Twitter evolves. A study could also be carried out on how social networks are used to talk about social services in the United States and how this differs from the discourse in Spain. Finally, another study could focus on how a different social-media platform, such as Facebook, is used to discuss social services and how the discourse differs from Twitter.

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Article

Networked Learning Communities in Promoting Teachers' Receptivity to Change: How Professional Learning Beliefs and Behaviors Mediate

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Abstract: More research on networked learning communities (NLCs) and the causal mechanism among the effects of NLCs are needed. To better understand the impacts of NLCs and the influential factors, this study intended to discover how teachers' participation in networked learning communities affects their beliefs and behaviors of professional learning and further influence their receptivity to change. Adopting a survey design, we collected 226 valid questionnaires from the pilot schools joining the program of Learning Community under Leadership for Learning supported by the Ministry of Education in Taiwan. First, the results indicated that the program's intervention of NLCs had a significant positive effect on teachers' receptivity to change. Second, teachers' participation in NLCs also showed a significant impact on their beliefs and behaviors regarding professional learning. Third, teachers' beliefs in professional collaborative learning could significantly enhance their behaviors of professional collaborative learning. Fourth, the program's intervention, employing hands-on professional learning activities, had a significant impact on teachers' inclination to realize the program, both through direct influence and the mediation of beliefs about professional learning. The results acquired from this study would be conducive to developing strategies to support implementing the NLCs program.

Keywords: curriculum reform; lesson study; networked learning community; professional learning community; program evaluation; receptivity to change; teacher beliefs; teacher behaviors; teacher change; teacher learning

1. Introduction

Responding to the challenges of a fast-changing society, many countries in the 21st century have launched curriculum reform to equip students with competencies for the future [1]. A constructivist-based curriculum features this wave of reform [2]. It demands that teachers transform their roles from delivering knowledge to facilitating student learning. However, receptivity to change is a prerequisite for teachers to move toward learner-centered pedagogy. To trigger the drive to innovate teaching, teachers can collaborate to create new professional knowledge, make professional experiences visible, and share instructional practices.

A variety of professional activities provides teachers to collaborate. One of the options is professional learning communities (PLCs). In the PLCs, teachers share ideas, resources, and expertise to improve their professional practice and students' academic success. Noteworthily, learning communities do not only occur within a school. A recent focus is on working across schools [3]. This form of teacher collaboration is referred to as networked learning communities (NLCs). Clusters of schools work in partnership to uplift professional learning quality and engage in continuous improvement [4]. Whether PLCs or NLCs, many countries have promoted them as a promising approach to school improvement. Since

2010, in Taiwan, the Ministry of Education has also taken steps to encourage their development [5]. In addition, a different approach to learning communities developed by Manabu Sato, a Japanese scholar, was introduced to Taiwan [6,7]. Pan et al. [8,9] also developed an indigenous model of learning communities to meet the specific needs of teachers in the country and embarked on a learning community program across cities/counties. The program provides opportunities for teachers to work across schools. Investigating its effects renders this study.

The previous studies revealed that networked learning communities could be instrumental in helping teachers work across schools and share knowledge and resources [3,4,10,11]. By collaborating with teachers from other schools, teachers in NLCs can gain a broader perspective on teaching and learning and access a more comprehensive range of ideas and strategies. It can be constructive in addressing the increased complexity of challenges teachers face. Nevertheless, the effects of NLCs are not yet conclusive [12,13]. How learning communities result in the desired outcomes and if teachers' beliefs and behaviors play a role in the causal mechanism also await to be understood. Moreover, receptivity to change is influential in implementing reform initiatives [14,15]. Investigating the concept of receptivity may provide hints for policymakers and school leaders to design effective policy tools. So, we used it as the outcome variable. In summary, this study aimed to examine the program effect of NLCs in promoting teachers' inclination to adopt the change initiatives regarding operating their classrooms as learning communities and being actively involved in teacher learning communities. A further attempt was to unpack the causal mechanism among teachers' participation in NLCs, beliefs and behaviors of professional learning, and receptivity to change.

2. Conceptual Background

2.1. Networked Learning Communities

Professional learning communities are one of the most effective strategies for teacher change and school improvement [16–20]. They involve a paradigm shift from traditional professional development focusing on one-shot activities to continuous learning in the workplace [21–23]. In the literature, PLCs are described with the characteristics of shared values and vision, collective responsibility, reflective professional inquiry, and the promotion of group and individual learning [24,25]. In addition to the discourses and practices of PLCs developed by the West, there are also unique ways created in Asia to implement PLCs. In Japan, Sato [6,7], based on the theories of Dewey and Vygotsky, proposes the "learning community" (xue xi gong tong ti) approach to transform schools. Building collegiality among teachers and constructing classrooms as learning communities through collaborative learning are the two essential elements of his viewpoints. The former originates from traditional lesson study in Japan. As a Japanese form of professional development, lesson study refers to the collaborative study of classroom lessons [26]. Teachers conduct an action-inquiry cycle in three steps: working together to plan the lesson, conducting the lesson with one teacher teaching and others observing, and discussing the lesson taught based on the data collected [27].

In a reform context of extending basic education from nine to twelve years, Sato's learning community approach was introduced to Taiwan in 2012 [7]. To accommodate the needs of local teachers, Pan and colleagues [8,9] constructed an indigenous learning community model called *Learning Community under Leadership for Learning*. It integrates the conceptualizations from Sato, Western theories, and place-based discourses and practices. The university, school, and government partnership was established to promote the indigenous learning community model. There were schools from five cities/counties which joined the program. The program's operation has made PLCs not limited to one school. Networked learning exists across schools.

Based on the theory of action, professional learning materializes significant changes in practice. In the learning process, interactions occur within and across schools. Networked learning communities distinguish themselves from other networks by focusing on learning.

Their orientation is to involve collaborative participation in creating knowledge. Through the process of engaging in cultural practices and shared learning activities, individual and collective knowledge in the communities is enriched or transformed. The creation of knowledge leads to participants' cognitive reframing and new ways of working that can be applied to classrooms and schools [4,28]. The networked learning communities are to nurture innovative knowledge communities within schools by connecting school-based groups with their counterparts in other schools. They can facilitate the key actors to share ideas and practices and create new knowledge. Individuals play a role in connecting schools and networks through active participation in the community and the construction of artifacts that serve as links between the network and the school. It creates a two-way flow of information and knowledge, allowing schools to upload and download ideas and practices from the network [3,4,17].

2.2. Professional Learning

Professional learning activities are designed to advance teachers' knowledge and skills and develop new teaching approaches that can help improve student achievement. However, traditional professional development strategies have been criticized as being fragmented, poorly conducted, and neglectful of the role of adult learning [29,30]. Cole [31] also commented that conventional teacher training was often decontextualized from teachers' classroom practice. Professional development, to be effective, requires teachers to manifest their learning processes in their roles in the classrooms and school communities [30].

From a complexity theory perspective, teaching knowledge is not a static body of information in the teacher or outside of the teacher [32]. Instead, it is a dynamic and constantly evolving process influenced by various factors, such as the teacher's experiences and interactions with colleagues and students. In this view, learning is also a continuous process that involves the ongoing transformation of both the learner (teacher) and the knowledge being learned. As the teacher learns and gains new knowledge, their understanding of the subject matter and teaching practice are transformed. Thus, more intensive, collaborative, job-embedded, and long-term professional learning is needed, which is PLCs [4,22,33,34].

Lesson study is another approach to professional learning that has been successful in Japan and other Asian countries. In lesson study, teachers work together to plan and observe lessons and then reflect on the results to improve instruction. Another model for teacher learning is the Taiwanese model, which promotes learning communities at the classroom, teacher, and school levels. As noted earlier, Sato's [7] learning community approach was transformed with other ingredients into an ingenious Taiwanese model [8,9]. In this model, students, teachers, and staff can learn and grow together when shaping the school as a learning community. Teacher learning communities gather teachers to share knowledge and expertise, ask questions, and seek feedback from colleagues. In the classrooms as learning communities, teachers enact learner-centered pedagogy, students learn collaboratively, and all the participants work together and support one another. As a result, learning occurs between teachers, between teachers and students, and between students.

There have been numerous studies on professional learning communities (PLCs) that have examined their effects on various aspects of education, including teachers' instructional practice [35,36], teacher trust and commitment [14], and student learning outcomes [37]. However, there is limited research on the causal linkage of learning community effects [3,34], and the evidence for the effectiveness of NLCs is inconclusive [12,13].

Another area that has received little attention in the research on learning communities is the way in which teachers' beliefs and behaviors may change as a result of participating in networked learning communities. This is a critical issue to explore as understanding how teachers' beliefs and behaviors are impacted by their participation in NLCs can help us understand how they may be more receptive to change. The previous research on beliefs and behaviors in education has often focused on teaching and learning [38–42]. This study attempted to fill the gap by examining how teachers' beliefs and behaviors

about professional learning may mediate the effect of participation in NLCs on receptivity to change.

2.3. Receptivity to Change

Receptivity to change refers to an individual's inclination to adopt new ideas, practices, or processes. In the literature, receptivity is often measured using four aspects: "characteristics of the change, managing the change at school, value for the teacher, and perceived value for students" [43] p. 358. Behavioral intention is employed as an indicator to assess teachers' receptivity toward reform initiatives [43–45]. Several studies applying the model proposed by Waugh and colleagues [42–44] have explored teacher receptivity to reform in Hong Kong and China to understand how it influences teachers' implementation of change initiatives [14,15].

The measurement of teacher receptivity considers the content of the proposed change initiatives. So, we need to address the reform context of the research site. In Taiwan, the government has encouraged the adoption of constructivist pedagogy and collaborative curriculum development as part of an effort to extend basic education from nine to 12 years and implement the new Curriculum Guidelines [46]. In this study, we examined teachers' receptivity to change regarding implementing the learning community program, which aligns with the reform trend of promoting learner-centered pedagogy and teacher collaboration. Understanding teachers' receptivity to this program can help policymakers and school leaders support teachers in implementing the program and achieving the desired outcomes.

As noted earlier, investigating receptivity to change has practical implications for program implementation, and the reviewed literature unfolds that explorations of the causal mechanism for networked learning communities are still scarce. Therefore, we intended to discover how teachers' participation in NLCs affects their beliefs and behaviors of professional learning and further influences their receptivity to change. The conceptual framework proposed is displayed in Figure 1. The research questions we formulated are as follows:
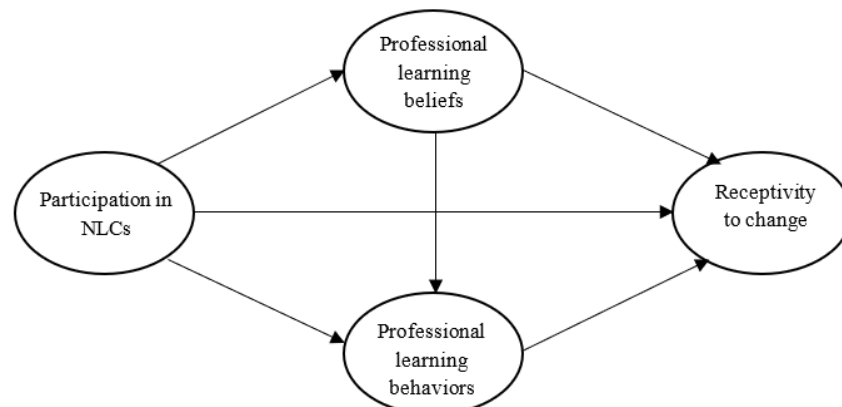
Figure 1. The conceptual framework.

1. What are teacher perceptions of participation in networked learning communities, beliefs and behaviors of professional learning, and receptivity to change?
2. How does teachers' participation in networked learning communities affect beliefs and behaviors of professional learning and receptivity to change?
3. What are the associations between teachers' beliefs and behaviors of professional learning and their receptivity to change?

3. Methodology

3.1. Participants and Procedures

This study employed a quantitative survey design to examine the effects of the networked learning community program. The participants were selected from the pilot schools of the *Learning Community under Leadership for Learning* program supported by the Ministry of Education in Taiwan. There were 737 teachers at the 33 pilot schools (15 elementary, 16 junior high schools, and two senior high schools). This study only analyzed the data of elementary and junior high school teachers. With half of the teachers participating in the program as subjects (including teachers, office directors, and office section chiefs), a total of 226 valid questionnaires were collected from an online survey. The characteristics of the respondents are shown in Table 1.

Table 1. Characteristics of the respondents.

Variables	Categories	N	%
Gender	Male	75	33.2
	Female	151	66.8
Years of experience at the school	5 years and below	66	29.2
	6–10 years	35	15.5
	11–15 years	55	24.3
	16–20 years	43	19.0
	21 years and above	27	11.9
Duty	Office directors	39	17.2
	Office section chiefs	46	20.3
	Homeroom teachers	101	44.7
	Subject teachers	40	17.7
Subjects	Mandarin	83	36.7
	English	26	11.5
	Mathematics	19	8.4
	Natural sciences	30	13.3
	Health and physical education	15	6.6
	Social studies	13	5.8
	Integrative activities	11	4.9
	Arts	17	7.5
	Life curriculum	1	0.4
	Other types of courses	11	4.9
School level	Elementary school	131	58.0
	Junior high school	95	42.0

3.2. Instruments

In order to measure the effects of the networked learning community program, the questionnaire consisted of four scales. Teacher participation in the learning communities is conceptualized as the program activity (independent variable). Professional learning beliefs and behaviors are regarded as the short-term program outcomes (mediating variables), and teachers' receptivity to change is used as the intermediate program outcome (dependent variable). To confirm the construct validity of the scales, we conducted confirmatory factor analysis (CFA) and reported values of the composite reliability (CR) and average variance extracted (AVE). CR shows the degree of internal consistency of the latent variables, with a value higher than 0.60 as the standard [47]. AVE indicates the average variation explanatory power of each observed variable to the latent variable to which it belongs, and the value is preferably higher than 0.50 [48].

Networked learning communities. Teachers' participation in learning communities is used to assess their critical experiences of the program. The scale consists of three items: "participating in class observations in learning communities", "participating in discussion

after class observation in learning communities", and "participating in joint lesson planning in learning communities". On a five-point Likert-type scale, participants were asked to respond to the frequencies of their participation in each activity from "never", "one to two", "three to four", "five to six" to "seven and more" times. The CR value was 0.93, and the AVE value was 0.81.

Professional learning beliefs. Based on social constructivism [49] and the ideas of teacher learning communities proposed by Sato [7] (2012) and Pan et al. [8,9], three items were developed to measure teachers' beliefs of professional learning. Participants were asked to rate their actual feelings about the statement of each item on a six-point Likert-type scale (1 = strongly disagree; 6 = strongly agree). The items are "Although joint lesson planning takes more time, it is more effective and rewarding than doing it alone", "Although the open class is a bit disturbing, it is still worth it", and "As a teacher, you must be able to discuss your teaching ideas and methods with others in order to teach better". The CR value was 0.76, and the AVE value was 0.52.

Professional learning behaviors. Teachers' behaviors of professional learning are evaluated by three items using a six-point scale. These items reflect the behaviors that are encouraged in the communities [5,9]. The items are "I discuss with my peers how to design learning activities, such as big ideas, key questions, and what students are able to know and do", "I discuss with my peers whether and where student learning is happening", and "I discuss the multifaceted nature and particularity of student learning with peers through class observation". The CR value was 0.88, and the AVE value was 0.71.

Receptivity to change. In order to evaluate teachers' receptivity to implement the learning community program, three items are developed using a six-point scale. The items are "I like to teach using the learning community model", "I am proud of being a teacher who implements the learning community model", and "I like to think about how to teach better by using the learning community model". The CR value was 0.93, and the AVE value was 0.82.

Overall, the CR values for the four scales ranged from 0.71 to 0.93, which all exceeded the desired level of 0.60. The AVE values for the four latent variables also met the required standard (>0.50) [48]. The indexes indicate that the model's convergent validity was satisfactory. Concerning the discriminant validity, it was verified by comparing the square root of the AVE of each variable with the correlation coefficients of the variable with other variables. A variable is regarded as distinctive from other variables when the square root value is higher than the correlation coefficient [48]. In Table 2, the square root of the AVE of each variable in the diagonal is greater than its contrasting correlation coefficients. Therefore, it shows acceptable discriminant validity of the model.

Table 2. Discriminant validity of the main constructs.

	AVE	Participating in NLCs	Professional Learning Beliefs	Professional Learning Behaviors	Receptivity
Participation in NLCs	0.81	**0.90**			
Professional learning beliefs	0.52	0.18	**0.72**		
Professional learning behaviors	0.71	0.29	0.71	**0.84**	
Receptivity to change	0.82	0.34	0.67	0.58	**0.91**

3.3. Analysis Strategies

We used SPSS 24 and AMOS 24.0 to conduct the statistical analysis. First, the descriptive statistics, including means, standard deviations, and correlations of the variables, were computed to understand teachers' participation in networked learning communities, their beliefs and behaviors of professional learning, and their receptivity to change. Second, structural equation modeling was conducted to verify the relationships among the variables. Generally recommended indices, including the root mean square error of approximation (RMSEA), the comparative fit index (CFI), the Tracker–Lewis index (TLI), and the standardized root mean squared residual (SRMR), were used to determine the model fit. The

standard values CFI $\geq$ 0.90, TLI $\geq$ 0.90, RMSEA $\leq$ 0.08, and SRMR $\leq$ 0.08 were used as cutoffs for acceptable data fit [50]. Third, to ensure the quality of the mediation analysis, bootstrapping was used to confirm the significance of the indirect effect by resampling the data 5000 times to yield a parameter estimate for indirect and total effects. When the 95% bias-corrected confidence interval for the parameter estimate does not contain zero, the mediating effect is regarded as statistically significant [51,52].

4. Findings

4.1. Descriptive Statistics and Correlation Analysis

The descriptive statistics of all variables are presented in Table 3. The mean score for teacher participation in networked learning communities was 2.74 on the five-point Likert-type scale. Regarding beliefs and behaviors of professional learning, the mean scores were 4.71 and 4.74 on the six-point scale, respectively, which were at a high–intermediate level. In terms of receptivity to change, the mean score was 4.46. It shows that teachers had a moderately high willingness to participate in the program. Concerning the correlation, the four variables were all positively related.

Table 3. The means and correlation matrix.

Variables	M	SD	1	2	3
1. Participation in NLCs	2.74	0.96			
2. Professional learning beliefs	4.71	0.72	0.18 **		
3. Professional learning behaviors	4.74	0.76	0.31 ***	0.59 ***	
4. Receptivity to change	4.46	0.91	0.36 ***	0.57 ***	0.54 ***

Note: ** refers to $p < 0.01$, *** refers to $p < 0.001$.

4.2. The Effects of Networked Learning Communities on Professional Learning and Receptivity to Change

Based on the theory of the teacher learning community program, the study hypothesized the relationships among teacher participation in networked learning communities, beliefs and behaviors of professional learning, and receptivity to change and examined them using a mediation model. The standardized estimation of the structure model is shown in Figure 2, with a satisfactory fit for the data (RMSEA = 0.040, CFI = 0.991, TLI = 0.988, SRMR = 0.041) [47,53,54].
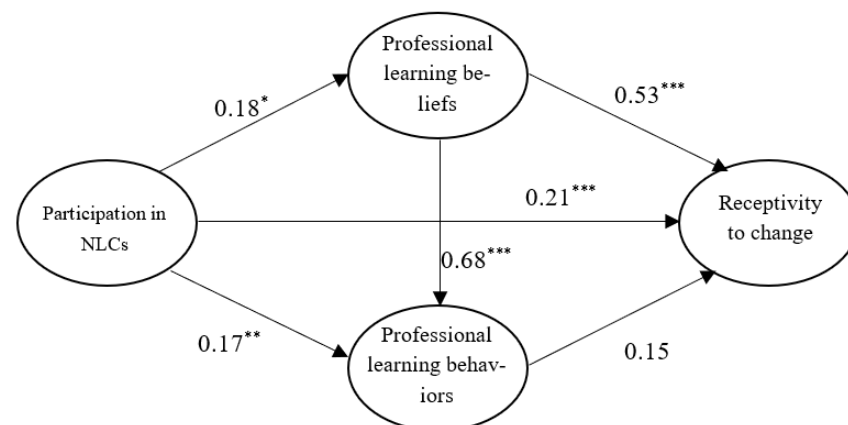
Figure 2. The mediation model of networked learning communities affecting professional learning and receptivity to change. Note: * refers to $p < 0.05$, ** refers to $p < 0.01$, *** refers to $p < 0.001$.

Examining the influencing paths, the program activity, namely, teachers participating in networked learning communities, could directly affect teachers' beliefs of professional learning ($\beta = 0.18$, $p < 0.05$), behaviors of professional learning ($\beta = 0.17$, $p < 0.01$), and receptivity to change ($\beta = 0.21$, $p < 0.001$). Teachers' beliefs in professional learning had

a significant positive effect both on their behaviors of professional learning ($\beta = 0.68$, $p < 0.001$) and receptivity to change ($\beta = 0.53$, $p < 0.001$). However, teachers' behaviors of professional learning did not have a significant impact on their receptivity to change ($\beta = 0.15$, $p > 0.05$).

To confirm the impact of the mediation effects, we conducted significance tests on the mediators' specific indirect effects using bootstrapping procedures with a 95% percentile interval. The results in Table 4 reveal that participating in networked learning communities could promote teachers' receptivity to change by strengthening teachers' beliefs in professional learning. However, the impact of participating in networked learning communities on receptivity to change was not effective through the mediation of behaviors of networked learning communities. In other words, the model displayed a partial mediation, and teachers' beliefs in professional learning were the key mediator.

Table 4. Bootstrapping results of standardized indirect effects.

	Point Estimates	Product of Coefficients		Bootstrapping		
				Percentile 95% CI		
		SE	Z	Lower	Upper	*p*
Participation in NLCs→PL Beliefs→Receptivity	0.089	0.044	2.023	0.017	0.194	0.015
Participation in NLCs→PL Beliefs→Receptivity	0.023	0.023	1.000	−0.010	0.086	0.159
Participation in NLCs→PL Beliefs→PL behaviors→Receptivity	0.017	0.019	0.895	−0.007	0.076	0.176

Note: PL Beliefs: professional learning beliefs, PL behaviors: professional learning behaviors.

5. Discussion and Conclusions

In order to assist teachers in operating their classrooms as learning communities and enacting learner-centered teaching, an essential part of the *Learning Community under Leadership for Learning* program investigated in this study is the teacher learning community of NLCs. It encourages teachers to participate in lesson study for sustainable professional development and support developing learner-centered classrooms [8,9,55]. By being exposed to the practice of lesson study, teachers can experience and practice the process of this "new" approach to professional learning. We gathered data from elementary and junior high school teachers in Taiwan and examined the extent to which participation in NLCs leads to changes in teachers' beliefs and behaviors of professional learning and receptivity to change. In addition, we addressed the research gap by unpacking the causal mechanism of the NLCs' effects. Four main findings can be concluded as follows:

First, the program intervention of networked learning communities had a significant positive effect on teachers' receptivity to change. Second, teachers' participation in networked learning communities also showed a significant impact on their beliefs and behaviors regarding professional learning. Third, teachers' beliefs in professional collaborative learning could significantly enhance their behaviors of professional collaborative learning. Fourth, the partially-mediated model showed that the program intervention employing hands-on professional learning activities had a significant impact on teachers' inclination to realize the program, both through direct influence and the mediation of beliefs about professional learning. In other words, although teachers' beliefs and behaviors about professional learning were important factors that affected their receptivity to the new program, only beliefs had a statistically significant mediating effect.

Three meaningful issues surfacing from the findings are worth discussing. The first is about the effects of networked learning communities. As the networked learning communities program promotes a form of contextualized collaborative learning rooted in authentic classroom situations, teachers can develop and deepen their knowledge through interac-

tions in the community of practice [56]. In particular, teachers participating in the program are encouraged to operate the lesson study procedure. Teachers can learn how to cultivate a learner-centered classroom through observation. They also learn how to plan a lesson collectively, how to observe a class, give feedback based on observations, and understand the whole procedure by joining the lesson study activities provided by the program. In addition, teachers not only exchange ideas within the school but also observe, discuss, or plan lessons with colleagues from other schools. Teachers actively engaged in their learning and are open to new ideas and approaches, particularly acquired benefits from external professional advice and resources through the NLCs. Teachers enhance their risk-taking skills and adapt to innovative teaching approaches through collaboration [57,58], contributing to their inclination to change.

When teachers witness the feasibility of classroom practice and the changes in student learning, their beliefs and behaviors may change with it [59,60]. Individual and collective knowledge is enriched in the learning process. The new knowledge teachers create leads to the reframing of conceptualization and finding new teaching approaches [4,28]. A two-way flow of information and knowledge further affords schools to upload and download thoughts and experiences from the network [3,4,17]. It broadens the avenues to promote the possibilities to render changes in teachers' beliefs and practices. Teachers' professional identities may also be reshaped gradually [61,62]. In sum, the results of this study demonstrated the effects and value of experiential learning in networked learning communities.

The second issue is about the relationship between beliefs and behaviors. There are different views in the previous literature on which of the changes comes first. Early theories of change derived from Lewin's [63] psychotherapeutic model held that professional development activities lead to changes in beliefs and attitudes, followed by changes in classroom behavior. However, some other studies argued that teachers only developed their recognition when they used it in the classroom. Guskey [64] proposed a new interpretation model by advocating that teachers' teaching behaviors change first. Then comes the change in teachers' beliefs and attitudes as teachers witness the improvement in students' learning.

Third, our conceptual framework hypothesized that teachers' participation in networked learning communities could directly affect teachers' receptivity and indirectly through its impact on teachers' beliefs and behaviors. However, the findings only suggested teacher beliefs as an effective mediator. It reveals that in practice-oriented learning communities, teachers could observe, participate, and witness the changes brought by practices. As a result, their temptation to experiment with operating their classrooms and active engagement in professional collaboration is triggered. Therefore, changes in teachers' beliefs were sufficient to enhance their receptivity to the program rather than through the mediation of behavioral change.

The findings highlight the importance of providing teachers with opportunities to engage with new ideas and practices in a supportive environment. By participating in networked learning communities, teachers can learn from each other and the experiences of their colleagues, which can help to shape their beliefs about teaching and learning. It, in turn, can increase their receptivity to change and encourage them to try new approaches in their classrooms. So, first of all, it is suggested to utilize practice-oriented teacher collaborative learning as the intervention in teacher learning and instructional innovation programs. It is more authentic and convincing for teachers to learn to change in a real classroom context and by observing, discussing, and practicing. Second, from this study, policymaking and school leaders may realize that teachers' beliefs are crucial for their willingness and openness to adopting new initiatives. Understanding and assessing teachers' beliefs would be essential when implementing reforms. Finally, the direction for future research is worthy of being noted. The study utilized a survey design to verify the influencing paths of an NLCs program. The more nuanced reasons why these effects take place is a question that further exploration could address. As demographic and personal variances of teachers might influence teachers' beliefs and tendency to change and affect the results of the survey,

comparing the variabilities can also provide insightful findings. Moreover, the effects of teacher NLCs on student learning is another critical empirical issue to be explored.

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Article

EFND: A Semantic, Visual, and Socially Augmented Deep Framework for Extreme Fake News Detection

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Abstract: Due to the exponential increase in internet and social media users, fake news travels rapidly, and no one is immune to its adverse effects. Various machine learning approaches have evaluated text and images to categorize false news over time, but they lack a comprehensive representation of relevant features. This paper presents an automated method for detecting fake news to counteract the spread of disinformation. The proposed multimodal EFND integrates contextual, social context, and visual data from news articles and social media to build a multimodal feature vector with a high level of information density. Using a multimodal factorized bilinear pooling, the gathered features are fused to improve their correlation and offer a more accurate shared representation. Finally, a Multilayer Perceptron is implemented over the shared representation for the classification of fake news. EFND is evaluated using a group of standard fake news datasets known as "FakeNewsNet". EFND has outperformed the baseline and state-of-the-art machine learning and deep learning models. Furthermore, the results of ablation studies have demonstrated the efficacy of the proposed framework. For the PolitiFact and GossipCop datasets, the EFND has achieved an accuracy of 0.988% and 0.990%, respectively.

Keywords: multimodal fake news detection; Multimodal Factorized Bilinear pooling; natural language processing; social sensing; misinformation/disinformation

1. Introduction

Context-aware methods, i.e., content-based models, and social context-aware methods, i.e., social context-based models, are two of the most used techniques for detecting fake news [1–4]. Content-based models focus on the content of news, i.e., title, body, image, and video. While, socially aware methods take user creation time, engagements, connections, comments, and reposts into consideration. The socially aware methods further extend their expertise in measuring the propagation patterns and comparing them with fake news propagation patterns to detect anomalies, known as propagation structure-based methods. Furthermore, comments, likes, and retweets of a post are also examined to detect irregularities. These methods are known as post-based methods [5–13].

The content-based techniques offer a simpler and more realistic method for detecting fake news, especially in the initial stages, but unimodal content-based fake news detection techniques are inefficient at identifying false news since they employ distinct textual [14–27] and visual characteristics [28–34]. However, users are purposefully led astray on social media by fake news that is packaged in a variety of genuine facts. Therefore, additional

measures such as social context are considered for the accurate detection of fake news. For news articles, we have also introduced a similarity measure between the title and body of news. As the majority of fake news titles are just clickbait and the body of the news does not match the title [35]. This will provide very crucial information about news articles' authenticity and support the process of fake news detection. Furthermore, stance detection is incorporated for social media news, this is an important measure to determine a public standpoint and judgment towards a user's social media post for fake news detection [9].

The socially aware methods are targeted and effective, but data collection, noisy data, irrelevant data, and missing data pose a lot of challenges. Therefore, a multi-model approach for fake news detection is proposed using socially aware methods including user profile associations, user engagements stance, and context-aware methods including textual, visual features, and similarity measures. Compared to the previous works [36–60], we have added a wider range of news-related and social context features. We attempt to uncover fake news within a few minutes of inception. Our research is the first of its kind to use both credibility and stance in a multimodal automated fake news detection system. The primary objective of this study is to integrate content-based approaches with the social context to significantly boost the model's effectiveness.

The following is the primary contribution that this study has made:

i.   A similarity measure for the news article title and body for the credibility of the article.
ii.   User credibility based on a multi-feature of a user profile.
iii. Fusing of textual and visual features via multi-modal factorized bilinear pooling.
iv.   A multimodal approach for identifying fake news based on news content and social context.
v.   Evaluation, findings, and a critical examination of the proposed framework.

The various sections of the paper are structured as follows: A review of the literature is provided in Section 2. In Section 3, the proposed model and its components are described. Section 4 describes the experimental setup. Section 5 incorporates the results and discussions. Finally, Section 6 concludes and explores future directions.

2. Literature Review

In this section, we provide a high-level summary of works that are pertinent to the proposed model. The researchers used content-based, social context-based, and hybrid features in multimodal fake news detection methods to verify the authenticity of the news. The following subsections provide descriptions of these techniques.

2.1. Content-Based Fake News Detection

The bulk of textual and visual data is utilized to create content-based characteristics. Textual qualities display the author's thoughts and ideas, additional it also exhibits their favored writing style [61,62]. Modeling and primarily expressing textual representations with deep neural systems [63–65] and tensor factorization [66–68] has been shown to be effective in detecting fake news. Various parts of fake news broadcasts can be discovered by extracting visual characteristics from visual components such as pictures and videos [35,69,70].

The framework provided by [71] merged textual and visual aspects into a unified totality. The authors utilized a hierarchical attention network with four layers to achieve their objective. They discovered hidden patterns in the title and body material of the news section. A unique component of the recommended method was the creation of a visual summary. The authors analyzed the semantic similarity between the produced visual summary and title with the content of the news article. They proved that their proposed strategy produced superior results compared to the current best practices. Moreover, a content-based study [72] offered a semi-supervised text fake news classification system utilizing a convolutional neural network that replicates temporal patterns. The authors trained the proposed technique by applying convolutional filters of different sizes on the titles and body of news items and then concatenating the generated feature vectors.

The analysis of testing findings revealed the promising performance of the suggested approach for evaluating whether or not news items were manufactured relative to their legitimate sources.

Vishwakarma et al. [70] suggested an image-to-text converter, entity extractor, web-scraping tool, and processing node to authenticate bogus news. First, it alters a news article's picture to extract its content. The second element of the system detects and removes text. The third component searches Google for suitable connections using entity strings. Finally, the fourth collects the links' text and estimates the proportion of entities shared by the image and the summed material. The proportion also reflects connection credibility. Finally, the ratio of trustworthy to untrustworthy connections determines news credibility.

Other studies examined content-based models using reinforcement learning, attention-residual networks, and fact-checking URL recommendation [73,74] "Hoax News Inspector" involves data collection and categorization [73]. The first module's query is the news article assertions. The second core module includes URL filtering, processing, and classification. URL filtering removes unwanted URLs. After collecting the most valuable URLs, the processing unit retrieves the characteristics needed to recognize fake news. A classification model predicts using all feature sets.

The Elementary Discoursed Unit, developed by Wang et al. [44], has a level of detail between the word and the sentence, making it ideal for the early detection of fake news. Mishra et al. [36] identified fake news by employing a probabilistic latent semantic analysis. Knowledge graph-based document representations can achieve state-of-the-art performance when combined with existing contextual representations, as demonstrated by Koloski et al. [37]. Dynamic fake news detection using a knowledge graph was proposed by Abdelnabi, Hasan, and Fritz [38] and Sun et al. [39]. Significant gains have been seen with some unimodal approaches to detecting fake news. Yet the majority of content published on social media and in the news is of the multimodal variety. So, it's clear that a detection method based solely on unimodal features is inadequate.

2.2. User Credibility Based Fake News Detection

Veracity in social media statistics is an urgent and modern problem. Given the sheer volume of information shared in the social media sphere, the authenticity of such information is especially important when individuals' personal details are concerned [75,76]. There are a number of proposed methods for assessing social media credibility [77–85]. There is a strong correlation between social network topology and user trustworthiness [86]. Using the strength of the ties between a user's Facebook friends, Podobnik et al. [83] offers a model to ascertain the level of trust between those friends. In addition, Agarwal and Zhou [82] provide an approach for gauging a social media user's reliability that makes use of a heterogeneous network in which each actor in the Twitter domain is represented by a distinct vertex type. An evaluation of reliability was conducted utilizing a regressive spread approach. However, the value of a weighting method and the passage of time are ignored in that work. The believability of each edge category should be evaluated independently, hence a weighting mechanism is required. Incorporating a temporal/time dimension is important since the value placed on trustworthiness changes throughout time. Aghdam et al. [87] and Al-Qurishi et al. [88] both go into further detail on the subject of credibility and the inclusion of network structure. Kožuh & Čakš [89] explored the topic of news credibility. They claimed that individuals' characteristics and level of interest in the news are the decisive factors in establishing credibility in social media news. The research also established a link between NFC and both confidence in the media and active participation in that trust.

Few studies [2,7–13,40–43] have tried to employ user profile characteristics for fake news detection. Wu et al. [12] identified bogus news by employing an LSTM network along propagation pathways and obtaining user personal information included from social media. To learn a representation for each tweet, Ma et al. [10] developed a recursive neural model that takes advantage of tree topologies in neural networks. To uncover the spread

of false information, Liu et al. [7] developed a time series classifier model using RNN and CNN. To better detect false news, Guo et al. [2] looked into the HSA-BLSTM model, which gathers information from both the text and the social context. One effective strategy for rumor detection was developed by Ma et al. [9] and Li et al. [8], which takes into account the user's perspective during multi-task learning. News circulation trends were graphically recorded by Wu et al. [13]. Unsupervised learning is utilized in the UbCadet model developed by Savyan and Bhanu [11] to identify compromised Twitter accounts.

The approach of rumor identification presented by Chen, Zhou, Trajcevski, and Bonsangue [40] makes use of multi-view learning and attention from several users. This method has the ability to learn and combine the representations of multiple users' perspectives throughout the tweet's propagation channel. Quantitative argumentation is the basis for Chi and Liao's [41] proposed QA-AXDS, a rumor-detection and user-interaction system that use a dialogue tree as its explanation model. Two parts make up the transformer framework-based model proposed by Raza and Ding [42]: an encoder element to extract representations from the fake news data and a decoder component to detect behavior based on previous data. To identify fake information on social media, Jarrahi and Safari [43] used CNN with three-dimensional input. They have concentrated their attention on the usefulness of the features offered by publishers

In this study, we analyze credibility as a complicated attribute used by publishers to identify fake news on social media and to present a multi-modal framework with a high level of performance.

2.3. Multimodal Fake News Detection

Deep neural networks have seen widespread application in multimodal data-dependent tasks in recent years, including the answering of visual questions [28], the captioning of images [53], and the identification of fake news [54,56,57,60]. Chen et al. [17] developed an attention-based RNN model that extracts and uses an attention mechanism to blend aspects of a text, image, and social context. For use in a variety of internet-of-things (IoT) applications, Singh et al. [55] developed a model known as an extreme learning machine (ELM). Yang et al. [59] analyzed both the text and the images and then used the adaptive tag (AT) algorithm to derive user-interested tags. The Text Image-CNN model proposed by Yang et al. [60] gathers information that is both overt and covert from both the text and the images to identify instances of fake news. Wang et al. [58] introduced the Event Adversarial Neural Network, a comprehensive framework for the identification of misleading information and event discriminators (EANN). Textual and visual characteristics were retrieved in the multimodal feature extractor section using the Text-CNN and VGG-19 models, respectively. Unfortunately, there is no clear method for using this methodology to uncover intermodal relationships. Khattar et al. [54] suggested a comparable framework, named Multivariational Autoencoder, for the identification of fake news (MVAE). An encoder module is responsible for teaching the MVAE model, the multimodal information's common representation or latent vector, which includes both textual and visual components. This latent vector is used by the decoder to recreate the original samples. SpotFake is a multimodal system for detecting false news that was developed by Shivangi et al. [57]. This model avoids the extra tasks of EANN and MVAE and achieves a greater detection accuracy increase. The BERT model for representing textual features and a pre-trained CNN model using the Imagenet database (VGG-19) for representing visual features, SpotFake delivers a reasonable accuracy improvement over EANN and MVAE compared to past efforts [54,58]. Shivangi et al. [56] created SpotFake+, an enhanced version of SpotFake [57]. This suggested architecture has the advantage of being able to manage a dataset including full-length articles. This model outperformed previous efforts [54,57,58] because it makes use of transfer learning to recognize a news item's written and visual characteristics.

As a means of exploiting both the visual and textual content of news articles, Zhou et al. [45] presented the FND-CLIP framework. A ResNet-based encoder and a BERT-based encoder were used to combine the deep-learning features of text and images,

respectively. Article classification has been improved by applying scaled dot-product attention to a fine-grained fusion of image and text data, as performed by Wang et al. [46]. Their technique focused on associations between visual characteristics and collected multimodal feature interdependence. Shivangi et al. [47] developed a method to selectively extract useful data from the dominant modality while discarding irrelevant data from the weaker modalities. Using a contrastive learning strategy, Chen et al. [48] have trained variational autoencoders (VAE) to compress pictures and texts and minimize the Kullback-Leibler (KL) divergence for news containing valid image-text pairs. The multimodal characteristics are then reweighted based on the matching cross-modal ambiguity score. An implementation of a two-stage network is provided by Wei et al. [49], which initially trains two unimodal networks to learn cross-modal correlation via contrastive learning before fine-tuning the network for false news detection. The model developed by Das et al. [50] incorporates a wide variety of characteristics seen in social settings and in news articles. The dynamic analysis uses a recurrent neural network (RNN) to model the temporal evolution pattern of the propagation tree and the stance network.

Davoudi et al. [51] identified news articles by source, username, and URL domain. These attributes were employed as statistical characteristics in an ensemble model comprising pre-trained models, a statistical feature fusion network, a unique heuristic approach, and news article variables. Segura-Bedmar and Alonso-Bartolome [52] categorized fake news using unimodal and multimodal approaches. Their multimodal technique integrates text and image data based on CNN architecture. Images were beneficial for manipulative content, sarcasm, and misleading associations.

The following are some of the issues that current multimodal fake news detection systems are facing. Although the majority of them attain plenty of context information, they still:

i.   Lack of similarity for title and body text.
ii.   Effective integration of text and visual features.
iii.   lack of user context information.
iv.   Lack of stance analysis.

The objective of this research is to extract characteristics that are helpful and relevant from the substance of the news. Because we take into account a variety of modalities, our attention is focused on the extraction of features from the text and visual contents of a news item. Many sequence models exist for processing text, but they can't develop persistent associations between words or access the input phrase in order. As a result, BRNN equipped with an attention mechanism is employed to analyze text features in both directions.

In addition, earlier research has employed CNN to extract visual characteristics, Nevertheless, as a result of its pooling operation and longitudinal sensitivity, CNN cannot retrieve more informative information. CapsNet has been used to address the issue of information extraction at CNN. The Routing-by-agreement approach and the Margin loss function are utilized to single out the visual components inside the photos of news items that are considered to be the most essential.

Furthermore, to improve the overall effectiveness of the identification of fake news, the suggested model combines semantically significant characteristics with cosine similarity perspective, and social context information to produce an improved feature vector representation for the supplied news. The goal is to combine the retrieved characteristics of the image and the text to get the highest possible correlation between the two and provide a more accurate shared representation. The Multimodal Factorized Bilinear-pooling (MFB) method allows us to accomplish this goal. The increased feature vector is further sent to the multi-perceptron layer. The output indicates whether or not the news item or tweet contains false news.

3. Methodology

The architecture of the proposed multimodal for fake news detection is presented in this section. Figure 1 represents the workflow and related modules.
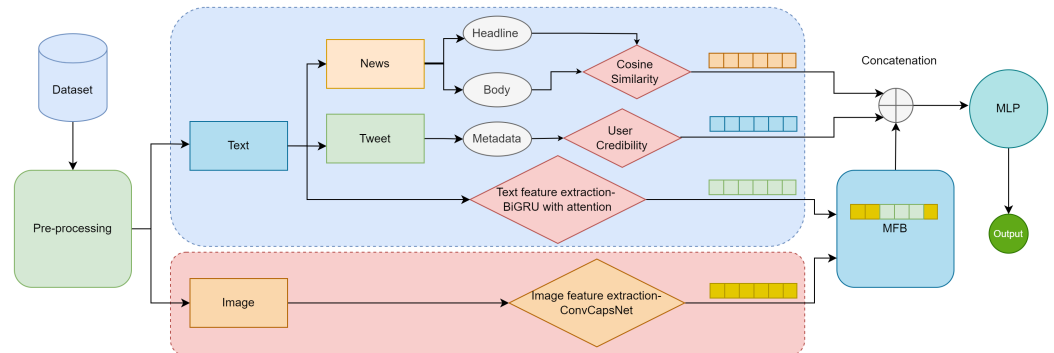
Figure 1. Architecture of the proposed multimodal for fake news detection.

Several text preparation techniques, like tokenization, phrasing, denoising, lemmatization, and stop-word removal, are used to turn documents into a representation appropriate for the classification model in the initial stage. The datasets feature photographs collected from various locations. Images have a high resolution, hence a robust system is needed to evaluate them in their native dimensions employing capsule neural networks. The processing of such high-quality images is time-consuming and expensive in all standard deep-learning models. We scaled all the pictures to 256×256 to overcome this problem. Image and text feature vectors are separately trained using neural networks. The news article credibility module calculates the similarity index for the item's title and body. Textual feature data from news articles is calculated with Semantic Encoding. Using metadata, the user credibility module ranks profiles. The fusion of textual characteristics and visual features is performed using multi-modal factorized bilinear pooling. Later the fused features are concatenated with text similarity and user credibility features. In the final stage, the concatenated features produced from the previous step are utilized as input vectors and fed into MLP for fake news classification.

3.1. Visual Encoding

The components of the image learning module are presented in Figure 2, followed by the description related to its processing.
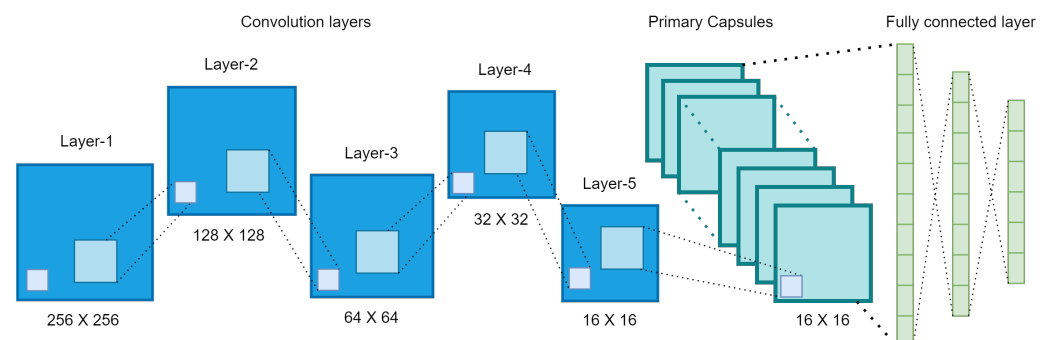
Figure 2. Image feature extraction using CapsNet with convolution.

To preserve item locations and attributes in a picture while modeling their hierarchical relationships, capsule networks have been constructed [90]. With the pooling layer, convolutional neural networks can extract the most insightful insights from their input. Since the data is pooled before being sent on to the next layer, likely, the network won't pick up on finer distinctions [91]. And the neural output that CNN generates is a scalar value. By

packing multiple neurons into each capsule, capsule networks provide a vectorial output of the same size but with distinct routings. [92] A vector's paths stand in for the pictures' settings. Scalar input activation functions like ReLU, Sigmoid, and Tangent are used by CNN. Instead, capsule networks employ a vectorial activation function described by the Equation (1) as squashing. If there is an item in the image, X_j squeezes short vectors toward 0 and long vectors towards 1 [93,94]. In capsule networks, the input value of capsule Y_j is calculated by adding the weighted sum of the prediction vectors $Z_{j|i}$ in the capsules of the lower layers, with the exception of the first layer. Multiplying the output Out_i of a lower-layer capsule by a weight matrix yields the prediction vector ($Z_{j|i}$) (W_{ij}).

$$X_j = \frac{|Y_j|^2}{1 + |Y_j|^2} \times \frac{Y_j}{|Y_j|}$$

$$Y_j = \sum_i N_{ij} Z_{j|i} \qquad (1)$$

$$Z_{j|i=W_{ij}Out_i}; N_{ij} = \frac{f(M_{ij})}{\sum_k f(M_{ik})}$$

where, X_j represents capsule j's output and Y_j its entire input. The dynamic routing procedure selects the coefficient N_{ij}. Logarithmic probability is a gift from M_{ij}. Log prior probability is calculated using SoftMax [95] and is equal to the total of the correlation coefficients between capsule I and capsules in the top layer. Objects of a certain class can be detected by calculating the margin loss in capsule networks using the Equation (2).

$$V_k = T_k \max\left(0, q^+ |X_k|\right)^2 + \alpha(1 - T_k) \max\left(0, |X_k - q^-|\right)^2 \qquad (2)$$

If class k exists, then and only then does T_k equal 1. The loss is down-weighted when the hyperparameters, $q^+ = 0.9$, $q^{-+} = 0.1$, are used [95]. Parameter information such as texture, color, location, size, etc. is contained in the direction of the vectors generated by the capsule networks, while the length of the vector reflects the likelihood of appearing in that region of the picture [94,96].

In this research, we present a capsule network with six convolution layers for classifying images of size 256×256. The number of convolution layers is raised to improve the performance of the primary layer's feature map. The first layer has 16 filters of size 5×5 with a stride of 1. After each layer, a Max-pooling of size 2×2 is applied. The second, third, fourth, and fifth layers contain 32, 64, 128, and 256 filters with dimensions of 5×5, 5×5, 5×5, and 9×9, respectively. The sixth layer is the primary layer, and it has 512 filters with 32 capsules containing filters of size 9×9.

3.2. Semantic Encoding

The text learning modules are represented in Figure 3, and the feature extraction process is discussed in the following paragraphs.

The proposed model seeks to learn information at the word, phrase, and document levels from various news articles and tweets. The word encoder is based on a bidirectional recurrent neural network (BRNN) [97], which allows the usage of variable-length contexts before and after the current word placement. Since we didn't want to use separate memory cells to keep tabs on the status of the input sequences, we turned to the Gated Recurrent Unit (GRU) [98], It works well for determining correlation over broad temporal ranges. Both reset gate $reset_t$ and update gate $update_t$ are included in GRU. Both attempts to control the state's access to the most recent data. The GRU computes its new state at time t using the Equation (3). Using the new sequence information, this is a linear interpolation between the old state C_{t-1} and the candidate state C_t. The update gate $update_t$ is responsible for deciding what percentage of the previously stored data will be kept and what percentage of new data will be added. Here, $update_t$ is calculated using Equation (4).
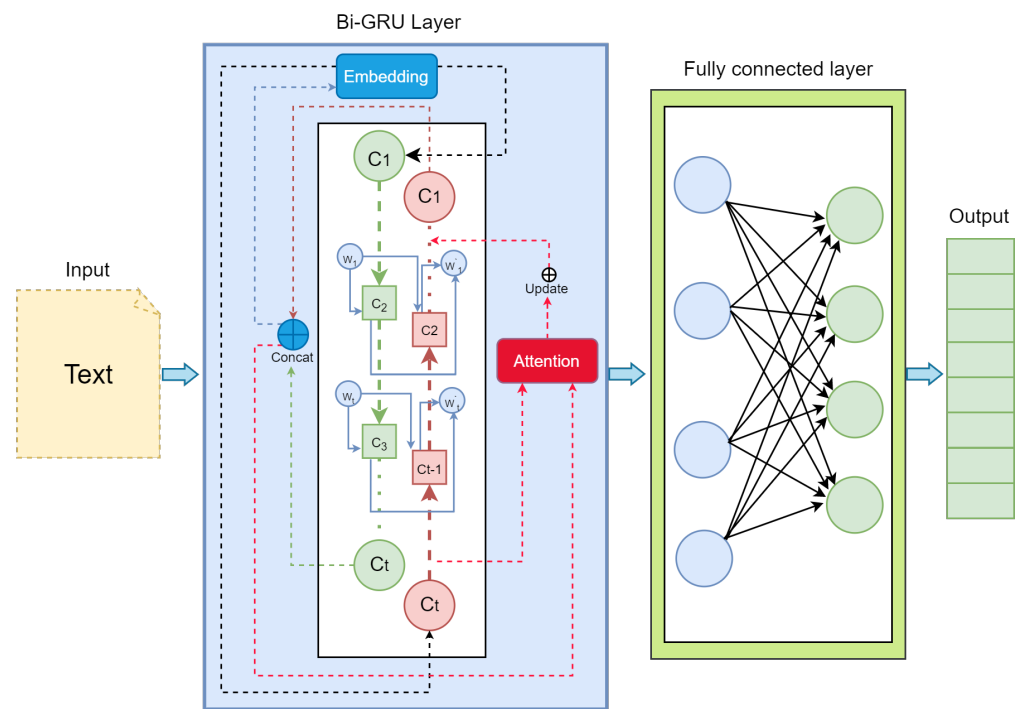
Figure 3. Text processing module using BiGRU and attention mechanism.

$$C_t = (1 - \text{update}_t)\tau C_{t-1} + \text{update}_t \tau \dot{C}_t \tag{3}$$

$$\text{update}_t = \sigma\left(W1_{\text{update}} Emb_t + W2_{\text{update}} C_{t-1} + W3_{\text{update}}\right) \tag{4}$$

where, Emb_t represents the embedding vector at time t. $W1$ represents the weight matric, $W2$ and $W3$ represents bias matrices with the proper dimensions. The symbol σ indicates a sigmoid activation function, whereas the operation τ denotes elementwise multiplication. The current state is calculated as $\dot{C}_t$ represented in Equation (5).

$$\dot{C}_t = \tanh(W1_C Emb_t + \text{reset}_t \tau((W2_C C_{t-1}) + W3_n) \tag{5}$$

where the reset gate reset_t is responsible for determining the amount of information from the previous state that is added to the current state. The bidirectional GRU employs hidden layers in both the forward and backward directions to perform an analysis of the input data, much like the unidirectional GRU does. The output is the result of adding together the computed values in both directions. Let $\overrightarrow{C}_t$ and $\overleftarrow{C}_t$ represent the forward and reverse outputs of the bidirectional GRU, respectively. The output is calculated by adding the forward and reverse outputs in order, such as $C_t = [\overrightarrow{C}_t, \overleftarrow{C}_t]$.

The sentence encoder takes the word representation as input and utilizes the embedding and bidirectional GRU layers to generate sentence-level vectors. After that, the sentence-level vectors are transformed into document-level vectors by the utilization of bidirectional GRU layers. There is a disparity in the amount of contribution made by individual words and sentences to the generative model. Consequently, the attention mechanism [90] is included in our effort to extract the crucial features of the model. Assume, the input text comprises M sentences, with T_i words per sentence. Let $word_{it}$ and $t \in [1, T]$ represent the words in the i. sentence. The embedding layer and bidirectional GRU layer are responsible for the transformation of a $word_{it}$ into the hidden state C_{it}. The transformation is described as Equation (6):

$$\overrightarrow{C}_{it} = \overrightarrow{GRU}(W1_e \text{ word }_{it}), t \in [1, T]$$
$$\overleftarrow{C}_{it} = \overleftarrow{GRU}((W1_e \text{ word }_{it}), t \in [T, 1] \tag{6}$$
$$C_{it} = \left[\overrightarrow{C}_{it}, \overleftarrow{C}_{it} \right]$$

where $W1_e$ represents the matrix of the embedding layer and $\overrightarrow{GRU}$ and $\overleftarrow{GRU}$ reflect the procedures described in the preceding section. Consequently, the attention weights of words α_{it} and sentences vectors s_i can be calculated as Equation (7):

$$W2_{it} = \tanh(W2_{\text{word}} C_{it} + W3_{\text{word}})$$
$$\alpha_{it} = \frac{\exp(W2_{it}^T W2_{\text{word}})}{\sum_t \exp(W2_{it}^T W2_{\text{word}})} \tag{7}$$
$$s_i = \sum_t \alpha_{it} C_{it}$$

During the training phase, the context vector $W1_{word}$ receives a random starting point and is simultaneously updated with new information. This vector may be thought of as a high-level representation of a fixed input across words [99,100]. The sentence vectors s_i are then transformed into the hidden state C_i using a second bidirectional GRU layer, as shown in Equation (8).

$$\overrightarrow{C}_t = \overrightarrow{GRU}(s_i), i \in [1, Q]$$
$$\overleftarrow{C}_t = \overleftarrow{GRU}(s_i), i \in [Q, 1] \tag{8}$$
$$C_i = \left[\overrightarrow{C}_i, \overleftarrow{C}_i \right]$$

Afterward, the attention weights of words α_i and item vectors v are determined using the formulas in Equation (9).

$$W2_i = \tanh(W1_s h_i + W3_s)$$
$$\alpha_i = \frac{\exp(W2_i^T W2_s)}{\sum_t \exp(W2_i^T w2_s)} \tag{9}$$
$$F = \sum_i \alpha_i C_i$$

To represent the sentence-level context vector, $W2_s$ is given a random starting point and is then updated in the same way as $W2_{w1}$. Through the foregoing training procedure, the item vector F that is generated from a text contains multilevel contextual information derived from both the word-level and the sentence-level structures. Therefore, we refer to it as F_T in the next parts.

3.3. News Article Credibility Module

Based on research by Dong et al. [101] on detecting sensationalism in headlines and bodies of articles, we hypothesize that the degree to which these two elements are the same is a good indicator of an article's reliability. To determine the degree of resemblance, we first embed the article body and title onto the same space and then calculate the cosine distance between them. Since cosine similarity captures the angle of the documents rather than the magnitude, it is an excellent similarity metric for determining the relationship of the documents regardless of their size. It is a mathematical measure of the cosine of the angle formed by the projection of two vectors into space, represented in Equation (10).

$$\text{Similarity (x,y)} = \frac{x \cdot y}{\|x\| \|y\|} = \frac{\sum_1^n x_i y_i}{\sqrt{\sum_1^n x_i^2} \sqrt{\sum_1^n y_i^2}} \tag{10}$$

The dot product of the two vectors is represented as $x.y = \sum_1^n x_i y_i = x_1 y_1 + x_2 y_2 + \ldots + x_n y_n$.

3.4. User Credibility Module

To locate socially trustworthy content, it is crucial to have a proper understanding of user interaction-based qualities. Examining the level of interest that users' followers have in their posts is a crucial part of this process. A feature-based ranking model is constructed using a measure that considers a number of critical characteristics shown in Figure 4.
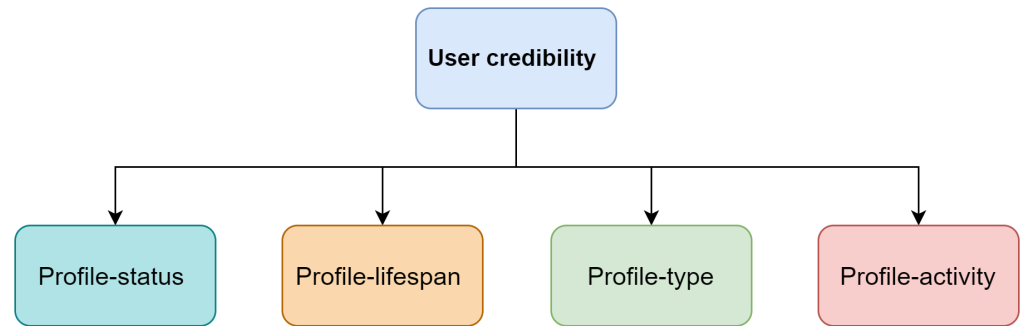
Figure 4. User credibility based on characteristics of user profile.

3.4.1. Profile Lifespan

It provides most information related to user credibility. Most of the time the misinformation is spread from user accounts that are not verified therefore the overall score for this feature is kept at the highest priority. The verified accounts get a 1 and the unverified accounts get a 0 P_{status} score.

3.4.2. Profile Status

It calculates the time information about the existence of user accounts on social media platforms. The variables under consideration are D_{SignUp} is the signup date for the user, D_{Start} is the date of creation of the social media platform, and D_{now} is today's date. The calculations are presented in Equation (11).

$$
\begin{aligned}
M_{\text{User}} &= D_{\text{now}} - D_{\text{signUp}} \\
M_{\text{Network}} &= D_{\text{now}} - D_{\text{start}} \\
P_{\text{lifespan}} &= M_{\text{User}} * M_{\text{Network}}
\end{aligned}
\tag{11}
$$

where M_{User} is the number of months of the user profile, and $M_{Network}$ is the number of months after the creation of a social network.

3.4.3. Profile Type

Every who uses social media agrees with the fact that the number of followers and friends can be a huge factor in determining the credibility of a user. The users on a social network can be roughly classified into three types. The first ones are looking for information, they mostly scroll through the platform, follow people, and barely post their own updates. The second ones are content creators with few to the huge number of followers, they update quite often and keep their followers interested in their content. The third ones do not get their head into the social network but rather keep it balanced. They don't follow everyone and mostly interact with their circle of friends only. The profile type is calculated as Equation (12).

$$
P_{type} = P_{followers} / P_{friends}
\tag{12}
$$

Here, the resultant P_{type} determines the type of the user. A score less than 0.7 indicates the user is a scroller, a score greater than 1.2 indicates the user is a content creator and a score between 0.7 and 1.2 indicates the user is a balanced user.

3.4.4. Profile Activity

The content of a post is very critical to gaining and losing followers. The number of times a user posts new content or retweets is an essential dimension of its credibility. In this study, we give less score to the retweet and more score to the original content posted by a user, represented in Equation (13).

$$P_{activity} = \left(\frac{P_{post}}{M_{User}} + \frac{P_{rt}}{4 * M_{User}} \right) \tag{13}$$

where $P_{activity}$ is the content score associated with the profile. P_{post} is the number of posts, P_{rt} is the number of retweets, and M_{User} is the age in the number of months for the user profile.

3.4.5. Total Credibility

The total user credibility C_{Total} score is computed by combing the profile status (50%), lifespan (20%), type (10%), and activity (20%) scores, represented in Equation (14). After that, a feature vector representing the user's trustworthiness is constructed by computing the average of the vector values associated with each location vector.

$$C_{Total} = (P_{status}) * 5 + \left(P_{lifeSpan} \right) * 2 + P_{type} + \left(P_{activity} \right) * 2 \tag{14}$$

3.5. Multi-Modal Factorized Bilinear Pooling (MFB)

To generate a common representation, MFB provides a phenomenon for the fusion of extracted features from semantic and visual encoders. Figure 5 represents the structure of MFB.
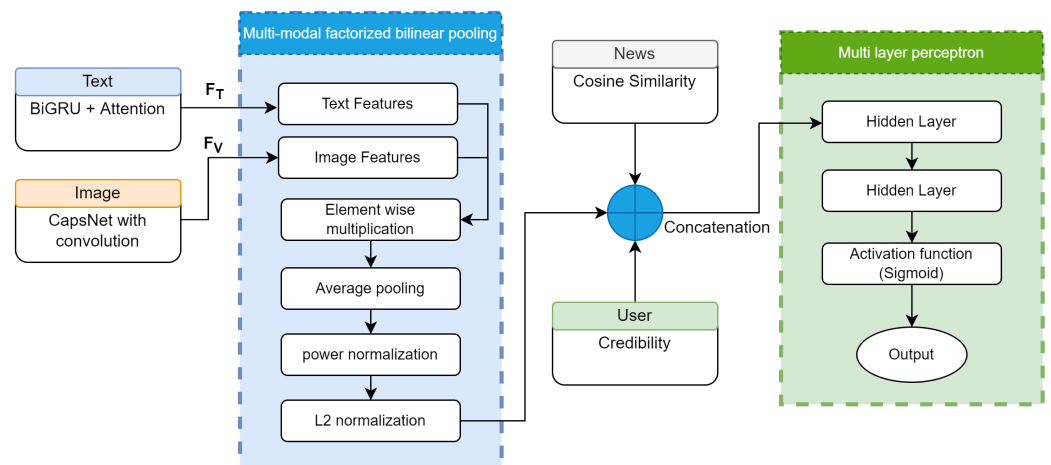
Figure 5. Representation of MFB, Concatenation, and MLP of the proposed model.

Using the MFB module, we combine the news article text feature (F_T) with visual (F_V) feature representations after acquiring them. MFB is preferred over regular concatenation for the reasons outlined below.

i. Using a typical concatenation of data from many sources, it might be difficult to identify the endpoint of the derived features.

ii. Because features are piled one after the other after concatenation, it is possible that the association between picture and text feature representations will not be recognized.

Using the MFB module, these two issues may indeed be effectively addressed. Furthermore, using this fusion technique, the association between textual and visual components is strengthened. Let us suppose that the textual feature vector is represented by ($F_T \in F_m$) and the visual feature vector is represented by ($F_V \in F_n$). The fundamental multimodal bilinear model is thus specified by the following Equation (15).

$$F_{TV} = F_T{}^T W_i F_V \tag{15}$$

where $W_i \in F_{m*n}$ is a projection matrix. The bilinear model's output is F_{TV}. Though it is effective at capturing pairwise interactions across feature dimensions, bilinear pooling introduces a large number of parameters, leading to a high processing cost and the possibility of over-fitting.

$$F_{TV} = \sum_{i=1} F_T{}^T U_i V_i{}^T F_V = 1^T (U_i{}^T F_T{}^T V_i{}^T F_V) \tag{16}$$

where k is the hidden dimensionality of the factored matrices $U_i = [U_1, \ldots, U_k] \in F_{m*k}$ and $V_i = [V_1, \ldots, V_k] \in F_{n*k}$ is the replication of two vectors, element by element, and $1 \in F_k$ is a vector of ones to obtaining the output feature F_T using Equation (16). First, we need to get familiar with two three-order tensors, $U = [U_1, \ldots, U_x] \in F_{m*k*x}$ and $V = [V_1, \ldots, V_x] \in F_{n*k*x}$, which will serve as weights for the output dimension. A further transformation into two-dimensional matrices is possible, $U' \in F_{m*k*x}$ and $V\prime \in F_{n*k*x}$ after which it may be rewritten as Equation (17):

$$F_{TV} = \text{Pooling}\left(U'^T F_{Tx} V'^T F_V \right)$$
$$F_{TV} = \text{Sign}(F_{TV})|F_{TV}|^{0.5} \tag{17}$$
$$F_{TV} = \frac{F^T TV}{|F_{TV}|}$$

3.6. Multi-Layer Perceptron (MLP)

In this step, we develop a multi-layer perceptron consisting of hidden layers and a sigmoid-activated sub-network. The input to this multi-layer perceptron network is a fusion of features from MFB concatenated with similarity features, and user credibility features. The final prediction probability of whether or not a news item or post is fake is calculated by mapping the input onto an objective space comprising two classes, shown in Figure 5. A binary cross-entropy loss between the ground truth and the predictions is designed as the optimal solution. The letters L and P in the Equation (18) stand for the original class and the predicted class, respectively.

$$MLP = \sum_i L \log P + (i - L) \log (i - P) \tag{18}$$

4. Experiment and Parameter Setup

The models are built, trained, tested, and evaluated all inside the confines of the Google Colab environment. Python is utilized to execute all coding strategies. The proposed multimodal is evaluated using the k-fold strategy for cross-validation. The TensorFlow and scikit-learn libraries are used to create machine learning models. CountVectorizer and the NLTK library are utilized for text preparation.

The news article's accompanying image is used in conjunction with convolutional CapsNet to generate a visual feature vector. The recommended batch size for training a convolutional CapsNet is 32, and the recommended number of epochs is 100. We used eight child capsules in the Primary capsule layer and two-parent capsules in the Child Capsule Layer. The number of capsules and the complexity of intermediary capsule layers determine the significance of the routing-by-agreement approach. The overall number of hyperparameters will vary depending on them, but it will be less than CNN. The capsule

connections in the CapsNet model are established between groups of neurons as opposed to individual neurons; hence, it has fewer parameters than CNN. In comparison to CNN, the Convolutional CapsNet model needs the least amount of time to learn entire sequence data. To produce the 32-dimensional visual feature vector, Fvisual, we evaluated and modified a higher-capsule layer.

The proposed model combines 32-dimensional textual and visual feature vectors using Factorized bilinear pooling to produce a 32-dimensional multimodal feature vector, F_{TV}, with high-level informative features. These multimodal features along with other important features are given into MLP, which is utilized to distinguish bogus and true news based on anticipated probability values.

4.1. Dataset

For our research, we used the publicly available standard fake news dataset called FakeNewsNet. It includes two datasets Gossipcop and Politifact, which comprise news stories about politics and entertainment, respectively. The performance of the proposed model is measured by its effectiveness on these two datasets. The collection consists of news stories, both text, and visuals. The details of various important aspects of datasets are provided in Table 1.

Table 1. Detailed information of the FakeNewsNet dataset.

Features of Datasets	GossipCop Fake	GossipCop Real	PolitiFact Fake	PolitiFact Real
Total number of news articles	6048	16,817	432	624
Related to text contents	785	16,765	353	400
Related to social interactions	4298	2902	342	314
Related to news content having social interactions	675	2895	286	202
Total number of tweets	71,009	154,383	116,005	261,262
Related to tweets having interaction	3040	2546	6686	20,720
Related to tweets having likes	10,685	2264	18,453	52,082
Related to tweets having retweets	7614	5025	13,226	42,059

4.2. Evaluation Metrics

We employed the standard set of performance measures, including accuracy, recall, precision, and f-measure. Furthermore, the challenge of establishing the veracity of a news item is modeled after a classification issue. Here's a quick rundown of what each metric measures from Equations (19)–(22):

$$Accuracy = \frac{T^+ + T^-}{T^+ + F^+ + T^- + F^-} \tag{19}$$

$$Precision = \frac{T^+}{T^+ + F^+} \tag{20}$$

$$Recall = \frac{T^+}{T^+ + F^-} \tag{21}$$

$$f - measure = \frac{2 * Precision * Recall}{Precision + Recall} \tag{22}$$

where, False positive (F^+) means that fake news was correctly identified as such, whereas false negative (F^-) means that real news was correctly identified as fake. The *Accuracy* value in the challenge of identifying false news indicates the proportion of news pieces that were properly labeled. *Accuracy* is measured by the percentage of anticipated false

news stories that were accurately labeled. By counting how many false news articles were accurately identified as such, we may determine the recall or true positive rate (TPR). The $f - measure$ is the harmonic mean of the *Accuracy* and *Recall*, and it is used to indicate the overall performance of the proposed model.

5. Results and Discussions

In the preceding paragraphs, we detailed our findings from an in-depth analysis of the experimental outcomes of the proposed model utilizing various indicators for measuring performance.

To access the performance of the suggested model, it is put up against FakeNewsNet, a publicly available benchmark dataset. Table 2 displays the collected data. The experimental results show that the proposed model has better accuracy, precision, recall, and f-measure than the baseline and state-of-the-art methods.

Table 2. Comparison of performance of the proposed model with baseline models on the FakeNews-Net dataset.

Models	GossipCop				PolitiFact			
	Accuracy	Precision	Recall	f-Measure	Accuracy	Precision	Recall	f-Measure
NB [22]	0.627	0.794	0.913	0.852	0.616	0.762	0.874	0.814
SVM [14,29]	0.494	0.467	0.914	0.613	0.582	0.467	0.911	0.613
RF [18]	0.858	0.984	0.85	0.916	0.847	0.896	0.845	0.872
VGG19 [54,56–58,60]	0.803	0.795	0.793	0.802	0.654	0.647	0.649	0.653
EANN [58]	0.915	0.904	0.899	0.918	0.747	0.728	0.734	0.741
MVAE [54]	0.775	0.759	0.767	0.769	0.673	0.657	0.659	0.652
SpotFake [57]	0.807	0.798	0.802	0.805	0.721	0.718	0.719	0.728
SpotFake+ [56]	0.856	0.832	0.828	0.851	0.846	0.835	0.829	0.842
Proposed	0.988	0.985	0.966	0.975	0.990	0.979	1.000	0.989

When compared to the textual model, it is abundantly clear that the visual model is responsible for producing superior results. This may be due to the fact that texts might occasionally include noisy and unstructured information, but images display evidence more clearly. It is possible to conclude from the findings that combining pictures and text is advantageous since it achieves superior performance when compared to either using images or text alone.

Furthermore, the proposed multimodal provides a complete solution for the fake news detection in news articles, since information like reposts, likes, shares, etc. are not available immediately after a news article is published, the actual content of the article is of utmost significance. Then content can be the only factor examined for detecting fake news. The proposed model uses both the textual and visual aspects of news articles as its input. Cosine similarity of the title and body of the news provides a concrete measurement for comparison of relatedness. Additionally, the information included inside the user profile as well as the behavioral features of the user was added to improve the efficacy of the proposed model.

To highlight the value of cosine similarity as a feature, we have attempted encoding the news headline and body together with their degree of similarity and found that this method beats encoding only the title and content. Evidently, the findings show a significant improvement in the reliability of the tests. To test the quality of our model and ensure that its findings are equivalent to those of other models using the same dataset, we have implemented a 10-fold Cross-validation resampling technique. The average loss and accuracy based on epochs are shown in Figure 6. Even though we used k-fold stratified cross-validation, there were still some misclassified test samples. The main reason for this is that it is difficult to tell the two groups apart due to the features that they share.
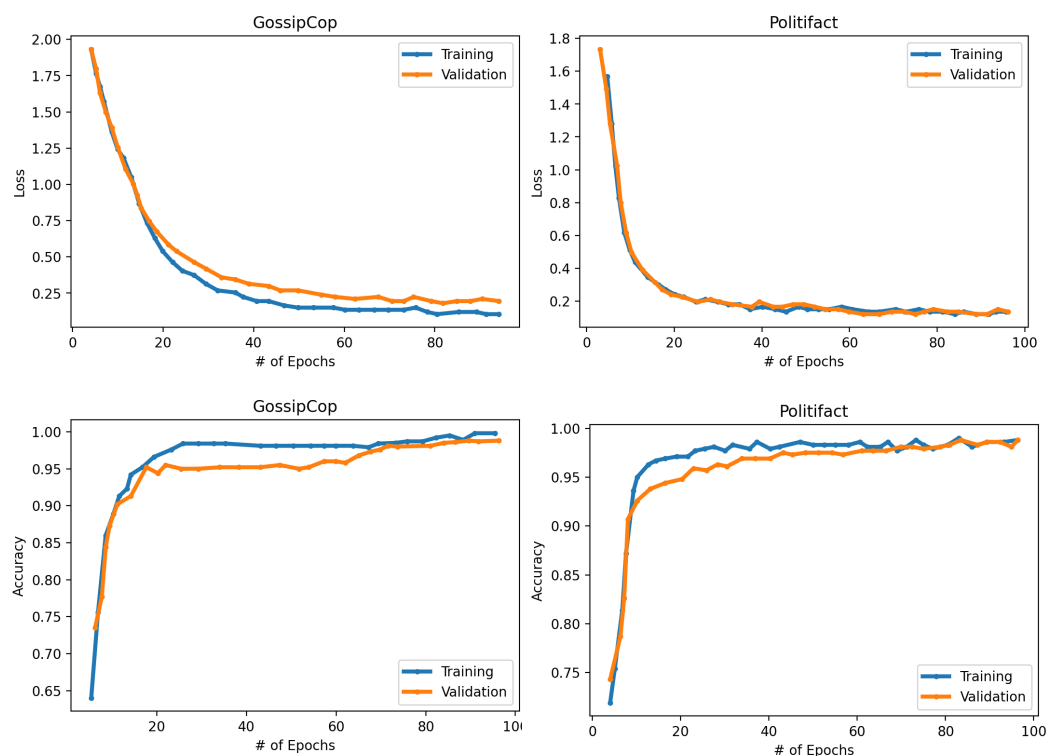
Figure 6. Average loss and accuracy for the proposed multimodal using FakeNewsNet.

As shown in Table 2, our proposed multimodal outperforms the state-of-the-art multimodal. The image features, cosine similarity, and routing-by-agreement method of the CapsNet architecture are crucial to the success of our suggested model. The accuracy improvement is also a reflection of the user credibility module's effectiveness. Despite the fact that textual characteristics are superior to visual features in unimodality mode, there are still some worries regarding textual features. Our suggested model achieves 7.3%, 21.5%, and 13.3% better performance than the current baseline models EANN [58], MVAE [54] and, SpotFake+ [56], respectively for the GossipCop dataset. Furthermore, for the PolitiFact dataset, our proposed model outperformed EANN [58], MVAE [54] and, SpotFake+ [56] with 24.5%, 32% and, 14.5% improved accuracy, respectively.

In the end, we also examined how well our suggested model performed in comparison to the most recent and cutting-edge techniques for identifying fake news. Table 3 represents the algorithms that were utilized for comparison.

The models compared here have the ability of early detection since they do not rely entirely on social interactions. OPCNN-FAKE combined the data from both sources into a single report. The outcomes in Table 4 show that the suggested model has the highest performance across all measures for both datasets. The comparison between the proposed multimodal and the state-of-the-art multimodal for the GossipCop and politifact datasets are shown in Figures 7 and 8, respectively.

The proposed multimodal provides improved performance because we took the necessary steps to address the issues discovered by previous techniques. The combined feature representation can only be obtained using the approaches that are now considered state-of-the-art by concatenating textual and visual characteristics, which does not result in a strong connection between the picture and the text. In this work, features are extracted from a variety of models, and then those characteristics are combined to generate a common representation. In a later stage, the extra feature representations are enhanced by concatenating the additional features. We have conducted empirical research to explore and confirm the significance that pictures and social behavior play in the identification of false news. Figure 9 provides a selection of tweets and news stories that illustrate how well the suggested algorithm was able to classify their content.

Table 3. State of the art multimodals and their description.

Model	Description
OPCNN-FAKE [102]	It is a Convolutional Neural Network model that has been improved to detect fake news. The network parameters were optimized using grid search and hyperopic optimization methods.
SAFE [103]	It uses both textual and visual data from news articles. First, neural networks are utilized to separate visual and textual components of news coverage. The connection between the extracted attributes is then investigated across methods. Finally, a method for predicting fake news is developed by learning the correlation between textual and visual representations of news.
dEFEND [104]	Exploiting both news content and user comments, it collects the linked sentences and user remarks for fake news detection using a sentence-comment co-attention sub-network.
TCNNCURG [105]	When applied to text, the Two-Level Convolutional Neural Network with User Reaction Generator (TCNN-URG) builds a generative model of user response to news items based on past user replies while simultaneously capturing semantic information from the text at the sentence and word levels.
3HAN [106]	3HAN employs a hierarchical attention neural network architecture to analyze the textual contents of news articles to detect false news. It does this by encoding the textual contents using a hierarchical attention network that is composed of three levels: words, phrases, and headlines.
CAFE [48]	For news articles with appropriate image-text pairs. while learning to contrastively reduce the Kullback-Leibler (KL) divergence, variational autoencoders are trained to compress both the pictures and the texts. Multimodal characteristics are rebalanced based on the relevant cross-modal ambiguity score.
FND-CLIP [45]	The modal combines images and text from the news using the deep learning properties of text and images through the use of a ResNet-based encoder and a BERT-based encoder, respectively.
CMC [49]	This method employs a two-stage network, initially training two unimodal networks to learn cross-modal correlation via contrastive learning, and then fine-tuning the network to detect bogus news.

Table 4. Results of the proposed model compared to the most advanced multimodal.

Models	GossipCop				PolitiFact			
	Accuracy	Precision	Recall	f-Measure	Accuracy	Precision	Recall	f-Measure
OPCNN- FAKE [102]	0.952	0.952	0.952	0.952	0.952	0.952	0.952	0.952
SAFE [103]	0.838	0.857	0.937	0.895	0.874	0.889	0.903	0.896
dEFEND [104]	0.888	0.729	0.782	0.755	0.904	0.902	0.956	0.928
TCNN-URG [105]	0.736	0.715	0.521	0.603	0.712	0.711	0.941	0.810
3HAN [106]	0.750	0.659	0.695	0.677	0.844	0.825	0.899	0.860
CAFE [48]	0.864	0.809	0.723	0.754	0.867	0.809	0.848	0.828
FND-CLIP [45]	0.880	0.83	0.754	0.783	0.942	0.9285	0.9285	0.9285
CMC [49]	0.893	0.873	0.81	0.813	-	-	-	-
Proposed	0.988	0.985	0.966	0.975	0.990	0.979	1.000	0.989
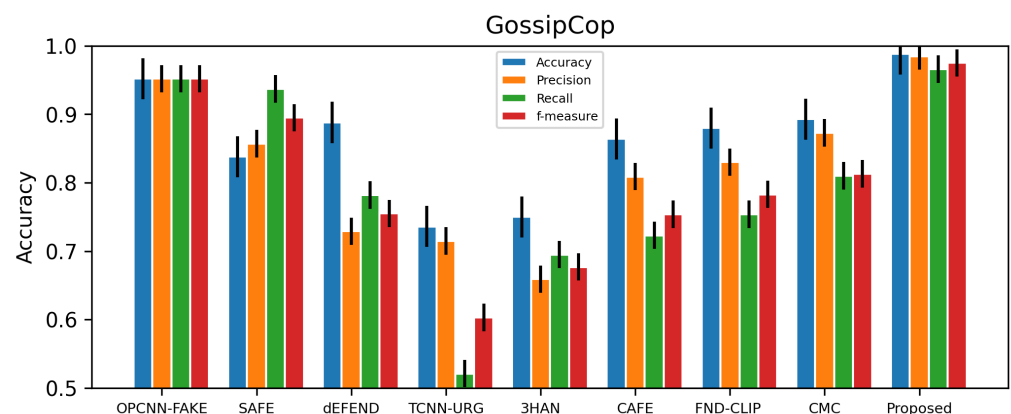
Figure 7. Comparison between the proposed multimodal and the state-of-the-art multimodal for the GossipCop dataset .
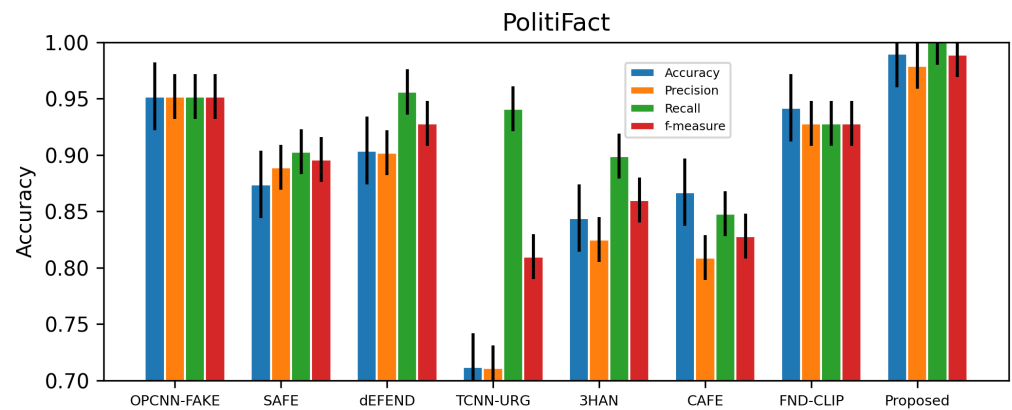
Figure 8. Comparison between the proposed multimodal and the state-of-the-art multimodal for the politifact dataset.

(a) HILLARY'S Campaign Likely FAKED Her Audience at NC Rally

(b) Anti-Trump Super PAC Launches Pre-Debate Video Featuring Hofstra Students

(c) DOJ: Chinese company tried to evade U.S. sanctions against North Korea

(d) Obama Claims It Will Be a Personal Insult If You Donate and Vote For Hillary

Figure 9. Examples of fake news correctly classified by the proposed model.

We have employed word, phrase, and document-level encoding for multilayer contextual information retrieval, which permits adjustable text length and simplifies the semantic encoder. In the instance of the visual encoder, we supply a six-layer convolutional network that is responsible for obtaining the most insightful insights and domain-specific characteristics. Some user-related qualities, such as cold start and unreliability, are particularly relevant in practical contexts. Because of the user's inexperience, very little information may be provided. In this research, we find that the cold start problem affects all of the attributes except for Credibility, Influence, and Sociality. It is not a major issue in the field of identifying fake news since content created by newcomers cannot be extensively disseminated on social media because of the absence of a considerable number of followers.

Furthermore, skepticism is crucial to uncovering fake news. This feature's unpredictability suggests it might be affected by the user's actions. It's possible that publishers will utilize this tactic to fool the system. Only the Sociality trait, out of all the ones we've studied, is suspect in this research. On the contrary, if a social influencer spreads misinformation or disinformation, it spreads quickly and widely. For this reason, we cannot recommend Sociality as a tool for identifying fake news. The median number of outlets sharing a given story shifted significantly among beats. There are more outlets that publish

political news than other types of news. Furthermore, while more outlets spread false celebrity news than fake political news, political fakery is produced by a smaller number of outlets. Accordingly, it's safe to say that publishers' online activities vary greatly depending on the type of news they're producing.

Ablation Study

The act of carefully assessing a framework in both the presence and absence of a certain component is referred to as an ablation study. This analysis is performed by individually removing and then grouping the framework's components. Identifying both the bottleneck and the unnecessary components lends a hand in the process of optimizing the design of the system. The ablation research is carried out to demonstrate the significance of the contributions made by each of the different modules as well as their level of efficacy. Text features, cosine similarity features, user trustworthiness features, and image features are included in the multi-modal that is being suggested. Experiments are being conducted with individual approaches, ensembles of two modules using the FakeNewsnet dataset with the same parameter settings as the overall proposed framework, shown in Figures 10 and 11.

Assessing the relative merits of alternative component arrangements within the framework, we made use of the top-1, top-5, and top-10 accuracies, as well as the reciprocal average rank (RAR) metric. The top-K accuracy measures how accurate the top-k projected scores are by calculating the percentage of correct labels within those scores, presented in Table 5. The RAR offers information on how far down the list the correct label is located.

Table 5. Results for the ablation study.

Models	GossipCop				PolitiFact			
	Top-1	Top-5	Top-10	RAR	Top-1	Top-5	Top-10	RAR
Image only	0.501	0.584	0.648	0.428	0.594	0.652	0.674	0.487
Text only	0.428	0.511	0.568	0.357	0.467	0.548	0.597	0.413
Credibility + Text	0.53	0.664	0.718	0.461	0.598	0.678	0.734	0.509
Similarity + Text	0.52	0.692	0.746	0.464	0.663	0.742	0.778	0.452
Credibility + Image	0.641	0.762	0.841	0.621	0.749	0.824	0.864	0.642
Proposed	0.727	0.951	0.988	0.791	0.751	0.967	0.990	0.826

Since we've taken the appropriate steps to address the issues uncovered by earlier methodologies, the ablation investigation also demonstrates the effectiveness of the proposed framework. picture and text features that have been obtained to maximize similarities and give a more reliable common representation. We can achieve this using the Multimodal Factorized Bilinear-pooling (MFB) technique. Furthermore, the proposed model integrates semantically significant characteristics, the cosine similarity perspective, and social context information to generate a better feature vector representation for the provided news, which in turn improves the overall effectiveness of the identification of fake news. Furthermore, the success of the user credibility module is seen in the increased precision.
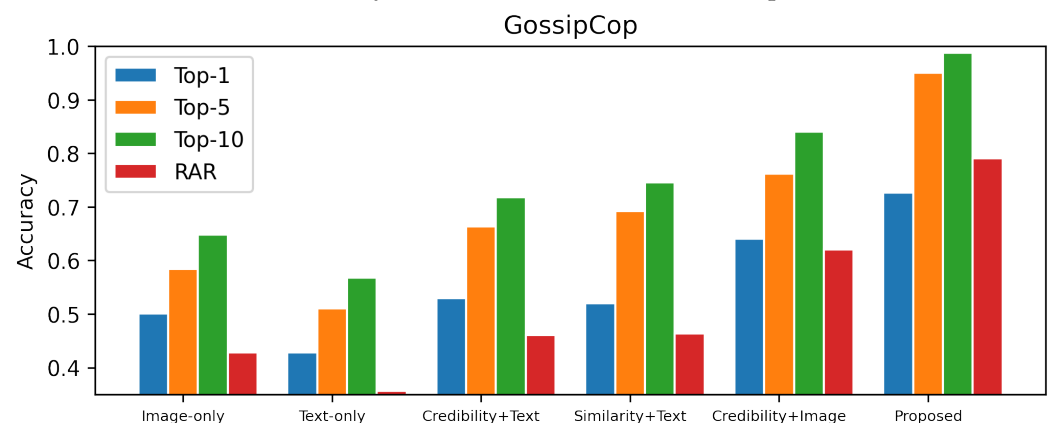

Figure 10. Comparison based on the ablation study for the GossipCop dataset.
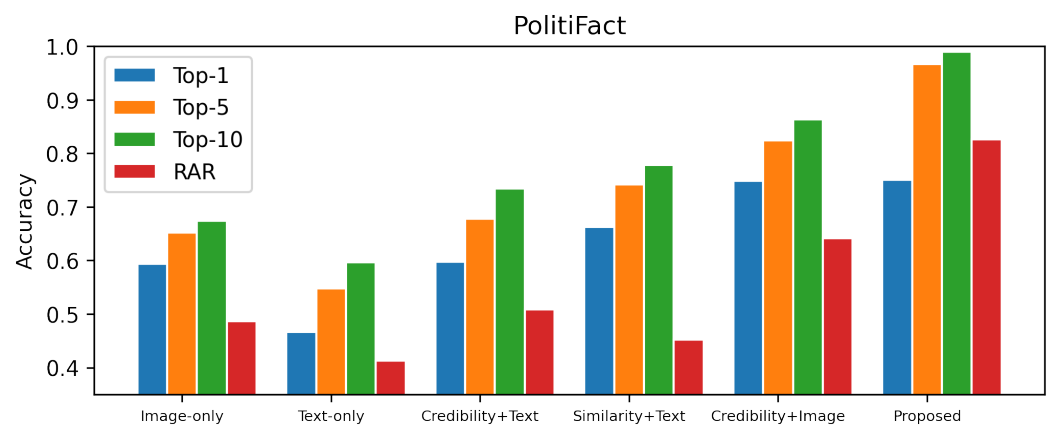
Figure 11. Comparison based on the ablation study for PolitiFact dataset.

This research provides a theoretical account of the steps involved in news classification using processed data, including the extraction of essential features from several modalities, the influence of social context and similarity characteristics, and the fusing of features to generate a common representation. We have conducted empirical research to verify the importance of cosine similarity in identifying fabricated articles. Second, our results provide light on hitherto unrecognized aspects of false news concerning social profiling and online behavior. Every one of these discoveries adds to the body of theoretical information on the subject.

The multimodal approach has several advantages, including the fact that it does not rely on a single data source, which is especially helpful in the case of the early identification of fake news on social media to halt the spread of disinformation. In its earliest stages, it just requires text and images as input, and based on these basic inputs, it derives the semantic and visual essential elements necessary to form a robust correlation. To further forecast whether or not a piece of news is true, it incorporates the cosine similarity properties. Based on our research results, multimodality is an effective technique for detecting bogus news. In this research, we show how to put a deep learning-based multimodal false news detection framework into practice.

In this study, we have developed a multimodal approach that considers the most essential information sources and extraction procedures for detecting fake news. In addition, we have resolved the issues of the current state of the art. However, our model also has some limitations: it does not support languages other than English because it has not been tested and calibrated for other languages. Due to the high association between visuals and accompanying language, complex and altered images with matching text descriptions can occasionally trick the framework. We could address these restrictions to generate a significant, long-lasting influence on the propagation and early identification of fake news. We can also add forgery detection, non-English languages, and meta information that may have a substantial impact on fake news detection. However, it requires the development of a suitable dataset, models, and experimental framework.

6. Conclusions

In this study, we created a methodology for identifying false news stories by combing through the piece's textual, contextual, social, and visual elements. Existing models for the fake news detection problem suffer from serious shortcomings due to the inability to acquire meaningful details from the text and its related images of news articles and social media posts. The proposed approach addresses this problem by combining textual, contextual, social, and visual data to learn a more accurate multimodal feature representation. In the proposed model, CapsNet is used to extract the most informative visual features from the image. It uses a BRNN with attention to extract linguistic aspects from texts as well. The cosine similarity between the headline and body of news articles is also calculated. In

addition, the user credibility module determines the user's relative social status. Visual and textual characteristics have been integrated using multi-modal factorized bilinear pooling, a common data representation has been generated, and further concatenated similarity and credibility features. Finally, the output is submitted to a multi-layer perceptron for classification as real or fake news. The effectiveness of the proposed model is measured with the help of the FakeNewsNet dataset, which is open to the public. The datasets come from the same sources as the news and social media sites, and they are called GossipCop and PolitiFact. Compared to other multimodal false news detection models, the suggested approach performs better in experiments. The results of this study suggest other research avenues worth exploring. The features solution domain may be successfully expanded by the extraction of various picture characteristics, which can then be used in the study of social media and news articles in the pursuit of false news identification.

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Abbreviations

The following abbreviations are used in this manuscript:

MDPI	Multidisciplinary Digital Publishing Institute
NLP	Natural Language Processing
ML	Machine Learning
DL	Deep Learning
Conv	Convolutional Layer
GRU	Gated Recurrent Units
BiGRU	Bidirectional GRU
CapsNet	Capsule Neural Network
LSTM	Long Short-Term Memory
MFB	Multimodal Factorized Bilinear-pooling
MLP	Multilayer Perceptron

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Systematic Review

Developing a Framework for Fake News Diffusion Control (FNDC) on Digital Media (DM): A Systematic Review 2010–2022

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Abstract: This study sought to investigate factors causing the spread of fake news on digital media (DM) and to explore the sometimes disastrous consequences of fake news on social media. The study also aimed to construct a framework for fake news disaster management to control the dangers of false news on DM. The study applied PRISMA guidelines and techniques for exploring, devising, and inclusion and exclusion criteria. The search was carried out through 15 of the world's leading digital databases. As a result, 31 peer-reviewed studies published in impact-factor journals of leading databases were included. Findings showed that several factors influenced the sharing of fake news on digital media (DM) platforms. Six major trending factors were the rise of technologies, social connections, political reasons, the absence of a controlling center, online business and marketing, and quick dissemination of information. The study identified the disadvantages of fake news (FN) on digital media (DM). A framework was constructed for managing fake news disasters to control the spread of fake news on digital media. This paper offers important theoretical contributions through the development of a framework for controlling fake news spread on digital media and by providing a valuable addition to the existing body of knowledge. The study offers practical assistance to top management, decision makers, and policymakers to devise policies to effectively manage problems caused by fake news dissemination. It provides practical strategies to address fake news disasters on digital media for redefining social values. This research also assists digital media managers in utilizing the proposed framework and controlling the harmful impact of fake news on social media.

Keywords: fake news; diffusion control; fake news sharing; spread of fake news; digital media; online fake news

1. Introduction

In the present age of information and communication technologies (ICTs), the phrase 'fake news' (FN) has become a common phenomenon used by people from all sectors. Technology-based applications have played an optimal role in the rapid growth of fake news [1–4]. FN is considered a serious threat to the peaceful environment of organizations and society. It can destroy communities and create unmanageable issues for individuals and nations as it damages information systems [5–8]. With the emergence of the internet and web-based applications, news providers have discovered new techniques for communication [9,10] and they keep readers consistently engaged with online news [11–13]. Disinformation is a type of fake news that aims to deceive others intentionally. It causes violence and conflicts among various groups and factions [14]. In the twenty-first century, digital media (DM) channels have reached heights of popularity [15] and are generating extensive amounts of information on a vast range of topics [16] but the authenticity of such information is a matter for skepticism [17–19].

Digital media is frequently used for a number of reasons including making social connections, seeking information, sharing information, and seeking to enhance one's

status [20–23]. DM provides ample opportunities for freedom of expression; therefore, the number of potential users is rising rapidly [24]. However, freedom of expression can open the way to fake news and has the potential to cause panic in society [25–27]. Major creators of fake news use Facebook, Twitter, and YouTube as these DM platforms are easy to use for news dissemination [28]. These social media apps are frequently used by people to share their emotions and experiences with other members of their community [29]. DM has played a vital role in the dissemination of information during natural disasters globally [30,31], and its tools, particularly FB and Twitter, have made phenomenal contributions during difficult times [32]. Nonetheless, it cannot be ignored that DM tools are potential elements for the creation of fake news disasters through user-generated content [33,34]. Galeotti [35] explains how fake news on DM is shared to promote false agendas by one country against another. FN is a modern weapon in the current age of social networking applications.

Information professionals can play a vital part in the war against fake news disasters on social media by inspiring users to upgrade their news literacy skills [36], and they need to encourage users to question the authenticity of news received through digital media channels so that dangers of fake news may be avoided [37]. They can play an important role in fake news diffusion control (FNDC) through the provision of information literacy courses to the community [38]. Şisman and Yurttas [39] claimed that media literacy is essential to combat FN disasters on DM. Kim et al. [40] proposed that confirmation of news sources is of paramount significance in the battle against FN. Rhodes [41] suggested disrupting the stream of compatible information as a means of reducing the effect and dissemination of FN on DM. Gimpel et al. [42] believed that fake news disasters could be controlled by encouraging people to call out fake news fearlessly on digital media. Schuetz et al. [43] regarded fact-checking platforms as a valuable source for fighting successfully against fake news on social media that has caused social disasters at national and international levels. Chauhan et al. [44] concluded that information disseminated on digital media has contributed a great deal to decision making; therefore, ethical sense-making is required to deal with the growing threat of fake news on DM. Dabbous [45] argued that proper control mechanisms are urgently needed on DM applications to check the authenticity of trending news stories.

Pundir et al. [46] carried out an empirical study on false news sharing on digital media, having used a planned behavior approach. The study intended to identify the impact of awareness about fake news on digital media, subjective norms, perceived behavior control, and users' intentions to confirm the accuracy of the news before sharing it on digital media. The findings of the study illustrated that attitudes towards news authenticity and perceived behavior control were important factors related to the verification of the news before sharing it on digital media. Barakat et al. [47] conducted research on fake news identification on digital media. The objective of the study was to determine the factors which contributed to individuals' identification of false news on digital media. Findings revealed that verification attitudes had a positive impact on fake news identification; nonetheless, blind trust in digital media forums reduced verification behavior. The study offered a behavioral model to reduce the risks of fake information on digital media. Olan et al. [48] inferred through empirical investigation that digital media impacted social values to a great extent and changed public opinion on critical national issues by dividing people about news items posted on digital media. Luo et al. [49], through an experimental study, found that deep learning methods proved valuable in easing the flood of fake news on digital media. Piazza [50] reported that digital media was contributing fake information extensively and misleading society. Therefore, solid measures needed to be initiated to save societies from the harm that fake news was causing.

Having analyzed the literature on this topic, we can identify the major themes that contribute practical measures to stop the fake news disaster on digital media. These include the fearless reporting of fake news, use of fact-checking platforms, checking the authenticity of trending information, developing awareness about fake news on digital media, digital literacy, deep learning and analyzing techniques, and the use of automatic machine-based

tools to detect fake news. This also highlights the need to develop a framework to control the flood of fake news on digital media. Hence, the present study has been designed to contribute to this goal.

Through in-depth content analysis of peer-reviewed papers, it is apparent from the literature that a framework for fake news diffusion control (FNDC) systems on digital media (DM) has yet to be developed, In order to bridge this significant gap, the current study was instigated. Factors causing the spread of fake news on digital media (DM) and the disasters of fake social media items have not been explored in the past through systematic literature review methodology. Developing a framework will not only offer solutions but also provide theoretical contributions to guide future researchers for further exploration of this area. Furthermore, it will offer a framework for the top management of institutions, information professionals, policymakers, government representatives, public figures, and other stakeholders to devise mechanisms to stop the flood of fake news on digital media effectively and efficiently.

Figure 1 demonstrates the main themes of this study. It aims to display major constructs through a mind-map diagram.
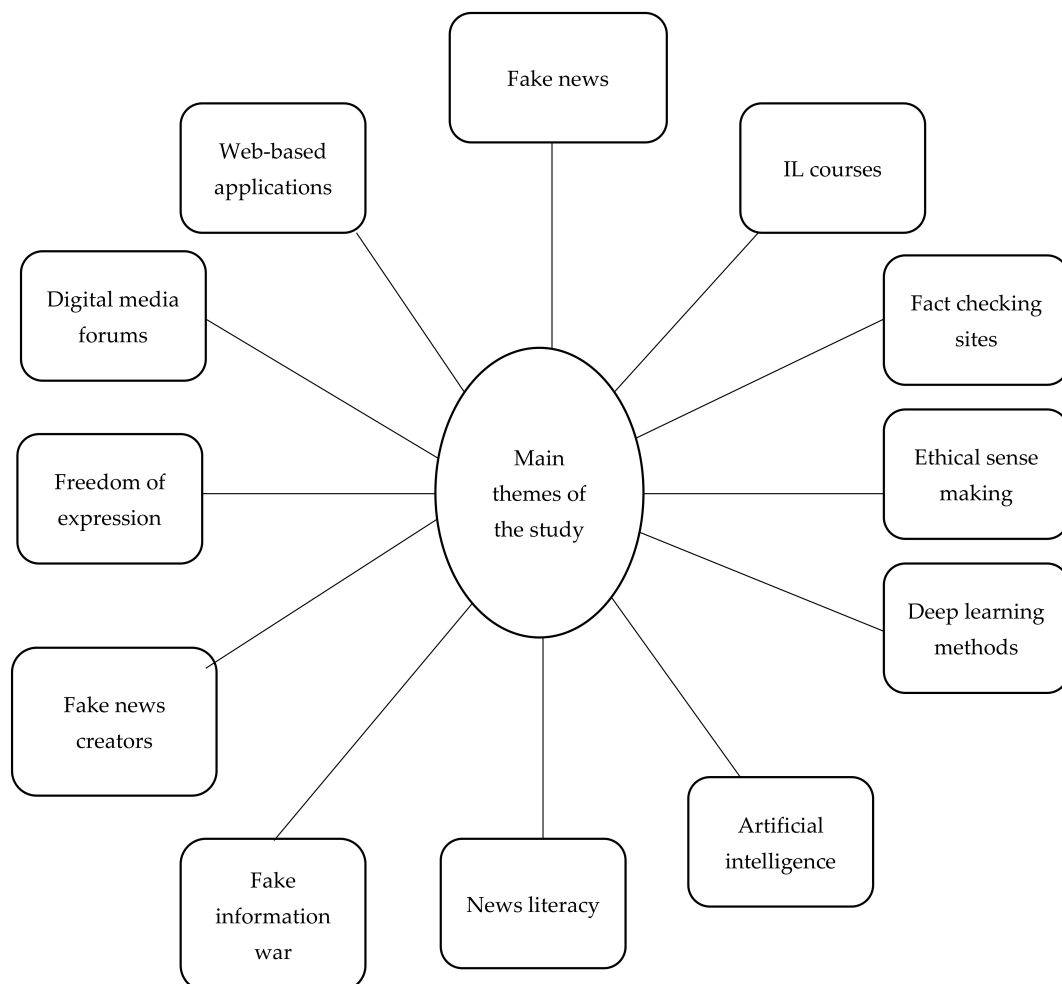
Figure 1. Main themes of the study.

Current research is of immense importance for library professionals, decisionmakers, government representatives, and all other concerned stakeholders to shape efficient methods for fake news detection through innovative approaches based on artificial intelligence systems for news authentication. The findings of the study will prove productive for experts in artificial intelligence and big data analytics in helping to devise technology-based

applications to examine the accuracy of news searched for on social networking websites. A framework based on techniques for fake news identification and removal on DM will contribute valuable content to the body of existing literature and provide a benchmark for policymakers to construct techniques and methods for avoiding the creation and sharing of fake news on digital media.

This paper offers certain theoretical and practical contributions. Our research has theoretical insights for research scholars as it has developed an evidence-based framework to control fake news diffusion on digital media. Future researchers may test this framework through empirical investigations. They can also design virtual systems to control the flood of fake news on digital media by using artificial intelligence. Another important contribution is through the provision of practical implications for policymakers to develop solution-based outcomes. This study also contributes productive guidelines for leaders and managers to apply the latest tools for checking the authenticity of online news. Recommendations based on the results of our study may prove of great value to society and the business community, as a legal document may be developed consisting of core methods to control fake news diffusion on digital media platforms; therefore, the study offers worthwhile social contributions.

2. Research Objectives

In light of the above, our study aimed to:

- Identify the factors causing fake news sharing on digital media;
- Investigate the issues caused by the dissemination of fake news on social media;
- Develop a framework to combat issues caused by fake news on DM.

3. Methodology

The research team carried out PRISMA ("Preferred Reporting Items for Systematic Reviews and Meta-Analyses" procedures [51]. "PRISMA is an evidence-based minimum set of items for reporting in systematic reviews and meta-analyses. PRISMA is used for reporting of review, evaluating randomized trials, but it can also be used as a basis for reporting systematic review" [52].

PRISMA consists of four major phases with many steps at each phase. The first phase is 'planning', based on two major entities which are known as focused research questions and search strategy. The second stage is 'selection', utilized for sorting and extrapolating retrieved data. The third stage is 'extraction' for evaluating content after applying rigorous criteria for the evaluation. The fourth phase is 'data synthesis', used to analyze the data through step-by-step approaches to produce a concluding set of procedures. These four stages are applied in the current study and are elaborated below:

A. Stage one: Planning

Focused research objectives

Focused research objectives of the study cover the specific scope which are: factors causing the sharing of fake news on digital media; dangers of fake social news on DM; and a framework based on techniques for fake news diffusion control (FNDC) on DM. These research objectives are in a specific order and may be addressed concurrently.

Search Strategy

The strategy applied in connection to search terms, means of literature, and the procedure of searching the content are explained in depth as follows:

a: Search terms

After applying predetermined criteria, search terms were constructed. The following search strings were developed:

- Development of constructs, keywords, and variables from research papers and articles as the main basis of the study;
- Construction of the general research objective of the research and select some words from that research objective that reveals the clear path of the study;

- Usage of keywords that other researchers have used in their articles in impact-factor journals;
- List of related terms;
- Employment of Boolean operator "OR" to include substitute terms;
- Apply Boolean operator "AND" for retrieving combined records of both terms used in search box;
- Usage of the Boolean operator "NOT" for excluding keywords in search terms to find productive and focused results.

After having applied diverse searching techniques and methods, all relevant results were retrieved. Search terms used in different databases, tools, and scholarly search engines were as follows:

("Fake news" OR "Factors of fake news sharing on social media" OR "Effects of fake news" OR "Dangers of fake news sharing on social media")

AND

("Fake news AND digital media platforms" OR "Role of different factors in fake news creation on digital media" OR "Impact of fake news disasters" OR "Causes of online fake news" OR "Fake news disaster management" OR "Role of social media in fake news disasters" OR "Challenges to combat fake news flood" OR "Fake news disasters AND the social media websites" OR "Fake news consequences upon individuals and societies" OR "Fake news" AND "digital literacy" OR "Framework to fight against fake news" OR "Sharing fake news on social media platforms" OR "Social networks" AND "Combatting fake news" OR "Social media literacy" AND "fake news detection" OR "Fake news" AND "context awareness" OR "Role of technology in fake news creation" OR "Role of libraries" AND "fake news detection" OR "Online news" AND "managing users' misconduct" OR "Fake news ethical issues" AND "Role of librarians" OR "Social media as disaster communication media" OR "Challenges for combatting fake news" OR "Problems for information professionals to detect fake news on social media" OR "Modern information war" AND "Tools to battle against fake news warfare" OR "Fake news" AND "Challenges and opportunities" OR "Framework for war against social fake news" OR "Solutions to fight against fake info-demic" OR "Sharing of fake stories on social networking websites" OR "Effects of fake social information" OR "Modeling fake news detection system" OR "Threats of social media" OR "Media literacy and fake news identification" OR "Role of social norms in fighting against fake news" OR "Combating fake social news through fact checking" OR "Fake news detection" OR "Methods to find online fake news" OR "Roles of information professionals in the age of fake news" OR "Librarians against fake news war" OR "Fake news" OR "Digital Media")

NOT

("Fake news" NOT "Traditional media", "Impact of online fake news" NOT "Conventional media", "Fake news detection" NOT "Printing press", "Fake news disaster" NOT "Old-fashioned communication media", "Fake news finding tools" NOT "Electronic media", "Fake news" NOT "Controlled media").

b: Literature resources and existing research

Researchers used 15 databases in a structured way for making an in-depth focused search. These databases were Scopus, EBSCO Host, Web of Science, LISTA, Emerald, LISA, Summon, Elsevier, Google Scholar, Taylor & Francis, Pro-Quest, IEEE Xplore, Springer Link, Cambridge University Press, and Wiley Inter-Science. Peer-reviewed research papers meeting relevant keywords were retrieved through the selected databases. The authors used index terms to further run terms for finding the available published content. Restrictive phrasing was used by the researchers for finding required results in consonance with the formulated objectives of the study. Different filters were used to limit the search. To avoid bias in the search, separate searches were carried out by the researchers from three different working universities of two different countries. Impact factor research papers published in the leading journals of the world were included. Years range of the selection criterion of

the articles was 2010 to 2022. The authors included only the latest impact factors research papers in the study.

B. Stage Two: Selection

(1) Search process

A comprehensive search is carried out in a systematic literature review (SLR) to find and locate all existing material on the focused research objectives. Figure 2 mirrors the steps in this process.
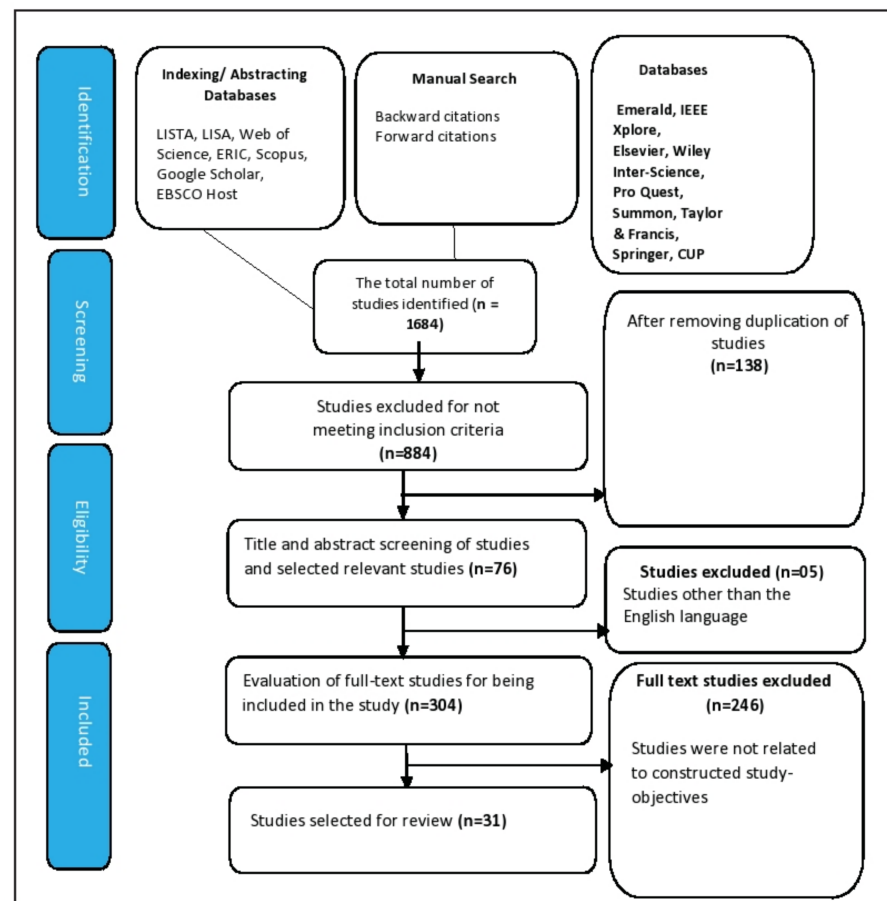
Figure 2. Diagram of the search process.

Step 1: Fifteen digital databases and tools were explored systematically to retrieve the results.

Step 2: The searched content was scrutinized to eliminate irrelevant results. For checking relevance, the titles of the research papers were checked carefully. Articles published before 2010 were not used in the research, so only recent robust studies were included. In total, 1684 results were retrieved. After the phase of elimination, 884 articles were excluded for not meeting the set criteria. A further 138 articles were removed after the exclusion of duplications. Through title and abstract screening, another 76 studies were excluded from the list. Five articles were not published in the English language so they were also withdrawn from the list. After evaluating full-text studies, a further 304 papers were excluded. Another 246 irrelevant studies covering no constructs of the study were also excluded. Researchers applied critical assessment criteria to integrate the evaluated articles with the objectives of the research for ensuring quality. Although substantial studies exist on fake news with regard to COVID-19, the research team did not include documents related to COVID-19 in order to maintain a focused and controlled set of study objectives. The investigators carried out the study in a general context, offering a broader outlook rather than projecting issues

relating to COVID-19. A total of 31 impact factor articles were selected as constructs of these research papers were similar to the constructed objectives of the research.

Scrutiny and filtering

Initial retrieved results (1684 as depicted via Figure 2) from fifteen diverse databases and tools were passed through an analysis filter to ensure relevance. Various steps were applied to execute this procedure. Titles of the papers were analyzed critically for conducting a systematic literature review (SLR) of the chosen studies. Various aspects including the language of the articles, content, type, impact factor, and non-impact factor journals, and publishing year were considered critically for including the most updated recent studies in the current research paper. An in-depth SLR of the 31 impact factor articles published from 2010 to 2022 was conducted. Table 1 reflects inclusion and exclusion criteria.

Table 1. Inclusion and exclusion criteria.

	Inclusion Criteria	Exclusion Criteria
A	Research papers published in the English language	Studies published in other languages
B	Articles covering relevant constructs of the study	Papers not covering variables of the study
C	Papers published from 2010 to 2022	Outdated papers
D	Papers discussing focused research questions of the study	Articles not covering study objectives
E	Articles published in Scopus, EBSCO Host, Web of Science, LISTA, Emerald, LISA, Summon, Elsevier, Google Scholar, Taylor & Francis, Pro-Quest, IEEE Xplore, Springer Link, Cambridge University Press, and Wiley Inter-Science	Papers published in general search engines and common databases
F	Articles published in impact-factor journals	Books, conference proceedings, dissertations, magazines, newspaper articles, organizational newsletters, grey literature, magazine articles, book chapters, reports, standards, etc.

C. Stage Three: Extraction

Keeping in view the formulated objectives, scorekeeping was assigned to the retrieved articles. Scoring was assigned to the answers which were integrated with the study objectives. The system of scoring was based on 'yes', 'no', and 'partly' options. Studies within set criteria were provided a score. Studies required to be included in the current research needed to obtain a good score. This system enabled authors to eliminate 1653 irrelevant results and to include 31 relevant research papers to respond to the focused research questions.

D. Stage Four: Execution

The last step was to ensure the validity of the searched content to ensure the quality of the work. The list was assessed against the criteria of eligibility which consisted of impact-factor articles from Web of Science and Scopus indexed journals. Research studies published before 2010 were excluded from the list. Explored studies were evaluated critically and carefully for the inclusion of the most recently published IF articles. Studies having no match with FN on DM were excluded. Books, conference proceedings, dissertations, magazines, newspaper articles, organizational newsletters, grey literature, magazine articles, book chapters, reports, standards, presentations, assignments, government documents, streaming videos, trade publication articles, and transcripts were not included in the current study. However, 31 IF research papers were included to execute the current study. Figure 2 reflects a graphical representation of the complete search process performed by the research team.

4. Results:

4.1. Overview of the Selected Studies

A total of 1684 results were retrieved through fifteen of the world's leading digital databases and electronic tools: 129 through Scopus, 97 via EBSCO Host, 85 from Web of Science, 154 by LISTA, 83 through Emerald, 84 via LISA, 89 from Summon, 223 by Elsevier,

128 through Google Scholar, 26 via Taylor & Francis, 85 from Pro-Quest, 94 by IEE Xplore Digital Library, 74 through Springer Link, 27 via Cambridge University Press, and 306 from Wiley Inter-Science. These results were retrieved from January 2022 to May 2022. After critical identification, screening, eligibility, and inclusion criteria, 31 impact-factor research papers were included to carry out the current study. Figure 3 shows the breakdown of the results from each digital database and electronic tool.
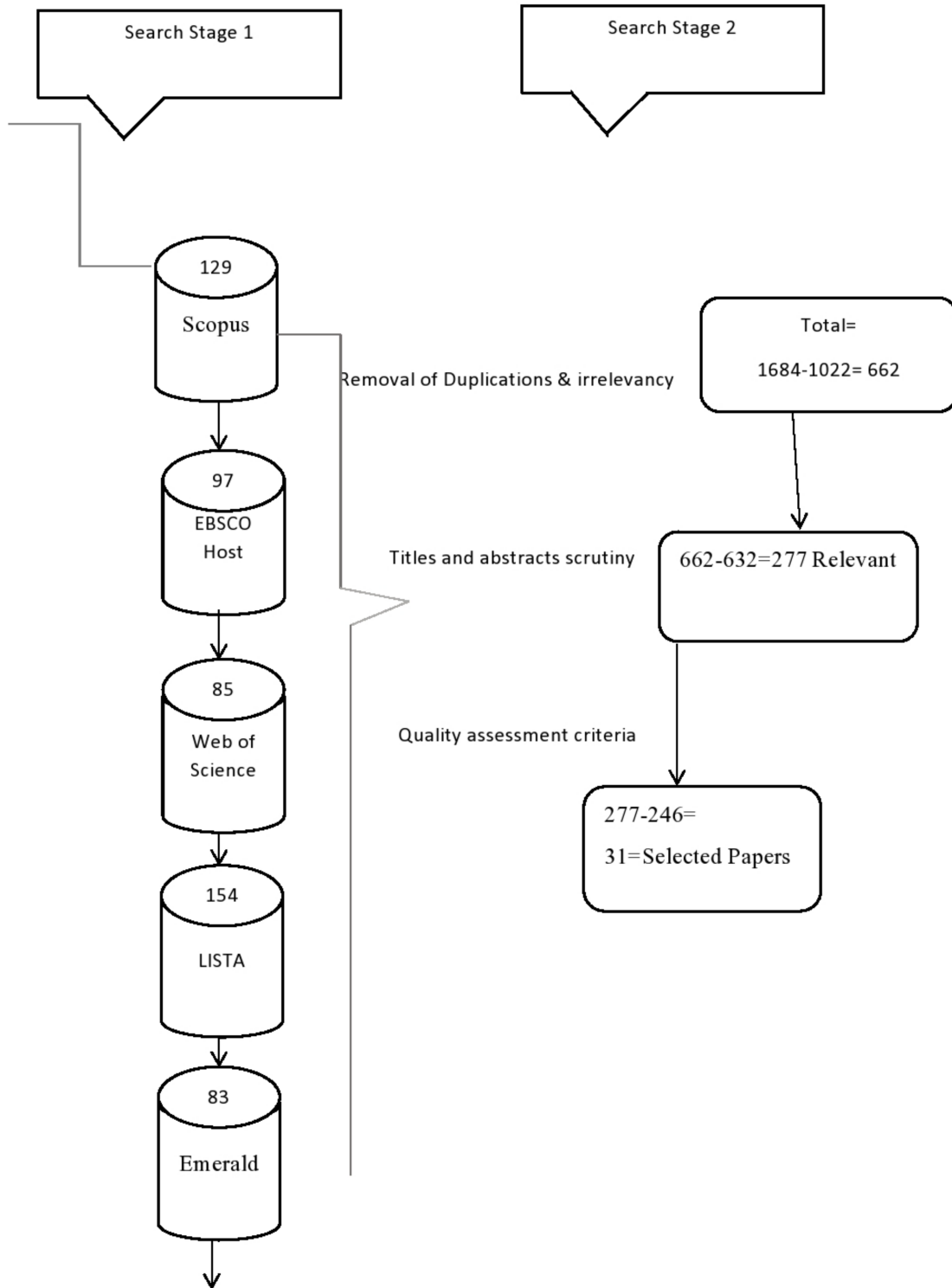
Figure 3. *Cont.*
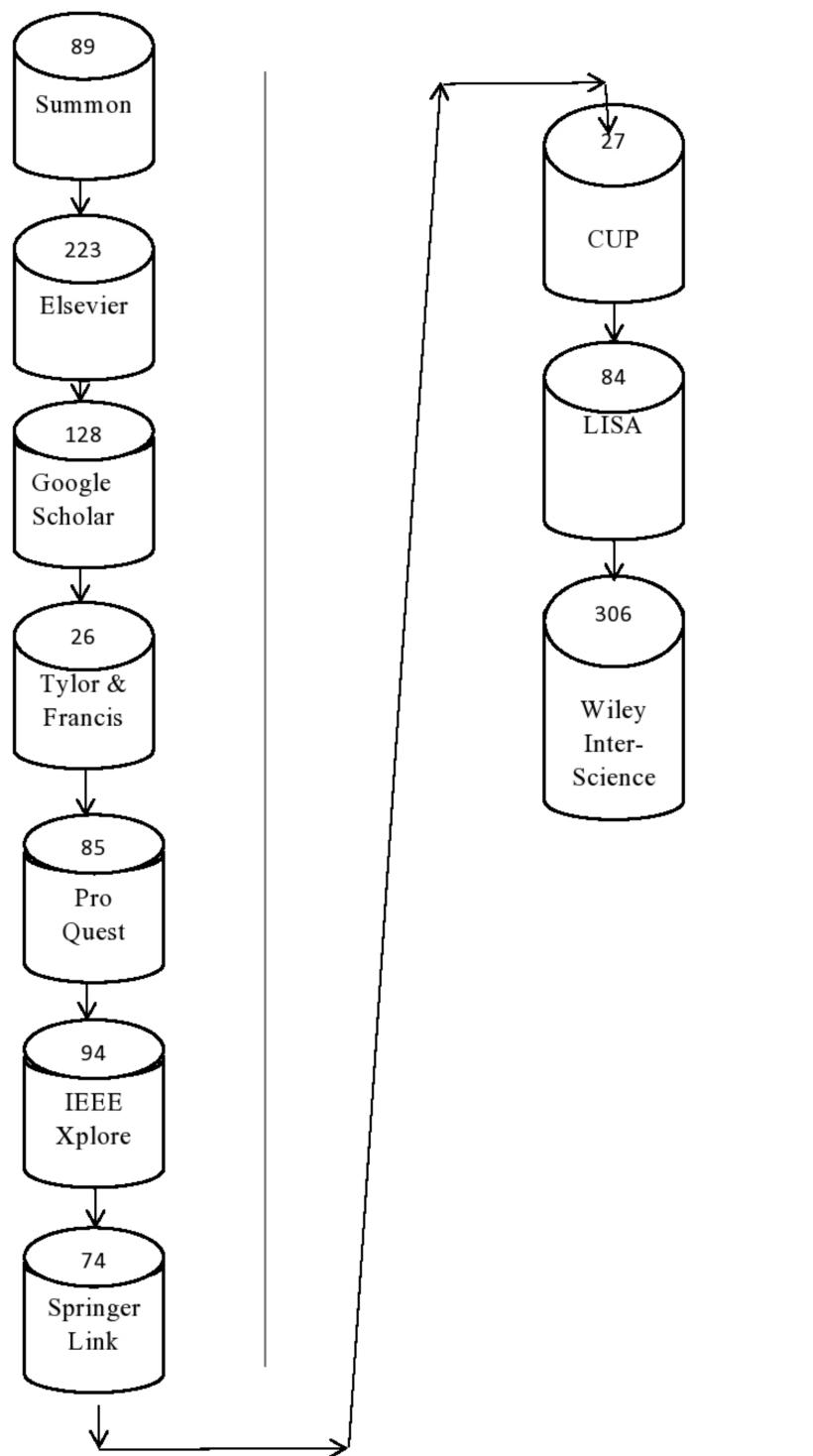
Figure 3. The search process.

4.2. Geographical Distribution of the Studies

It is pertinent to know the geographic distribution of the chosen articles in a systematic literature review as an inclusive picture becomes evident of the studies investigated around the world. Table 2 reflects the geographical distribution of the studies. It was found that selected papers came from thirteen different countries across the globe. It was noted that the majority of the studies on the topic (*n* = 16) originated from the United States of America, indicating that fake news has been a trending topic for researchers in the USA.

Table 2. Geographical distribution of studies (*n* = 31).

Sr. No.	Country	No. of Studies Held
1.	India	2
2.	USA	16
3.	UK	1
4.	Sweden	1
5.	Kenya	1
6.	Sri Lanka	1
7.	Germany	2
8.	China	2
9.	France	1
10.	Turkey	1
11.	Lebanon	1
12.	Brazil	1
13.	Canada	1

4.3. Research Methodologies Used in the Studies

Table 3 mirrors the research methodologies used in the selected studies. It was found that experimental and survey methods (both used six times) were the most widely used by the researchers in their studies, followed by interviews and a theme-based approach. Hence, it showed that in studies related to fake news on digital media, experimental methods and questionnaire approaches were widely used by the researchers to meet the set objectives of their studies.

Table 3. Research methodologies used in the studies.

Method	Number of Studies
Survey (Questionnaire)	6
Interviews	4
Interviews and diary entry	1
Evaluative approach	2
Case study	1
Literature-based	4
Concept-based models	2
Theme-based approach	4
General review	1
Experimental	6

Table 4 illustrates the datasets extracted through 31 research papers. An in-depth SLR of the 31 impact factor articles published from 2010 to 2022 was conducted.

Table 4. Data Extracted from 31 Research papers.

S.N.	Author	Year	Country	Journal	Factors Causing Fake News Sharing on SM	Disasters of Fake Social News on SM	Techniques for Fake News Diffusion Control (FNDC) on DM
1.	Kaplan and Haenlein	2010	France	Business Horizons	• Collaborative projects • Content communities • Virtual social worlds	• Information overload	• Careful selection of social media applications • Ensure activity alignment
2.	Wasike	2013	Kenya	Library High Tech News	• Online social relations • Online advertisements • Financial success • User-generated content • Enables users to actively interact with the content as well as its creators • Users can add value to the content they are accessing • User-friendly interfaces • No center of control • Rampant inappropriate behavior on social media platforms	• Identity, privacy, surveillance, befriending, and user exploitation • False sense of security • Some people use it to spread rumors, release naked pictures, or just poke fun at a celebrity • Disclosure of confidential or other non-public information; disparagement or harassment; conflicts of interest; espionage or fraud; privacy; and personal reputation damage • Social media outlets are controlled by third parties	• Need to raise awareness of social media to information users • User privacy policy • Verify the integrity, reliability, accuracy, and authenticity of the information • User education • Librarians need to play an active role in online communities • Creation of subject Bibliographies, indexing, and online information organization and provision • Social media creators should incorporate into their professional ethics aspects of social media policies
3.	Chen and Abedin	2014	USA	Computers in Human Behavior		• Fake news leads to aggression • Mental disorder • People become more uncivil on social media • Excessive criticism upon others • Psychological issues	
4.	Sisman and Yurttas	2015	Turkey	Procedia–Social and Behavioral Sciences		• Prevail false doctrines • Promote hidden agenda	• Systematic media literacy • Education • Raise awareness in the public

Table 4. *Cont.*

S.N.	Author	Year	Country	Journal	Factors Causing Fake News Sharing on SM	Disasters of Fake Social News on SM	Techniques for Fake News Diffusion Control (FNDC) on DM
5.	Jayasekara et al.	2016	Germany	Decision Support Systems	- Electronic marketing - Access to additional contextual information	- Mislead consumers about particular goods - Promote an aggressive public attitude - Fake campaigns - Manipulate decision-making approaches - Fake ratings - Fake Facebook likes - Fake social information affects the decision-making of backers on crowdfunding platforms over time	
6.	Zhu et al.	2016	China	Physica A	Development and mobile-based technologies	- Fake financial information may seriously lead to turbulence in global financial markets - User privacy violation	
7.	Fernandez	2017	USA	Library High Tech News	- Web-based publishing platforms - Fallible human tendencies - Technology companies are legitimately reluctant to engage in obvious censorship	- Cause of Anxiety - Emotions and identities are influenced	- Both librarians and other stakeholders should work to reconfigure information literacy instruction - Deep understanding of the technology - A partnership among interested individuals, libraries, and technology companies
8.	Batchelor	2017	USA	Reference Services Review			- Promote effective research and critical thinking skills - Non-partisan: An effective resource for checking facts does not have a partisan agenda or bias - Documentation: The resource must have sufficient references and original documents to support analysis - Track record: A history of reliability, recognition, awards, etc. - Information Literacy instruction

Table 4. *Cont.*

S.N.	Author	Year	Country	Journal	Factors Causing Fake News Sharing on SM	Disasters of Fake Social News on SM	Techniques for Fake News Diffusion Control (FNDC) on DM
9.	Anderson	2018	USA	Library High Tech News	• Social media apps • YouTube		• IL sessions • Web education • Media literacy • News literacy
10.	Ahmed and Lugovic	2018	UK	Online Information Review	• The decline of traditional media channels • Increased consumption of news through social media shaping political opinions and indeed potentially influencing the public	• Mental disorder • Generation of swarms of content	• Identify influential users as well as pinpoint the content they share
11.	Sullivan	2018	USA	Journal of Librarianship and Information Science		• Dangerous for certain results • Promote false beliefs • Online frauds	• Awareness about fact-checking • Training activities • Creation of spam folder
12.	Auberry	2018	USA	The Reference Librarian	• To create advertisements	• Dissemination of rumors and unverified claims	• To evaluate searched information • News literacy modules • Civic engagement • Library instruction sessions • Locate news sources • Course on fake news harm and detection strategies
13.	Hunt et al.	2018	USA	Journal of Creativity in Mental Health	• Online marketing • Social connections	• Prevail biased attitudes • Fear and isolation • Fake news can result in polarized, more racist, or ethnocentric ideation—ideation that, in some instances, would endorse violence • Flourish false ideas • FN can create distance in family and friends, relationships, and social supports • FN causes depression and anxiety	• The active role of counselors • Role of psychologists • Social media literacy • Digital expertise
14.	Copenhaver	2018	USA	The Reference Librarian			• Information literacy • The active role of information professionals • Digital literacy initiatives in institutions • News literacy skills • Media literacy

Table 4. *Cont.*

S.N.	Author	Year	Country	Journal	Factors Causing Fake News Sharing on SM	Disasters of Fake Social News on SM	Techniques for Fake News Diffusion Control (FNDC) on DM
15.	Junestrom	2019	Sweden	Journal of Documentation	• User generated content • Legal and cultural differences between countries • Aggressive online news forums	• Abusive, hateful and offensive content • Frustration in the public • Horrible consequences	• Avoid the sensationalist impulses guiding tabloid media culture • Administer and manage antagonistic posts • Guidelines for users and content moderators • Law for violators
16.	Jayasekara	2019	Sri Lanka	International Journal of Emergency Services	• Vital contributions to information dissemination during natural disasters and emergencies • Evolution of ICTs • To start campaigns on massive scales	• Sharing of misinformation to disturb others' lives • Decline of mental health • Fear among society	• Health and other disaster management bodies should work together to stop the sharing of fake news on SM • Governments should develop official social media channels • The government must develop a strategy to use SM channels before natural disasters
17.	Lei	2019	USA	Foresight	• Modern information warfare • Low cost • Anonymity • Rapid evolution of information technologies	• Effect on international relations • Cyber crimes • Threat to international peace	• Censorship
18.	Kim et al.	2019	USA	Journal of Management Information Systems	• Creation of news by anyone • Fast spread of content	• Flourish conspiracy against others • Prevalence of fake news has not only shaken the public's trust in journalism but also stirred up criticism towards social media for not taking more proactive countermeasures • Impact upon users' actions • Effect on beliefs	• Assessment of the source of news reputation • If a lack of ratings increases skepticism, then widespread application of ratings to reputable sources may help limit the impact of fake news
19.	Talwar et al.	2020	India	Journal of Retailing and Consumer Services	• To plant a seed of mistrust • To promote a specific point of view • Sharing fake news due to lack of time • Sharing fake news due to religiosity • Instantaneous sharing for creating awareness	• Consumers may also be misled into buying certain products based on fake reviews	• Authenticate news before sharing on SM

Table 4. *Cont.*

S.N.	Author	Year	Country	Journal	Factors Causing Fake News Sharing on SM	Disasters of Fake Social News on SM	Techniques for Fake News Diffusion Control (FNDC) on DM
20.	Liu and Wu	2020	USA	ACM Transactions on Information Systems	• General popularity of SM • Cost effective • Easy dissemination of news	• Inestimable social harm	• Fact-checking sites • Automatic machine learning-based detection approaches
21.	Sampat and Raj	2021	India	Aslib Journal of Information Management	• pass time, information sharing, and socialization gratifications • Entertainment		• Agreeable and conscientious personality traits lead to authentication news
22.	Rhodes	2021	USA	Political Communication	• Social media as a primary gateway to news source • Overwhelming interest to use social media • Fake account on SM	• Creation of fake stories • Individuals are more likely to absorb false information because human beings are wired to trust familiar sources that confirm their existing world view • A communication environment brimming with misinformation exacerbates confusion in open societies	• Fact-checking tools appear to decrease the sharing of questionable material
23.	Gimpel et al.	2021	Germany	Journal of Management Information Systems	• To search news stories • Source of entertainment • Profit through advertising • Access to broad audience • Low effort in setting up an account on SM	• Deception • Severe negative impact on individuals and society • Negative feelings	• To report fake news so that the fake news can be professionally checked, flagged, or even removed • Social norms • Fact-checking organizations
24.	Schuetz et al.	2021	USA	European Journal of Information Systems		• Threat to mental health	• To empower citizens to detect and contest fake news • Public awareness • Fact checking
25.	Chauhan	2021	USA	Ethics and Behavior	• Social interaction • Freedom of expression	• Fictitious job companies • Manipulation of media presentation context • Moral issues	• Ethical sensemaking strategies
26.	Dabbous et al.	2021	Lebanon	Behaviour and Information Technology	• To produce and exchange information • Online marketing	• Horrible consequences due to absence of adequate control mechanism	• Verification behavior • Information skills • Adequate education
27.	Yuan et al.	2021	China	Decision Support Systems		• Psychological effects • Fake news causes enormous distress and inconvenience to peoples' social lives	• Knowledge-based analysis

Table 4. *Cont.*

S.N.	Author	Year	Country	Journal	Factors Causing Fake News Sharing on SM	Disasters of Fake Social News on SM	Techniques for Fake News Diffusion Control (FNDC) on DM
28.	Silva et al.	2021	Brazil	Journal of Applied Security Research	• Rise of smartphones • High-tech data analytics, coupled with ultra-sophisticated personality testing based on social networking activity have been used to produce and direct fake news to highly specific sections of the population to influence people in the most diverse segments, such as politics and public security • Use of propaganda • The new mood of war		• Fact-checking websites • Usage of artificial intelligence
29.	Velichety and Shrivastava	2022	USA	International Journal of Information Management	• Source of gathering and disseminating information • Online advertising	• Biased attitude • Confused psychological state • User-generated content leads towards falsehood and ambiguity	
30.	Piazza	2022	USA	Dynamics of Asymmetric Conflict		• Social media fake news contributes to domestic terrorism within countries • Change in public opinion • Intolerant attitudes • Online fake news is linked to increased hostility towards liberal, centrist, or establishment political figures, erosion of faith in the trustworthiness of social and political institutions and heightened toleration of or support for fringe, anti-establishment or radical political actors and movements	• Strict policy for fake news disseminators • Strict check on fake news
31.	Raza and Ding	2022	Canada	International Journal of Data Science and Analytics			• Early detection of fake news • Quality big data • Block fake social media accounts causing fake news • Artificial intelligence • Content-based methods

5. Factors Causing Fake News Sharing on Digital Media

Various factors influenced fake news sharing on digital media platforms. These factors are classified into the rise of technologies, social connections, political reasons, no center of control, online business and marketing, and quick dissemination and retrieval of information. These factors are discussed below:

5.1. Rise of Technologies

Results showed that the rise of technologies, social networking websites, smart devices, high-tech tools, and gadgets created an obsession with fake news sharing on social media. Social media platforms including Facebook, YouTube, and Twitter [37], the rise of smartphones, and high-tech data analytics [53] stimulated users to share fake news on social media for influencing people across diverse segments. The decline of traditional media channels led to increased consumption of news through social media [54], web-based publishing platforms, the evolution of ICTs, rapid developments in information technologies, and innovations in mobile-based technologies [4,55–57], enabling users to actively interact with the content as well as its creators and add value to the accessed content [58]. User-friendly interfaces provided access to additional contextual information [55,58].

5.2. Social Connections

According to the results, online social relations were also an influential factor to disseminate FN on DM. Social connections, online social relations and friendships, virtual social worlds, content communities, and social interaction [10,44,58,59] provided information-sharing and socialization gratifications [60]. Online friendships led not only to collaborative projects, access to a broad audience, and freedom of expression, but also to sources of entertainment [10,42,44,60].

5.3. Political Reasons

Fake news was created on digital media due to certain political factors as some political leaders promoted specific agendas to gain public favor [16]. Fake news on DM was posted to shape political opinions [54]. Aggressive online news forums were developed [61] to plant seeds of mistrust, promote a specific point of view [62], and use propaganda against others [53]. User-generated content led to ambiguity [63], contributed to domestic terrorism, changed public opinion, increased hostility towards liberal political figures, caused loss of faith in the trustworthiness of social and political institutions, and increased intolerant attitudes [50].

5.4. No Center of Control

The 31 studies identified that often, no center of control in social media platforms existed through user-generated content [58]. There were legal and cultural differences among countries [61] and it resulted in reluctance on the part of technology companies to engage in censorship laws that might hinder the spread of fake news on social media [4]. The anonymity of users on social media platforms [56] enabled them to create news of any type [40]. Fallible human tendencies, fake account creation on DM, and the ease of setting up multiple accounts on social media were obvious factors of fake news sharing on social media [4,41,42].

5.5. Online Business and Marketing

Social media, as a primary gateway to the news source, inspired businesspeople, freelancers, advertisers, marketers, and entrepreneurs to bring innovation to their businesses through the use of social media [41,64]. Nevertheless, fake financial content on digital media created problems for online clients regarding product quality [62]. Online advertisements helped start campaigns on a massive scale and facilitated the attainment of financial success [55,58]. Social media was a useful factor in electronic marketing [55] as it provided instantaneous sharing for creating awareness to a broader spectrum of soci-

ety [62]. Businesspeople had an overwhelming interest to use social media on account of features such as cost-effectiveness, maximum profit via electronic advertising, and online marketing [40,41,59,63,65,66].

5.6. Quick Dissemination and Retrieval of Information

Fake news on digital media had become a low-cost modern weapon [53,56]. DM spread false online content quickly, searched fake news stories, and produced and exchanged fake information [40,42,45]. It gathered and disseminated news easily, and shared fake news due to religious belief [62,63,66]. Due to the general popularity of DM related to the fast delivery of online information, fake news was shared during natural calamities [55,66].

6. Problems Caused by Fake News on Digital Media

The study identified the problems caused by fake news (FN) on digital media (DM). It was found that fake news caused an information flood, and generated swarms of content [10,54]. Fake news exploited privacy, provided a false sense of security, spread rumors, released naked pictures, poked fun at celebrities, disclosed confidential information; provided possibilities for harassment, raised issues of conflicts of interest, and damaged personal reputations because FN on DM was controlled and administered by third parties [58]. Fake news on digital media led to aggression, created mental disorders, promoted uncivil norms, increased excessive criticism of others, influenced emotions, and raised psychological issues [4,67]. FN on digital media perpetrated false doctrines, promoted hidden agendas; misled consumers about particular goods, promoted aggressive public attitudes, caused fake campaigns, manipulated decision-making approaches, provided fake ratings, and led to the turbulence of financial markets across the world [19,39,55,57].

Fake news on digital media disseminated unverified claims, promoted biased attitudes, caused fear and isolation to increase, resulted in ethnocentric ideation, claimed false ideas, created distance in family and friends, relationships, and social support and also caused depression [59,65]. It caused abusive, hateful, and offensive content, frustration in the public, horrible consequences, the decline of mental health, panic in society, and disturbance in the lives of others [43,55,61]. It was a threat to international relations, national and international peace, and caused cybercrimes [56]. It triggered conspiracies against others, impacted on users' actions, gave birth to inestimable social harms, and misled consumers to buy certain products based on fake reviews [40,62,66].

Fake news has caused enormous distress and inconvenience to people's social lives, exacerbated confusion in society, and stimulated individuals to absorb false information [41,68]. It has had a severe negative impact on society as it has enhanced negative feelings, raised moral issues, lacked adequate control mechanisms, manipulated the media, and given rise to fictitious job companies [42,44,47].

7. Framework to Combat the Problems Caused by Fake News Dissemination on Digital Media

A framework was constructed based on the results of the selected studies for fake news diffusion control and is portrayed in Figure 4. The framework was developed having drawn insights via thematic analysis of the derived literature for fake news detection on digital media and measures to combat it successfully. It consists of 73 synthesized themes grouped according to four major constructs—effective research and critical thinking skills, usage of artificial intelligence, information laws and ethics, and media and news literacy—to fight against fake news disasters on social media platforms. These themes are elaborated as follows:
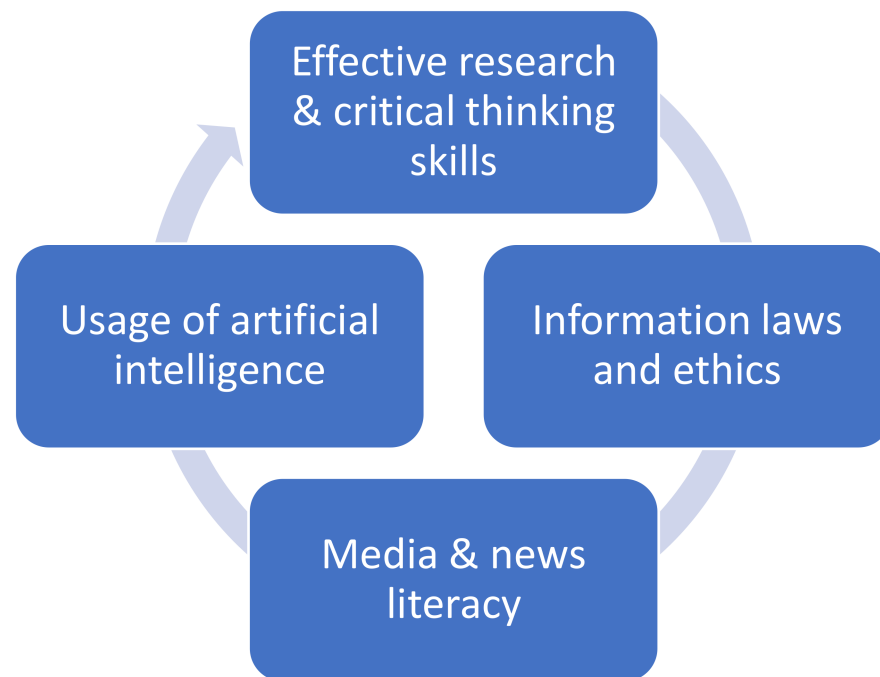
Figure 4. Model of fake news disaster management.

7.1. Effective Research and Critical Thinking Skills

Social media users should possess effective research and critical thinking skills for fake news diffusion control. They should verify the integrity, reliability, accuracy, and authenticity of information that exists on social media platforms [58]. They should identify influential users as well as pinpoint the content they share on DM [54], and be aware of the necessary documentation behind posted news on social networking websites [38]. They should avoid the irrational sensationalist impulses related to fake news [61], and use social media applications carefully to authenticate news before sharing it on DM [10,62]. They need to focus on verification and ethical sensemaking strategies so that the fake news can be professionally checked, flagged, or even removed [42,44,45]. They should have certain personality traits for assessment of the source of news reputation, and follow social norms for fact-checking tools that restrict the sharing of questionable material [40–43,53,60,66]. Critical thinking skills urge information-literate people to locate news sources that can be used to evaluate the searched information through social media applications [65]. It is a fact based on empirical evidence that effective research and critical thinking skills can lead to fake news being identified and reported to digital media administrators.

7.2. Usage of Artificial Intelligence

Usage of artificial intelligence facilitated fake news diffusion control as automatic machine learning-based detection approaches proved useful in limiting the impact of fake news on social media forums [40,53,66]. Emerging technological tools [4] including big data analytics helped in the track record for testing reliability of the information [38,69,70]. Automatic content identifier machines created spam folder for fake news, and provided knowledge-based analysis automatically through the creation of subject bibliographies, indexing, and online tools [19,58,68]. Technology companies needed to work collaboratively with interested individuals and information professionals in this regard [4]. Early detection of fake news, quality big data, blocking of fake social media accounts causing fake news, automatic fake news detection tools, and content-based methods were productive methods to control fake news diffusion on digital media [69]. Results have clearly shown that the usage of an artificial intelligence-based information authentication system is a useful source to successfully fight against the fake news war on social media platforms.

7.3. Information Laws and Ethics

Social media creators should incorporate into their professional ethics aspects of social media policies to keep a strict check on fake news [58]. Acts of censorship need to be introduced to ensure a controlled system on social media [56]. User privacy policies should be administered, and guidelines for users and content moderators must be drawn up [58,61]. Governments should develop official social media channels and develop a strategy to use DM before natural disasters to prevent the sharing of false news [55]. Laws against the violation of such policies should be implemented to administer and manage antagonistic posts [61]. Health and other disaster management bodies should work together to stop the sharing of fake news on DM [55]. A strict policy should be enforced for fake news disseminators [50]. Therefore, implementation of information laws and professional ethics by concerned bodies prove helpful in stopping the spread of fake destructive news on social networking websites.

7.4. Media and News Literacy

Systematic media literacy education is required for fake news disaster management on social media and to raise public awareness of the harm that online fake news can cause [39,43]. Information users should be made aware of social media so that they can be empowered to detect and contest fake news [43,58]. Information literacy instruction, user education, web education, news literacy, awareness about fact-checking, training activities, news literacy modules, civic engagement, library instruction sessions, courses on fake news damage and detection strategies, digital literacy initiatives in institutions, digital expertise, social media literacy, adequate education, and information skills are needed to manage fake news on social media effectively and efficiently [19,37,38,45,58,59,65,71]. Library and information professionals must play an active role in online communities to reconfigure information courses in collaboration with other stakeholders [4,58,71]. The role of counselors and psychologists is also imperative and indispensable in reducing the negative effects of fake social news on digital media [59]. Literacy skills in new media can prove a useful tool in controlling fake news diffusion in digital media. The literature shows that there is a strong positive relationship between literacy in new media and control over fake news diffusion in digital media. Without imparting media and news literacy in digital media users, disinformation may not be stopped. Adequate information literacy skills are a useful and valid source to detect and stop the proliferation of fake online news. Hence, media and news literacy are effective weapons for controlling the spread of fake online news.

8. Discussion

Fake news on digital media platforms is causing problems globally. Digital media is a leading source of fake news creation that leads to mental aggression among men and women in society and causes destructive consequences. The negative aspects of DM cannot be ignored as they create restlessness, panic, and disaster in the lives of individuals, societies, communities, and countries through the generation of false online news. FN disasters on DM have a global impact. Demand for fake news management systems is rising rapidly. Measures adopted to combat fake news on digital media are of immense value in the present era of misinformation. In order to safeguard the precious future of current and future generations, fake news disaster management is of paramount significance as social survival is not possible at all without controlling the flood of fake digital information [39,67].

This instant study is the first of its kind and has systematically selected and critically reviewed 31 studies published in the English language from geographically dispersed locations of the world to provide insights into the area of fake news diffusion control.

Related to the first objective, the study identified six major factors which cause fake news sharing on social media platforms. These factors are the rise of technologies, social connections, political reasons, no center of control, online business and marketing, and quick dissemination and retrieval of information. These are further classified into several sub-groups.

Related to the second objective, the study revealed disasters caused by online fake news which destroy individuals, societies, and nations to a great extent. These disasters include a false sense of security, possibilities for harassment, issues of conflicts of interest, loss of personal reputation, aggression, mental disorders, uncivil norms, psychological issues, promotion of hidden agendas, aggressive public attitudes, fake campaigns, depression, mental health issues, and panic in society. Fake news causes enormous distress and inconvenience to people's social lives, confusion in society, and leads individuals to absorb false information. It has a severe negative impact on society as it enhances negative feelings, raises moral issues, manipulates the media, and gives rise to fictitious job companies [42,44,45].

Based on the findings of the selected studies, the authors have constructed a framework for "fake news diffusion control" related to the third objective of the study. The framework consists of four constructs: effective research and critical thinking skills, usage of artificial intelligence, information laws and ethics, and media and news literacy. Effective research and critical thinking skills are the first step needed for the detection of fake news on social media. Information users with effective research and critical thinking expertise will find questions in their mind regarding the reliability and validity of online news, and will critically check sources of news and fact-checking websites. Various authors such as Wasike [58], Ahmed and Lugovic [54], Junestrom [61], Liu and Wu [66], Chatterjee [72], Chang [73], and Rhodes [41] support the theme of effective research and critical thinking, reinforcing the view that verification attitudes, personality traits, and creative skills facilitate the detection of fake news via social media platforms.

The second construct of the fake news control system model is the usage of artificial intelligence in which automatic machine-based tools are used to report fake social online news. Artificial intelligence assists in detecting fake news in every field of life. It proves useful in privacy and security-related matters. Google is also focusing on artificial intelligence to improve lives of people in society. Artificial intelligence tools are user-focused and human- centered. Raw data are examined efficiently through AI-powered applications. In the third construct, information laws and ethics are applied to take strict action against fake news disseminators on social media. The fourth construct of the framework is media and news literacy in which different courses are designed to spread civil literacy related to fake news disasters for efficient management. These strategies are concurrent with the findings of various studies conducted by Sisman and Yurttas [39], Fernandez [4], Sullivan [19], Copenhaver [71], Hunt et al. [59], Junestrom [61], Yuan et al. [68], Dabbous [45], and Piazza [50].

Fake news management is a continuous process and effective online fake news detection depends upon the combined efforts of humans and machines. An active role for disaster-management bodies and governments is highly significant for the implementation of fruitful measures for fake news diffusion control. As Jayasekara [55] has argued, disaster-management bodies and governments should work together to stop the sharing of fake news on DM and develop a strategy to use DM channels during natural disasters.

The rise of technologies, social connections, political reasons, no center of control, online business and marketing, and quick dissemination and retrieval of information are significant factors for the spread of fake news on social media applications. These factors need to be addressed using modern-driven technologies and tools so that the spread of false online news may be avoided. Our study also identified various problems that have arisen because of fake news on social media. Pertinent problems include exploitation of privacy, prevalence of rumors, leakage of vulgar content, hidden agendas, mental health issues, violence, aggression, excessive criticism, biased attitudes, cyber-crimes, and moral issues. Similar problems have been reported by Chen and Abedin [67], Fernandez [4], Ahmed and Lugovic [54], Lei [56], and Chauhan [44].

The results of this instant study are equally beneficial for all stakeholders including civilians, professionals, media personnel, and all users of digital media. The study has constructed a framework based on the findings with four propositions devising an efficient

system for fake news diffusion control. The study has provided breadth by developing a framework to control fake news. When all stakeholders are actively involved in applying the given framework, the risks of fake news disasters may be minimized and social survival is possible. The framework is more applicable and productive when realizing the social disasters of fake news via digital platforms. Decision-making bodies can use the results of the study as a benchmark to frame impactful policies for controlling fake news diffusion. Our findings will help the creators of social media websites to generate such methods as are useful in minimizing the spread of fake news on DM.

This study has worthwhile strategic and managerial implications. Institutions and organizations may follow the provided guidelines to stop fake news diffusion on digital media. The findings of the study aptly indicate that the identification of fake news on digital media provides shared benefits to individuals and companies. The social harms of fake online news may be avoided through the practical implementation of the recommendations provided in this study. If legal policies are not applied to stop the spread of fake digital news, then its effects may damage the roots of society. This study reinforces practical steps to control the virus of fake news on social media through strategic practices. This paper provides a theoretical basis for the best practices, strategies, practical measures, and techniques for fake news diffusion control on digital media which are important for the proper development and advancement of society. The framework provided in the study is equally beneficial to all stakeholders.

9. Conclusions

This instant study carried out a systematic literature review through 31 selected studies to identify factors behind the sharing of fake news on digital media, disasters of fake online news, and strategies to handle the flood of fake news stories effectively and efficiently. Based upon the insights drawn from the synthesized studies, a framework for fake news management was developed which consists of four steps (Figure 4). This study is the first attempt to offer a comprehensive and critical review on the topic of fake news diffusion control. Previous studies have adopted empirical methods to investigate and explore the topic of fake news; however, the authors of the instant study have used a systematic review methodology as it provides a vast range of diverse disciplines in which area of fake news has been identified and varying themes are found for the provision of deep insights to identify impactful findings. This study is an important contribution to the theoretical development of the issue. The model developed in light of the findings of 31 selected studies will assist policymakers to devise policies to control fake news proliferation on digital media applications.

10. Recommendations

Based on the study findings, the following recommendations are offered to control the spread of fake news on digital media:

- News posted on digital media should be verified as verification and accuracy checks via fact-checking websites are instrumental against harmful and horrible claims of fake news stories on digital media applications.
- Rating sources is a viable approach to combat false news on DM and to avoid the overwhelming wave of FN that is bringing destruction to the lives of people across the world.
- Social values and norms should be inculcated among web users as these are fast socio-technical solutions to fake news disasters on social networking websites.
- Modern-driven techniques based upon linguistic cue approaches via machine and network approaches are required to tackle the FN flood that is created by content generators.
- Web users require digital media literacy to win the war against fake news on social media that is causing disasters globally.
- Information professionals should raise civic literacy among the public to detect fake stories.

- Algorithmic solutions are of immense value in the fight against fake news disasters.
- Library professionals should play their part in combating misinformation that is replete with uncontrollable dangers.

11. Limitations and Future Studies

Despite significant contributions, our study has some limitations that need to be reported. A key limitation of the instant study is the inclusion of research articles (*n* = 31) to conduct systematic review for constructing an evidence-based framework to control fake news diffusion on digital media. Other sources of literature have not been included in the study. Another pertinent limitation is the exclusion of research papers that have not been published in the English language. The instant study is conducted through systematic review methodology; nonetheless, a model to combat fake news on digital media needs to be conducted having used empirical approaches. Further studies should be conducted into the relationship between new media literacy and web-based fake news epidemic control.

Conflicts of Interest: The authors declare no conflict of interest.

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
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Article

WhatsApp as a University Tutoring Resource

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Abstract: Tutoring, as a process of accompaniment of university students, has among its purposes identification of and reflection on the various difficulties that can interfere in the development of student competencies. To the same end, the present research explores the possibility of using WhatsApp as a tutoring resource in universities, with an emphasis on identifying and reflecting on the academic, personal, and family problems of students. This case study uses a quasi-experimental approach with a treatment group and a control group intentionally selected at the Escuela Profesional de Educación Secundaria de la Universidad Nacional del Altiplano de Puno, Peru, during the first semester of the 2020 academic year. Data were collected using semi-structured interview guides and individual tutoring cards. The results show that this technological resource improved the university tutoring service among the students in the experimental group. It proved more flexible and attractive to students, who were motivated to externalize and reflect on their personal, family, and academic difficulties and showed increased openness to receiving help in problem solving them. On the other hand, student participation was less active in the control group. These findings affirm that WhatsApp is a resource that can allow more spontaneous and friendly communication between tutors and students, creating a context conducive to achieving the objectives of university tutoring.

Keywords: WhatsApp; social networks; interpersonal relationships; higher education; digital communication

1. Introduction

Currently, social networks and instant messaging applications have been proven to support educational processes, though not as substitutes for face-to-face interaction [1]. ICTs can provoke emotions and feelings, which implies the channeling of emotions when interacting with these tools [2].

Today, WhatsApp is one of the most popular instant messaging applications in the world. According to Statista [3] data, monthly active users of WhatsApp will number 2 billion in 2021, followed by Facebook Messenger with 1.3 billion users and WeChat with 1.2 billion users. WhatsApp has a record of nearly one billion messages sent in a single day. In addition, the platform allows other functions, such as making calls, sending voice messages, and sending multimedia content such as images and videos, among others.

During the COVID-19 pandemic [4], 15 billion minutes of voice and video calls per day were recorded [5]. As for the users who use the platform, data indicate that most of them are young people between 18 and 24 years old. In the United States alone this sector represents 44% of WhatsApp users, followed by approximately 30% representing users between the ages of 25 and 29 and 26% between the ages of 30 and 49. Finally, seniors over the age of 65 account for 7% [6].

In this sense, WhatsApp is a tool that can be used in different fields of application both for its availability on various platforms and its reach to different types of users.

WhatsApp has a high level of acceptance in online learning thanks to its practicality, the availability of support, motivation, and continuous connection with friends, as well as the possibilities it offers students in terms of exchanging information and participating in learning discussions [7].

In the field of education, it can help to promote participation in the classroom and encourage students to build knowledge. Activities such as sharing educational content in various formats such as text, video, audio, and web resources are among the advantages offered by this tool. In addition to being a tool available 24 h a day, students can establish student-to-student or teacher-to-student communication, which promotes the generation of discussions on educational topics in context.

WhatsApp in the educational environment can represent an area of opportunity in the teaching–learning process, and with the right strategies can be adapted to the contexts of each student and teacher for the promotion of research, knowledge construction, student self-learning, and collaboration.

Previous studies have shown that WhatsApp offers diverse educational possibilities; for example, WhatsApp is known to be a space of opportunity that acts as a conduit to help African schoolchildren succeed in school [8]. During the COVID-19 pandemic, it was evidenced that WhatsApp application can increase English language learning during summer intensive courses [9] and that social networks and applications such as WhatsApp can serve as communication and teaching tools in developing countries [10].

The general objective of this work is to explore the possibility of using WhatsApp as a tutoring resource at the Universidad Nacional del Altiplano de Puno, Peru. In addition, particular objectives we propose to identify through this tool are recognition and reflection on academic, personal, and family difficulties of students and explaining how the use of this technological resource can help to improve interaction between tutors and the tutored.

This work is composed of seven sections. The background Section 2 delves into the topic of university tutoring through the use of WhatsApp. Works in the literature concerning the use of WhatsApp as a tool for teaching and learning are presented in Section 3. Section 4 presents a case study with students of the Professional School of Secondary Education of the National University of the Altiplano of Puno, Peru, and Section 5 presents the results. Section 6 discusses the obtained results in terms of university tutoring, and finally, Section 7 presents our conclusions and future work.

2. Background

2.1. University Tutoring

In the model of university training by competencies assumed by Peruvian universities, the tutoring system is a fundamental aspect that provides help, guidance, and counseling to students in order to achieve academic success [11]. University tutoring helps in the personalization of teaching and the integral development of students, focusing on preventing desertion and encouraging the practice of transversal competencies [12], leading to a strategy that allows individualized attention in a heterogeneous context [13].

The tutoring system at Universidad Nacional del Altiplano de Puno aims to guide and accompany students in the academic and personal aspects of their professional training process with an orientation towards achieving quality learning, reduce=ing student dropouts, and contributing to their timely graduation. The purposes of tutoring are referred to as guiding the student's learning process (general and specialty competencies) and guiding their personal development (soft skills).

This last idea is built on the proposal of the three-dimensional approach to tutoring, that is, personal, academic, and professional [14] and the decision taken by the Universidad Nacional del Altiplano de Puno to modify this three-dimensionality, analyzing the academic, personal, and family components.

Tutoring is an effective strategy to improve academic performance, although it requires good tutors, an adequate relationship with students, and a favorable environment [15]. Tutoring refers to both the academic field and other aspects, such as personal, family,

social, professional, and administrative matters [16], turning the tutorial action into a process of academic, personal, and professional counseling that responds to diverse student needs [17,18].

The dimensions addressed in the study which are considered in the university tutoring system of the UNAP are derived from these positions.

University tutoring is performed by professors as a function inherent to the exercise of their academic and research activities [19,20]. However, tutors do not always use the best strategies to approach their students and help them reflect on difficulties that may be interfering with their academic performance. It is this last aspect that is the foundation of this research. Tutoring comprises interaction processes between tutor and students based on mutual knowledge of their specific problems, needs, and interests [21]. Currently, three complementary and non-exclusive modalities of university tutoring can be distinguished, namely, individual or personal tutoring, group tutoring, and the newest, virtual tutoring [22].

In order to realize these tutoring modalities, it is necessary to create an environment that allows close, systematic, and permanent accompaniment to support the student and facilitate the process of constructing different types of learning, cognitive, affective, socio-cultural, and existential [21], including tye necessary use of mechanisms that allow easy and timely communication through information and communication technologies (ICT) and the advent of applications for smartphones, which offer effortless communication [23].

2.2. WhatsApp and University Tutoring

Mobile phones, social networks, and instant messaging applications such as WhatsApp are tools that allow immediate communication, create discussion environments, and allow for sharing files to facilitate personalized learning [24–26], all of which are perfectly adapted to a virtual tutoring system.

WhatsApp is one of the most common and widely accepted tools for communication and collaboration [23]; it is adapted to mobile use, allowing convenient and practical communication to the point of replacing phone calls in youth communication [27]. Therefore, WhatsApp has recently been proposed as one of the most popular applications used by students [28].

The pedagogical potential of WhatsApp has been addressed in several different aspects, including formal, informal, face-to-face, and distance education [29], and represents an innovative and effective resource for achieving beneficial communication [13,30]. WhatsApp can be used as a productive and viable pedagogical tool for creating a participatory learning environment [31], and has even greater pedagogical use in the university [32]. Students can use it to create instant messaging groups to keep up to date and support each other academically [33], as WhatsApp motivates students and professors and encourages them to share information [34].

Additionally, WhatsApp creates a more individualized relationship with the teacher, motivates students to learn, and generates cooperation and participation even from the shyest students, allowing them to develop communication [35], which is made more expressive and varied by the use of various textual and non-textual elements such as images, videos, audio, and stickers [36]. Likewise, students communicate more through WhatsApp, and do so with enthusiasm and a feeling of freedom [37], constituting a useful tool for virtual tutoring [38].

WhatsApp has proven useful for both tutors and students, who claim that its usefulness lies in its power for efficient communication, both synchronous and asynchronous [39].

Likewise, WhatsApp is an application that allows teachers to provide students with timely support, guidance, and advice, guaranteeing quality contact and a "virtual closeness" that counteracts the social distancing implemented worldwide [11]

The use of WhatsApp as a tool for the development of university guidance and tutoring processes has proven to be effective, as students ae able to access any type of information anywhere and at any time [40].

Although research on this topic is scarce, the results on the use of WhatsApp as a tutoring support resource show several advantages: it generates individualized interaction with students and a positive view of communicative competence that a tutor should have; it allows students to engage in consultations to perfect their academic work, and generates a group class feeling. However, disadvantages have been identified as well, the main ones being the students' idea that the tutor should be available to them every day and at any time and a preference for using individual chat and not the groups created for consultations [29,41]. These aspects are essential to the consideration of WhatsApp as a resource that generates the appropriate context to carry out university tutoring.

3. Related Work

WhatsApp is a messaging tool that allows for sharing information with other users, forming groups of interest, and coordinating these groups, among other functions. This makes WhatsApp a tool that can be used for educational purposes as part of the various existing teaching–learning processes. In the literature, there are several initiatives in which WhatsApp is the base tool for knowledge acquisition strategies.

In the last five years, WhatsApp has been used as a tutoring support tool thanks to the ease with which is can be adapted to the educational context through intertwined student–teacher interactions. The use of technology as an educational resource in educational institutions has allowed students to extend the range of possibilities in their learning experience. Authors such as [29] have emphasized new technologies, as today's students are digital natives and these tools are an essential part of both teaching and study as a means of simple generation of teaching–learning. An example of tutoring using WhatsApp is the case of [42,43], in which doctors and students established a communication mechanism within the Problem Based Learning (PBL) approach. The findings of this work indicate that WhatsApp can be a feasible study mechanism for study groups. In the case of [44], the authors focused on the use of methodologies for the integration of qualitative methods in order to learn how tutors adapt to teaching in groups. In both of these papers, the authors intended to establish effective tutoring styles through digital tools.

Other works such as those of [45–47] are oriented to the use of WhatsApp as a tool that can be incorporated into educational processes. These papers explore the possible success effects on students when using a technological environment compared to a traditional learning environment. In [48], the authors present a study using a sample of 166 law students in which teacher–student interactions through the use of WhatsApp were analyzed. The objective of this study was to determine the various mechanisms of interaction between students and teachers through a technology tool that teachers can use to monitor different academic tasks, coordinate in real-time, and analyze the interactions of students that affect the learning process. The authors of [49] presented a study with the objective of analyzing the potential of WhatsApp as a tool to promote health education aimed at reducing breast cancer by using WhatsApp groups to help women acquire the necessary knowledge for early identification of cancer. The results identified an improvement in women's knowledge on issues related to myths and truths about breast cancer.

In other areas of medicine, [50] focused on understanding how WhatsApp can result in a positive academic impact for veterinary students.

As can be seen, these works help to change the paradigm of education through the use of technology, promoting participation, freedom of dialogue, and the search for new resources and educational strategies to improve the quality of education.

4. Case Study

4.1. Materials and Methods

The case design was quasi-experimental, with a pre-and post-interview focused on a sample chosen for convenience in which there was no randomization in the choice of participants in the two groups. The goups were, first, the experimental group, which used

WhatsApp for tutoring, and second, the control group, which did not. The analysis was conducted through a mixed research approach.

4.2. Participants

The research was carried out during the first semester of the 2020 academic year, a semester that was conducted entirely virtually. The study population consisted of the students of the Professional School of Secondary Education of the Universidad Nacional del Altiplano de Puno, Peru (UNAP), numbering 1162 students in total.

The sample was purposive by convenience, considering as a selection criterion that the tutor should have an academic load of at least one subject in the 2020-I semester with that group. Under this criterion, 28 students were considered for the experimental group (IV semester) and 30 for the control group (III semester), drawn from the schools of Language, Literature, Psychology, and Philosophy. It should be noted that the study was carried out as a pilot educational experience at the university, and as such the selection of the purposive sample was considered acceptable.

4.3. Variables and Instruments

Two research variables were used. The first, WhatsApp, was considered as an independent variable, the use of which in the experimental treatment involved four resources inherent to the application: messages (text and voice, for synchronous and asynchronous communication), calls (for synchronous communication), attachments (Word, pdf, ppt, images, music, and videos for asynchronous activities), and emojis and stickers (supplementing text messages or replacing them in synchronous and asynchronous communication). These were used by the tutors according to their relevance for each activity and by the students according to their preference. The second variable, university tutoring, was considered as a dependent variable oriented towards identification and reflection on academic, personal, and family difficulties that could affect students' performance as related to specific aspects considered in the university tutoring system of the UNAP (Figure A1).

Data were collected using interviews, with semi-structured interview guides and individual tutoring forms as instruments. The interviews had the following two purposes:

- Generally, aiming to collect information on the academic, personal, and family difficulties that students faced which could negatively affect their development in the university environment; this was conducted before and after the experiment with the members of both the experimental and control groups.
- Specifically, oriented towards determining the perceptions of students concerning the use of WhatsApp as a virtual university tutoring resource; in this case, the interview was only applied after the experiment with the students of the experimental group.

The first semi-structured interview guide had nine guiding questions oriented towards identifying and addressing the academic, personal, and family problems of the students. This was accompanied by the individual tutoring form, an official instrument approved by the Academic Vice-Rectorate of the UNAP (see Figure A1 of the Appendix A) to record the difficulties that students might have, promote reflection, and aid in deciding on what help might be needed. The second semi-structured interview guide consisted of three questions related to the usefulness of WhatsApp as a university tutoring resource.

Both interview guides were evaluated by experts in psychology and tutoring at UNAP in order to ensure their validity. The results showed an Aiken's V coefficient of 0.88 for the first interview guide and 0.75 for the second, indicating the validity of the study instruments.

4.4. Procedure

We began with entrance interviews with the members of both groups, which were conducted through phone calls and video calls. The entrance interview aimed to identify academic, personal, and family problems which could affect the students' university

performance. Subsequently, a protocol was approved for the use of WhatsApp as a resource for academic, personal, and family tutoring during the semester in the experimental group, which contained guidelines about the purpose, activities, and rules for using this application. Figure 1 shows examples of tutoring through WhatsApp.
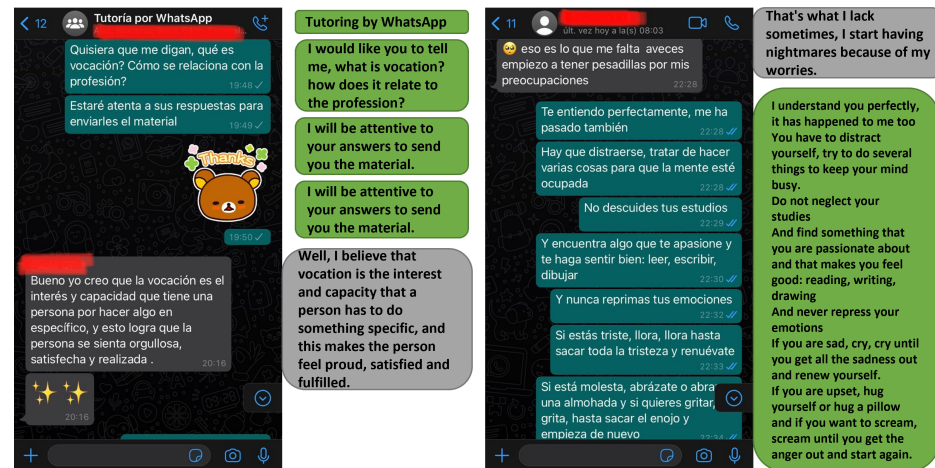

Figure 1. Examples of tutoring carried out through WhatsApp.

Informed consent was requested from all of the students, including the assurance that their identities would be handled confidentially, with 100% of them expressing agreement. Fourteen activities were carried out, always initiated by the tutor in the WhatsApp group, each one comprising a dynamizing and motivating element (six video, six audio, and two image activities were used), accompanied by questions and reflection activities to encourage comments on each topic addressed. Individual or group chat was used to address individual and group tutoring through WhatsApp. The topics were directly related to the problems identified in the entrance interviews and were modified according to the context. Each activity lasted one week, with the space for comments able to be extended until students felt comfortable sharing their experiences or required support.

At the end of the experiment, an exit interview was applied for both groups in order to take stock of how academic, personal, and family problems were addressed during the semester and aided by the university tutoring system. Students in the experimental group were interviewed to learn about their experiences concerning the use of WhatsApp as a university tutoring resource. It should be emphasized that in the control group the same topics were addressed and programmed in a work plan; the difference was that the activities were oriented towards setting up consultations or requesting support from the tutor and responding through telephone calls or by e-mail. The specific procedure is presented below in Figure 2.

The information collected in the entrance and exit interviews was processed quantitatively (percentages per item) and qualitatively (open-ended responses). To obtain the quantitative data, the students' responses were concentrated in individual tutoring cards, which made it possible to record and count the percentage of students in both the experimental group and in the control group who identified and reflected on their academic, personal, and family problems, establishing a comparison before and after the experimental treatment. Likewise, it was possible to establish a flow of reactions to the tutoring activities encouraged through the use of WhatsApp in the experimental group by recording the number of responses per week to the reflection questions, the number of individual conversations, and the number of group conversations.

The qualitative responses were studied from the point of view of discourse analysis, with the creation of categories based on the monitoring of dimensions that already exist for tutoring at UNAP, allowing us to understand the main academic, personal, and family problems affecting the lives of university students and to encourage reflection on them. Additionally, the final interview with the experimental group allowed us to capture the

perceptions of students regarding the usefulness of WhatsApp in the relationships between tutors and tutored.
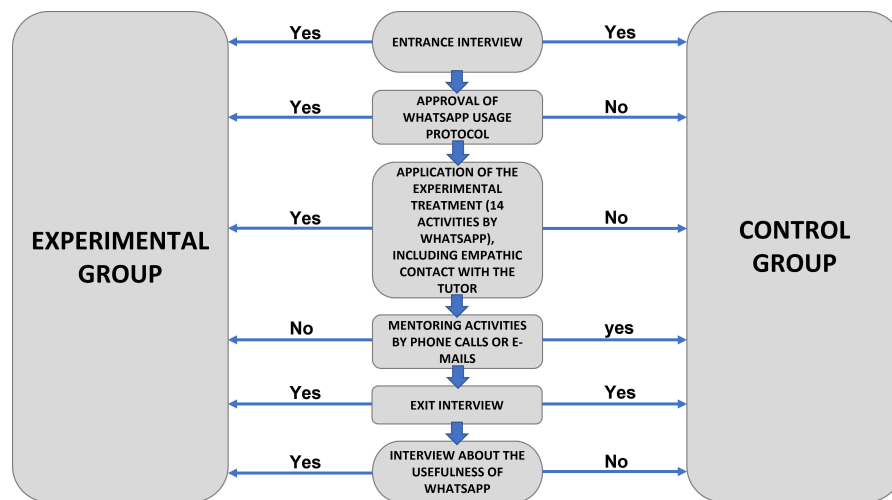
Figure 2. Experimental procedure.

5. Results

5.1. WhatsApp and University Tutoring

The obtained results show that WhatsApp helps to achieve the objectives of university tutoring, allowing the identification of academic, personal, and family problems of students in order to offer them the necessary support under permanent accompaniment in a way that does not interfere in their studies. Figure 3 shows a comparative approach to these problems through university tutoring in the experimental and control groups before and after the experimental treatment.

Before the experimental treatment, an average of 10% of the students in both groups allowed themselves to discuss their academic, personal, and family problems with their tutor, with no marked differences between them. After the application of WhatsApp as a university tutoring resource, 26% of the students in the experimental group on average managed to identify, reflect on, and try to solve their academic, personal, and family problems with the help of their tutors, creating spaces for reflection in order to prevent these difficulties from interfering in their development as university students. There was a difference of 16% compared to the input evaluation. In the control group, the difference between the entrance evaluation and the exit evaluation was only 4%, with no change in the treatment of students' problems through tutoring.
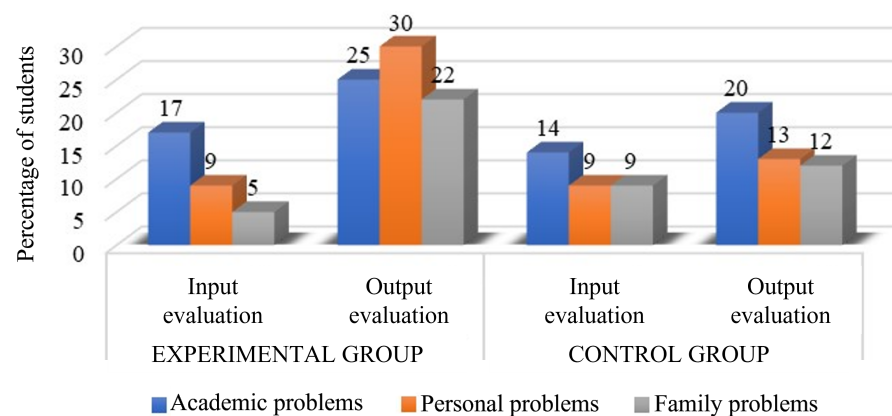
Figure 3. Comparative graph showing the students' reflection on their problems through university tutoring in the experimental and control groups before and after the experimental treatment.

5.2. Use of WhatsApp for Identification of and Reflection on Academic Problems

In the experimental group, the treatment of students' academic problems was the aspect that showed the most minimal progress; between the input evaluation and the output evaluation, there was only a difference of 8%, from 17% to 25%. Nonetheless, this result is positive, indicating that the problems presented are those that occur frequently to students and that they have no qualms in sharing them with their tutors to try to overcome them. Among all the features evaluated in this dimension, there are two aspects in which WhatsApp tutoring showed the best results:

- Interest and motivation to study, for which the approach increased from 25% to 50%, indicating that this group of students could not find clear reasons to study and required accompaniment and the implementation of activities that promote autonomous and conscious learning.
- Vocational instruction and identification with a career, which went from being addressed by 14% of students to being adressed by 29% in the experimental group, demonstrating that using WhatsApp for tutoring can generate reflection in students and help them to strengthen these aspects. Several of the students' answers are transcribed in Table 1.

Table 1. Students' expressions when addressing some academic, personal, and family difficulties (Note: Comments transcribed from WhatsApp).

Aspect	Subject Matter	Comments
Academic	Interest and motivation to study	E.14. I do things because I have to do them and that's it; but I don't do it with much enthusiasm, since I don't know if it is what I want. E.16. I have a goal and that leads me to study and make an effort because I want to get ahead. That's what you should do, classmates, identify your purposes and everything will be easier to understand.
	Vocation and career identification	E.13. Teaching is not my forte; but I believe that the career I study can have other missions. E.23. The problem with vocation is that in the society in which we live it is not valued…it can be observed that an individual with influence is worth more than an individual with knowledge and vocation of service…this discourages.
Personal	Personal goals and aspirations in a life plan	E.1. I have many projects and many goals; but I get discouraged when I see them disappear without being achieved…I believe that building a life project should begin in childhood, so that we don't get lost along the way. E.20. Establishing a life project is a serious thing, I think I should formalize this aspect; but I am afraid of being disappointed when I see that my goals are very far away.
	Autonomy and decision making	E.16. Most of the time, I take my own…but it happens to me that sometimes I find a very difficult situation and I get paralyzed, that's the problem (Emoji of an embarrassed and smiling face). E.17. I am afraid to make my own decisions, I always look for the approval of others before deciding something…I am fearful and I always need someone to advise me.
	Continuous stress	E.9. There are too many activities, I get headaches almost every day and I get desperate because I can't accomplish all my tasks. E.5. Sometimes I fall into despair, especially when things do not go as I plan; but today I understood that we must take things calmly. Thank you for the reflection.

Table 1. *Cont.*

Family	Conflicts in family relationships	E.11. I feel that my parents do not understand me, they do not agree with me and then we argue a lot and that affects me. E.17. Everyone looks for their own personal wellbeing and we forget that we are a family…sometimes I feel alone.
	Loss of a family member	E.3. I think I will never accept it, it hurts too much to know that I will never hug her again (Emoji of sadness and crying). E.17. I never thought it could happen to me, I never thought about death and now I see it so close, I don't like it, I don't want it… it took away almost all my will to live (Emoji of crying).

5.3. WhatsApp in the Identification and Reflection on Personal Problems

Of the three components of university tutoring conducted through WhatsApp, the aspect that had the best results was personal tutoring, which sought to identify and address the personal problems of students in order to help them find viable solutions and prevent these difficulties from interfering with their academic performance. Between the input evaluation and the output evaluation, there was a difference of 21%, from 9% to 30%, demonstrating that WhatsApp is a resource that can motivate students to externalize their personal problems, address them, and try to solve them with the help of their tutors and the services provided by the university. Among the traits evaluated in this personal dimension, three aspects stand out:

- The limitations that students have in establishing personal goals and aspirations in a life project, where their approach increased by 54%, from 7% to 61%, showing the need that students have to share their difficulties through a medium that is easy and convenient to use, such as WhatsApp.
- Fifficulties in autonomy and decision making, a trait where treatment increased by 42%, from just 4% to 46%, showing students' interest in addressing this issue and finding strategies that allow them to overcome it.
- The presence of continuous stress that leads students to an unstable and fragile emotional state. For this last trait, there was a difference of 39% between the input evaluation and the output evaluation, showing the need that students have to express the discomfort generated by various stressors. Several of the students' comments are transcribed in Table 1.

5.4. WhatsApp in the Identification of and Reflection on Family Problems

Family problems that could affect the academic performance of students were among the issues identified and reflected upon, increasing this aspect by 17%, from 7% in the entrance evaluation to 22% in the exit evaluation. This shows that tutoring via WhatsApp is a good strategy to motivate students to address their family concerns and to try to find a solution. Within this item of tutoring, two aspects were the most outstanding:

- The identification of conflicts in family relationships, where treatment increased by 43%, from 14% before the treatment to 57% after the treatment. This evidences students' need to share their family difficulties through a medium that provides confidence and makes them feel comfortable.
- With respect to the loss of a family member, the treatment of this trait increased by 25%, from 7% in the entrance evaluation to 32% in the exit evaluation. Several comments are transcribed in Table 1.

5.5. WhatsApp in Interactions between Tutors and Tutored

The communication processes in the experimental group using WhatsApp became more fluid from the fourth week onwards, when sharing problems with the tutor became a way for the students to generate empathy and promote mutual assistance and help among the members of the group, creating greater affinity by showing that the tutor might

have the same problems as the students, which promoted more expressive communication using the various resources of WhatsApp. Thus, reflection on the students' problems increased in individual and group conversations via WhatsApp (Figure 4), mainly evidencing the increase in individual conversations, reaching thirteen during weeks 11 and 12 of the experiment, when in the first weeks there were only three on average. In addition, group conversations remained constant between one or two per week, which was positive, as it helped to generate companionship and empathy among the group members. On the other hand, the answers to the reflection questions remained constant, with an average of twenty students answering them each week.

As mentioned, the use of WhatsApp as a university tutoring resource has been very useful in accompanying students who require help, allowing the establishment of affectionate and friendly ties between tutor and tutored, which is essential to generating support strategies in the academic, personal, and family development of students. This result is supported by the students' comments on their experience with the use of this instant messaging application, which are transcribed in Table 2.

Table 2. Comments on the use of WhatsApp as a university tutoring resource (Note: exit interviews with the experimental group).

Question Raised	Comments
Has this type of tutoring helped you to address your problems?	E.16. Not to overcome them, but to cope with them, to treat them as something normal that happens to many people and that I should not feel bad for having them. E.11. Some, others not; but at least it has made me feel accompanied. In addition, the strategies used were very reflective and made me feel that all human beings have problems and that they should not interfere in my development as a future professional. E.23. It has helped me to recognize many weaknesses that I had and did not want to accept, the reflections that the teacher sent us were very interesting and made me think about how important it is to love and value myself.
Why tell your problems or concerns via WhatsApp?	E.15. Since I formed the WhatsApp group, I felt comfortable with the tutoring system, it seemed to me something informal and it adapted to me; then I understood that within that informality there were clear objectives...I don't feel comfortable talking to her looking at her face, I feel that she is going to criticize me, but through WhatsApp I feel freer. We use WhatsApp for almost all the courses and doing it for tutoring is something comfortable. E.8. Because I feel more like my friend through this medium, I can say things that I would not say in a direct conversation, face to face. ...I was encouraged to tell her about my fears and my difficulties in putting together my life project. E.1. Because I can do it when I feel the need to talk to someone, using WhatsApp helps me to find support when I need it. Previous semesters it was difficult to make an appointment with my tutor and if I had problems. I had to wait until that day to tell him about my difficulties; instead with WhatsApp it is easier to find help and feel that there is someone willing to listen to you.
How did you feel interacting with your tutor through WhatsApp?	E.6. Super comfortable, in my tutor I found a friend, I had already worked the previous semester with her; we would set a date for the tutoring session and few times later we met again, our schedules did not coincide and we did not find the time to talk, it was a colder relationship; on the other hand, through WhatsApp it is better. E.14. I felt that she was a very special friend, whom I had to treat with respect, but with trust. The relationship became stronger because I could always contact her. At the beginning I was a little embarrassed to tell her something; but then I got used to it and it provoked me to tell her many things. E.10. Comfortable, because I use WhatsApp for almost everything, so it was perfect that I also use it to contact and talk to my tutor.
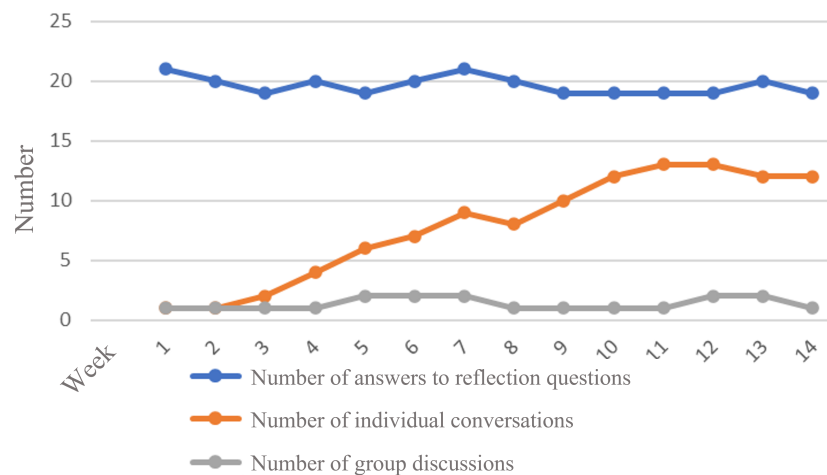
Figure 4. Graph showing the flow of reactions to tutoring activities in the experimental group.

5.6. Statistical Tests

This section presents a description of our statistical analysis using SPSS software [51]. In the experimental analysis group, for the three dimensions according to the Shapiro–Wilk test [52,53] the data are homogenized, that is, the perceptions are relatively the same in all cases. The same is true of the control group, except that in the personal dimension there is an approximation of non-normality, that is, the dispersion increases.

Student's *t*-test [54] was used to analyze the academic and family dimensions, and the Mann–Whitney test was used for the personal dimension.

The interpretation of the significance obtained here assumes that there are no differences in either group, that is, for the values corresponding to the before and after peiods for the academic aspect the perceptions are equal for Student's *t*-test, as the *p*-value is greater than 5% (see Table 3).

Table 3. Student's *t*-test: independent samples.

		Levene's Test for Equality of Variances		*t*-Test for Equality of Means				95% Confidence Interval of the Difference	
		F	**Sig.**	**t**	**gl**	**Sig. (Bilateral)**	**Mean Difference**	**Standard Error Difference**	**Lower**	**Upper**
expac_	Equal variances are assumed	0.351	0.560	−1.377	20	0.184	−2.27273	1.64994	−5.71445	1.16899
before	Equal variances are not assumed			−1.377	18,838	0.185	−2.27273	1.64994	−5.72811	1.18265

For the Mann–Whitney U-test [55] (see Table 4), the significance is less than 5%, meaning that there are differences between before and after, i.e., the personal aspect increased in difference as shown by the statistical test (see Figure 5).

Table 4. Summary of Mann–Whitney U-test for independent samples.

N Total	26
Mann-Whitney U	146.500
Wilcoxon W	237.500
Test statistic	146.500
Standard error	19.329
Standardized test statistic	3.208
Asymptotic sig. (bilateral test)	0.001
Exact sig. (bilateral test)	0.001

Figure 5. Mann–Whitney U-test: values corresponding to before and after for the academic aspect.

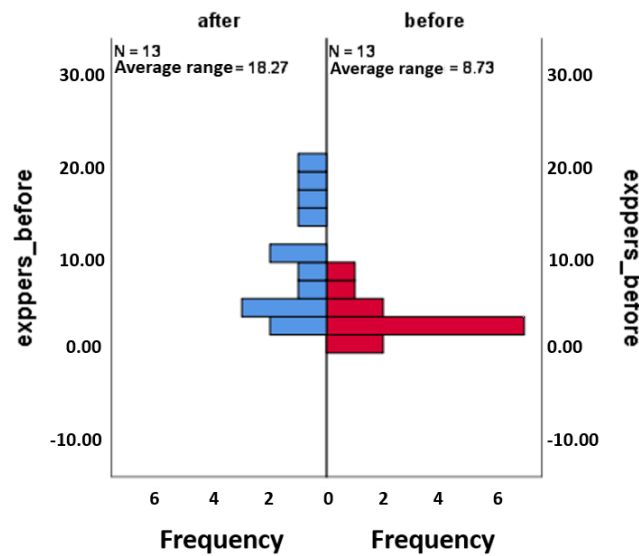For the comparative test (see Table 5), these results allow us to conclude that, statistically speaking, it is evident that the academic and family aspects are similar, that is to say, that there is no variation between before and after from the inferential test. In the case of the personal aspect the difference is evident, allowing us to see the importance of using WhatsApp in tutoring.

Table 5. Summary of hypothesis testing.

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of exp-fam_before is the same across VAR00013 categories.	Mann-Whitney U-test for independent samples.	a	It cannot be calculated.

Asymptotic significance is shown. The significance level is 0.050. a. The group field does not have exactly two values.

6. Discussion

WhatsApp is a resource that allows various topics to be addressed through university tutoring. Previously, tutoring has been identified as a determining factor in the development of autonomous learning, although its scope of action was focused on the academic aspect [56]. This situation has been overcome with the results of the present research, as we have shown that, with the use of WhatsApp as a university tutoring resource, the personal and family aspects of students' lives can be addressed in addition to academic ones, showing an advance in the coverage of this student accompaniment strategy. The tutoring space represents an environment of freedom and trust, where it is important to prioritize students' expression of doubts and concerns regarding their school life as well as their emotions and feelings [57], allowing the development of resilient attitudes and the achievement of a degree of satisfaction with life [58].

Additionally, having a protocol for the use of WhatsApp allows students and tutors to respect agreements concerning schedules and rules of interrelation through this medium, generating conversations that are developed according to the proposed objectives. This ratifies that the organized and planned use of WhatsApp, allowing students to respect the hours of consultations and comments, with reasonable exceptions [29]. Our results confirm that the presence of the teacher influences group conversations [59], especially if they show empathy to generate reflection. Therefore, WhatsApp represents a tool that, when used well, can be a great help for the proposed objectives [33], be these educational more generally or specifically in reference to tutoring.

The success of the use of WhatsApp in university tutoring is linked to the resources used: videos, audio, images, emojis, stickers, and others; linked to a clear objective, they allow for effectively addressing the academic, personal, and family difficulties of students. The tutor can encourage reflection on the topics of interest of students with the aid of teaching resources, recreational activities, and audiovisual material, among others [57]. Our results confirm that information and communication technologies (ICTs) contribute in various ways to the integral development of people, provoking reactions that allow the channeling of emotions when interacting with these tools [2].

It is further highlighted that between the group and personal tutoring modality, students prefer the latter, ratifying the claim that personal tutoring is the most valued by students, far above group tutoring [60]. This confirms that, although WhatsApp did start to be used as a tool for group use, most students preferred to make their doubts, queries, or opinions known in a personal way through private messages [29].

The relevance of communication and interaction evidenced by the use of WhatsApp was constituted as a resource that improves the university tutoring service, as it makes it more flexible and attractive to the student, especially for its influence on fast and effective communication [23], this being a feature that is related to the ease of using this application; ratifying that either by convenience, shortage of time, or shyness, young people prefer to communicate by WhatsApp than face to face [27].

It is confirmed that WhatsApp is the resource that works best for tutorial work, surpassing even face-to-face tutoring, which is explained by the knowledge and skills that students have in the management of this application [11], generating student satisfaction by recognizing the advantages of this method of tutoring compared to other traditional methods [40].

Likewise, it is ratified that students prefer to concretize tutoring communication in real time using technological applications [61], with synchronous communication by message or video call being the aspect that has turned WhatsApp into a resource that can promote the process of academic guidance, counseling, and effective support to students [11].

These statements coincide with the idea that both tutors and students prefer social networks and instant messaging applications such as WhatsApp in non-face-to-face tutoring processes because they are part of their daily life [24].

7. Conclusions and Future Work

WhatsApp is a resource that allows for more spontaneous and friendly communication between tutor and tutored, creating a context conducive to realizing the objectives of university tutoring. This is an aspect that confirms the idea that through WhatsApp a community and a very positive group feeling is created, as students feel that the teacher or tutor is always present [33]. In addition, it is ratified that the relationship between tutor and tutored is framed in a high level of communication, trust, closeness, empathy, and mutual acceptance, aspects that are achieved through permanent interactivity [20], which is greatly favored by the use of WhatsApp. Likewise, it is confirmed that students value having a tutor to help them in their academic work using this instant messaging system, which allows the tutor to respond and comment in a more agile way, further ratifying that quick responses from tutors can help students to continue addressing a problem [62].

With the application of WhatsApp as a tutoring resource, the bonds between tutor and students became more effective, helping group members to develop social skills. This ratifies that the relational connection is very important among group members, and although both vertical and horizontal relationships are possible in tutoring groups, it is more frequent and useful that these are horizontal [63]. Our results agree with the premise that these spaces generate relationships of trust and collaboration which are conducive to the exchange of experiences, opinions, and practical advice [64]. This situation challenges the tutor in a demanding role, forcing them to develop their leadership and fundamental interpersonal skills, as they must relate, listen, and respond to different personalities [65] while training thei own personal dimension [66].

In addition, the results obtained here demonstrate the usefulness of virtual tutoring, as WhatsApp allows permanent accompaniment and communication between tutor and tutored, dispensing with the physical presence of both. This result overcomes previous conceptions that have downplayed the importance of virtual tutoring, indicating that neither students nor tutors were fully aware of the possibilities that ICT can bring to the tutoring modality [60].

The results obtained in this work are positive, and allowed us to contrast the three dimensions of academic, personal, and family. Although the results did not show a significant difference in the academic and family dimensions, in terms of the personal dimension an increase of 5% was found, highlighting the importance of the use of WhatsApp. In addition, this study made it possible to capture impressions. It was possible to determine the effectiveness of WhatsApp as a platform that allows the use of other resources, such as videos, files, and images, as a reinforcement to tutoring. As limitations in this work, it can be mentioned that the quasi-experimental work was conducted with a single teacher-tutor and an experimental group of students intentionally selected as a pilot study. Therefore, the results cannot be generalized. A prospective replication of the study with a larger number of tutors and students would help to provide a more complete view of the usefulness of WhatsApp as a resource for academic, personal, and family tutoring at the university. The possibility of measuring the improvement in the achievement of student competencies as a result of the tutorial action remains open as well.

Finally, the challenges for the future of this work include learning more about the advantages and disadvantages of using WhatsApp through more case studies within higher education institutions, using a larger number of students to strengthen quantitative studies, identifying teaching–learning styles through the formation of study groups between tutors and students, addressing user satisfaction studies for teachers and students in the use of WhatsApp as a tool in the classroom, and adapting the use of WhatsApp to existing learning models and even to generating improvements in them.

Appendix A

INDIVIDUAL TUTORING SESSION

STUDENT NAME:_____ ENROLLMENT CODE:_____

PROFESSIONAL SCHOOL:_____ DATE:_____ TUTOR:_____

The session begins with the question, How are you doing in college? What problems do you have?
From this initial dialogue, ask again, What problem affects you the most? According to the answers, mark with (X) the indicators of vulnerability:

Area	PROBLEMS IDENTIFIED BY THE STUDENT			
ACADEMIC	A.1. Difficulties in attending on time		A.6. Relationship with a teacher	
	A.2. Failing midterm exams		A.7. Abilities and capacities to learn	
	A.3. Difficulties to work in groups		A.8. Study techniques and habits	
	A.4. Difficulty in presentation		A.9. Vocation and identification with the career	
	A.5. Difficulties to perform and present work		A.10. Interest and motivation to study	
	A.11. Others			
STAFF	P.1. Health and fitness		P.7. You feel stressed all the time.	
	P.2. Nutrition		P.8. Personal/emotional security	
	P.3. Housing		P.9. Feeling discriminated against, marginalized	
	P.4. Autonomy and decision making		P.10. Beliefs, spirituality, religiosity	
	P.5. Conflicts in relationships with fellow students		P.11. Limitations in setting personal goals and aspirations (Life Project)	
	P.6. Difficulties in integrating into the group		P.12. Self-esteem	
	P.13. Others			
FAMILY	F.1. Conflict in your relationship with a family member		F.5. Has family members who depend on the student F.6.	
	F.2. Lives alone and it affects him/her.		F.6. Has problems living together as a couple	
	F.3. Does not have the family financial support to continue your studies		F.7. Has children and difficulties coping with their responsibilities	
	F.4. Has a sick family member		F.8. Has suffered the loss of a close relative	
	F.9. Others			

THE STUDENT REQUIRES REFERRAL TO:

Psychology Department ☐

University Welfare Area
Medical Office ☐   Sports and recreation ☐   Residence and dining room ☐   Social Services ☐

Academic Area
Teaching of a subject ☐   School Director ☐   Dean ☐   Academic Vice Rector ☐

University Pastoral ☐

OTHERS:_____

_____   _____
Student's signature   Tutor's signature
DNI   DNI
Phone   Phone

Figure A1. Individual tutoring form approved at UNAP.

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Article

Counteracting French Fake News on Climate Change Using Language Models

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Abstract: The unprecedented scale of disinformation on the Internet for more than a decade represents a serious challenge for democratic societies. When this process is focused on a well-established subject such as climate change, it can subvert measures and policies that various governmental bodies have taken to mitigate the phenomenon. It is therefore essential to effectively identify and counteract fake news on climate change. To do this, our main contribution represents a novel dataset with more than 2300 articles written in French, gathered using web scraping from all types of media dealing with climate change. Manual labeling was performed by two annotators with three classes: "fake", "biased", and "true". Machine Learning models ranging from bag-of-words representations used by an SVM to Transformer-based architectures built on top of CamemBERT were built to automatically classify the articles. Our results, with an F1-score of 84.75% using the BERT-based model at the article level coupled with hand-crafted features specifically tailored for this task, represent a strong baseline. At the same time, we highlight perceptual properties as text sequences (i.e., fake, biased, and irrelevant text fragments) at the sentence level, with a macro F1 of 45.01% and a micro F1 of 78.11%. Based on these results, our proposed method facilitates the identification of fake news, and thus contributes to better education of the public.

Keywords: fake news detection; Natural Language Processing; sustainable education; Language Models; climate change

1. Introduction

Fighting for sustainable development involve adopting certain policies and investing resources to support them as well as raising people's awareness of this process and its consequences. To this end, sustainable education regarding climate change is a key issue that needs to be spread by both formal and informal channels. However, in recent years fake news and its growing presence in the public sphere has posed a major challenge to the resilience of societies to climate change. In particular, while information on climate issues is nowadays concentrated on the internet, a large quantity of fake news is as well.

As hypothesized by various studies in the field, fake news on climate change does not seem to have a major impact per se on public opinion in societies with a higher degree of literacy, given the audience's scientific culture [1]. However, the situation is far more complex in reality, as the presumed effect of fake news depends on various cultural constructs such as individualism, collectivism, and uncertainty avoidance [2]. In addition, misleading messages have been proven to have a viral effect when defended and disseminated by prominent figures from politics, media, and the entertainment industry [3]. In these cases, public appeals have had various purposes and meanings, from the lack

of individual responsibility for climate change to the open denial of the usefulness and legitimacy of the Paris Agreements.

It is therefore essential to fight against the spread of fake news, especially as concerns climate change. Thus, scholars have been paying more attention to this phenomenon, and the number of publications related to the detection of fake news has increased in the last five years. Choraś et al. [4] have shown this evolution by looking at the number of publications on Google Scholar containing the keyword "fake news". In 2014, this number was 504; five years later, it had reached 24,300. On the other hand, platforms such as Google and its subsidiary YouTube have been systematically demonetizing climate-skeptical content on their platforms starting with 2021 (https://support.google.com/google-ads/answer/11221321, accessed on 18 August 2022). However, the task of detecting fake news has become increasingly more difficult recently, mainly due to the extensive use of social bots [5,6]. Therefore, it is necessary to periodically update detection tools in order to properly identify text which falls under the category of fake news. Motivated by the exponential increase in fake news in the public sphere over the last several years as well as by the fact that the existing research meant to counteract the phenomenon has focused mainly on English-language content, the main aim of this article is to provide both an efficient model for automated detection of fake news and a set of properties meant to support individuals to better discern this kind of news in French.

In our work, we introduce and make publicly available a novel dataset of French news articles on climate change [7] as well as a complete toolset that helps predict whether an article is fake, biased, or truthful; the corresponding code is open-sourced on GitHub [8]. All the components mentioned above are in line with the latest recommendations regarding digital transparency and the administration of open data [9]. We use a CamemBERT Transformer-based model [10] and integrate it into an architecture that considers additional features. We rely on a dataset created from scratch, which contains 2300 articles annotated by two experts. To our knowledge, there are no other French fake news datasets on climate change, as most of the existing studies concerning fake news in French have focused on satire and social media [11–13]. In this study, we classify articles according to three labels by adding a class of biased articles which are neither fake nor real news. Moreover, we consider annotations on text fragments in order to obtain fine-grained information on whether a sentence is potentially biased, fake, or irrelevant. Finally, we suggest an interpretation of the results provided by our best model thanks to the LIME tool. Finally, we discuss the need to diversify the sources of articles to further reduce bias in the dataset.

1.1. Fake News Classification Task

The state-of-the-art in fake news detection is mainly built around social networks, the main platforms for their transmission. As each social network has its own specificities, we identified various datasets and classification methods that vary accordingly. For example, Jain and Kasbe [14] focus on Facebook with publications of variable length and dealing with various subjects. For a given topic, their method consisted of fetching information from reliable sources, news agencies in particular, and considering them as true in the training of their model. They challenged their model with publications from Facebook and classified them according to the proximity between the comments made on the social network with information from reliable sources.

A classification model is usually preceded by a word embedding model such as GloVe, as in the case of Kaliyar et al. [15]. Other solutions rely on bag-of-words approaches to represent texts [14]. Regarding the most commonly used classifiers, Naive Bayes is reported to achieve an 90% F1-score of around on the Facebook dataset [14]. SVMs or boosting methods such as Adaboost are used for this kind of task as well, as are Convolutional Neural Networks (CNN) on top of embedding layers [15]. Nevertheless, the current state-of-the-art prefers the use of CNNs when the embedding is coupled with other additional features, such as publication metadata or linguistic features; this is further detailed later in the paper.

Lai et al. [16] compared different machine learning and neural network models based on content-only features and discovered that neural network models outperform traditional models in terms of precision by an average of 6%. However, it is worth noting that the model accuracy is dependent on the difficulty of the task, being influenced by the number of classes and the degree of granularity of the data. Overall, performance is highly susceptible to bias in the dataset, and it is unfair to directly compare performance across datasets.

Recent BERT-based models are frequently employed in text classification tasks. In particular, Palani et al. [17] used BERT [18] to process textual information in its context. Transformer models are one of the most efficient ways of representing semantic relations within a sentence or text. This achievement represented a major advance in Natural Language Processing (NLP).

Upstream of these processes that transform content into machine intelligible representations, it is possible to identify an approach for processing the input text. Zhang et al. [19] relied on the verbs and their context to build "events", which they then classified. In our case, while we decided to keep more than just the verbs and their context, we removed redundant and meaningless terms in the vocabulary (i.e., stopwords) and sought to keep only those grammatical functions that carry meaning.

1.2. Existing Datasets and Research Topics

The state-of-the-art thus builds its classification approaches according to the nature of the content in the considered datasets. However, because the used datasets are mostly constructed from social networks or encyclopedias such as Wikipedia, we found content dealing with different subjects as well. One of the difficulties in the current literature is to precisely define what represents "fake news", which poses problems concerning the intelligibility of the model outputs and dataset labeling.

Our work is different due to its focus on a specific topic, namely, climate change. We can thus define "fake news" in a practical manner for our classification task. This allows us to gain precision when performing labeling of articles by human annotators. The topics discussed in the literature are often political or health-related. In particular, social networks have been subject to unprecedented waves of misinformation in terms of the COVID-19 crisis (see [20]). Most of the related work consists of the formulation of new classification methods, and it is necessary to compare them with the existing state-of-the-art, hence the widespread use of public datasets such as Politifact and Gossipcop in Palani et al. [17]. However, our approach considers the classification of a new kind of dataset, namely, articles written in French on climate change from various French websites. Moreover, there are only a few datasets in languages other than English [21].

Works on dataset creation are present in the literature, either for public general corpora or datasets used in specific cases such as ours, and include similar scraping algorithms to ours [19].

1.3. Linguistic and Non-Linguistic Additional Features

Taking into account additional linguistic or non-linguistic features other than textual analysis that considers the encoding of the content can further improve model performance.

Specific linguistic features, such as the number of adverbs and punctuation signs, can be extracted from articles and used for classification without the need to analyze the actual underlying language. This approach plays an important role in the literature, especially for topics centered on text classification. A recurrent question concerns the choice of these features, namely, which features are most predictive. Gravanis et al. [22] first reviewed features listed by other authors. Following up, Burgoon et al. [23] suggested four main groups of linguistic features:

- Quantity: number of syllables, words, and sentences;
- Vocabulary complexity: number of syllables per word, infrequent words;
- Grammatical complexity: sentence length, Flesh–Kincaid readability criterion, average number of words per sentence, number of conjunctions;

- Specificity and expressiveness: emotional indicators, ratio of adjectives and adverbs, number of affective terms.

Based on Gravanis et al. [22], the most relevant features are from the first three groups, and are related to the construction of sentences and the overall text comprehensibility. Moreover, they reported a performance gain after the addition of these features, namely:

- Accuracy based only on linguistic features: 0.861;
- Accuracy using word embeddings: 0.937;
- Accuracy when combining the two approaches: 0.949.

Our work uses such linguistic features to complement the contextualized embeddings extracted by NLP models such as BERT [18]. Other works encourage pursuing this approach. For example, Palani et al. [17] exploited images matched to Facebook posts. The authors built their CB-Fake multimodal model by extracting features from these images and concatenating them with the output of the BERT textual classifier (the same one used in our work), with encouraging results.

In addition to linguistic features, Aslam et al. [24] used non-linguistic features such as the metadata of an article, i.e., the political party, profession, or origin of the author. This information was then passed as input to a classifier, similar to the linguistic features. During the constitution of our dataset, we retrieved the metadata of the article, such as the date and author's name. However, this information is not used in our classification.

2. Method

2.1. Corpora

2.1.1. Extraction

The first step in building a dataset of articles on climate change was to select websites containing such articles and then extract the articles from these websites using web scraping methods.

Diversity and Plurality of Sources

One of the main challenges in building our database was to have diverse sources in terms of the processing and rendering of information. To this end, we distinguished five main categories of information websites dealing with climate change:

1. Websites of scientific research organizations;
2. Mainstream media;
3. Popular science websites;
4. Activist websites;
5. Conspiracy and climate-skeptical websites.

We initially selected 90 websites covering these five categories, while trying to represent as much as possible the diversity of sources present on the internet and to maintain a balanced distribution between the number of reliable articles and fake news.

Content Filtering and Website Selection

As several of the aforementioned categories of websites discuss climate change almost exclusively, it was sufficient to extract all the articles from them. However, in other cases it was necessary to filter and keep only those articles dealing with climate change, especially for traditional media with multiple topics. Two types of filters were used:

- If the website had topics or labels, our selection considered the "Climate" category or any similar category;
- If not, the search functionality present on all websites was used, with "Climate" or "Climate Change" as keywords.

After the previous filters were applied, the URL of each page was retrieved and used as the entry point for our scrapping tool. It was necessary to estimate the a priori distribution

of articles in order to ensure a balanced dataset at the end of the scraping process. We then reshaped the initial five website categories into three:

1. Popularization websites, scientific publications, mainstream media (Group A);
2. Activist websites (Group B);
3. Websites with a climate-skeptic bias (Group C).

Out of the 90 selected websites, 27 were chosen in the first scraping phase, with an even distribution among these three groups. We chose websites with a common scrapping pattern as well: Links $\Rightarrow$ HTML.

Meta-Information Selection

In addition to the content of the article, we kept meta-information that enabled better contextualization. For example, the author's name may be relevant, as several articles may be written by the same person. The date can be used to place the information on a timeline and to group articles appearing in a specific timeframe. Finally, the title generally consists of a summary of the article, and sometimes influences human decisions at first glance.

For each website, we associated the corresponding CSS selectors with the content of the article, its title, publication date, and author. Similarly, the CSS selector corresponding to the links leading from the list of articles on the initial page to a given article was gathered. These CSS selectors precisely indicate the position of an element within a web page, and thus allow the extractor to interact with them as a user would, such as by clicking on a link or copying content.

For each website, we identified common patterns in the articles that could bias the dataset, for example, an invitation to share the article at the beginning or end of the page, the name of the source, or a message from the editor that is displayed on every page of the website. It is crucial to remove these patterns in the final dataset in order to reduce bias in the classification models; thus, the different CSS selectors were tweaked to disregard such common patterns for each website. In addition, when common patterns could not be ignored by the CSS selectors, we removed them by labeling them as stop words in the scraping algorithm. Finally, we added an "irrelevant" annotation label during the labeling phase in order to manually highlighting additional patterns for removal, thus decreasing potential bias even further.

Extraction and Processing of Articles

After the scrapping was performed and the articles were retrieved, the following normalization operations were applied to each entry in our dataset:

- Date: transformation to the ISO 8601 standard, keeping only the year, month, and day if this information was available (YYYY-MM-DD);
- Author: isolation of first and last names while removing all unnecessary syntax (e.g., "written by");
- Content: line breaks were kept, with only one newline character preserved for each new paragraph.

After extraction, the articles were anonymized to avoid bias as much as possible in the subsequent labeling stage. At the end of this process, we extracted 6050 articles from 27 websites, distributed as follows considering the underlying website preliminary labeling: 2308 from group A, 1487 from group B, and 2255 from group C.

2.1.2. Labeling

The issue of fake news labeling is delicate; thus, it becomes essential that the attribution of a label to each article is based on objective criteria. After creating our article database, we established the following labeling criteria.

Labeling Rules

First, an article was classified as "true" or "fake" solely based on whether or not it was consistent with the currently established scientific consensus on climate change that is reflected in IPCC reports. As such, our aim was not to reveal the truth; rather, it was to identify articles that are not in line with current knowledge on climate change. Fake news does not necessarily consist of explicit false assertions; implicit, ironic, or subjective presentations of the facts can mislead the reader as well. Therefore, it is necessary to take into account what a rational and educated reader would deduce when reading each article, then compare these deductions with the knowledge of the current IPCC consensus.

Definition 1. *An article was classified as "fake" when it contained at least one piece of misleading or explicitly false information.*

We realized that certain articles that do not fit into this definition of fake news are hardly identifiable as "real news" at all. For example, many authors express their opinion on political issues that cannot always be directly linked to established scientific facts. For this reason, a third label, "biased", was introduced.

Definition 2. *An article was classified as "biased" when it contained at least one biased text fragment in which the author explicitly or implicitly put forward personal opinions.*

Definition 3. *Finally, an article was classified as "true" when all the stated facts were consistent with the IPCC scientific consensus, there was no misleading information, and the author remained neutral.*

In practice, we introduced a fourth label, "irrelevant", to the articles. Indeed, the scraping was not perfect, and portions of the extracted articles did not deal with climate change. This was due to the poor keyword classification of several websites, especially those containing conspiracy bias. In order to keep only articles explicitly dealing with climate change, we assigned the label "irrelevant" in order to disregard said articles from our dataset after the labeling process was complete. Out of 3268 labeled articles, 730 were labeled as "irrelevant", leaving us with a final dataset of 2538 entries (see Table 1).

Table 1. Distribution of labels.

	True	Biased	Fake	Irrelevant
Articles	1485	314	635	730
Proportion	47%	10%	20%	23%

The final distribution of labels had a higher density of true articles, despite our efforts to fairly balance the selection of websites during the extraction phase. This label imbalance was due to two main causes:

- A large proportion of the a priori "fake" articles (i.e., from climate-skeptical sources) turned out to be irrelevant due to poor referencing of articles by category and assigned keywords on the fake news websites;
- Not all articles extracted from climate-skeptical websites were fake. This shows the importance of having manually labeled articles, compared to the approach in which the label is automatically assigned according to the source of the article.

Agreement between Annotators

Establishing consistent labeling rules and high agreement among rates is essential for creating robust corpora. As such, a random sample of more than 100 articles (i.e., 114) was first labeled by both raters, with a Cronbach's alpha between them of 95.52%, which denotes very good agreement. The rows from Table 2 indicate the labels assigned by the

first annotator, while the columns reflect the second annotator. We note that the majority of errors concern the irrelevant label, which is nearly inconsequential because articles with this label were disregarded in the final dataset. Moreover, there is no disagreement regarding the distinction between *fake* and *true* articles, only in terms of biased articles, which are considerably more difficult to identify.

Table 2. Inter-annotator agreement.

	True	Biased	Fake	Irrelevant
True	31	1	0	7
Biased	2	13	3	0
Fake	0	5	27	2
Irrelevant	8	0	0	15

Text Fragment Annotations

The TagTog online interface enabled the annotation of text sequences from the articles in addition to the overarching labeling into one of the four previously mentioned classes. Thus, we annotated specific text fragments from each article with three labels:

- Irrelevant: Text fragments annotated in this manner should be removed from the text when the articles are processed, after labeling is complete. This annotation marks irrelevant text that was not automatically eliminated during the scraping phase and which should be removed in order to reduce bias.
- Biased: The text fragment contains biased information.
- Fake: The text fragment includes fake information, thus resulting in the corresponding labeling of the entire article.

The annotation of each article in parallel with its overarching label has a double advantage. First, it considerably enriches the dataset. For example, it is possible to teach the model to return fake or biased text fragments in order to make it more interpretable. Second, it ensures more rigorous and conscientious labeling of articles. Indeed, we set the rule that each article labeled as *fake* or *biased* must contain at least one such annotation. Thus, the rater was obliged to justify his/her choice of label on the basis of specific elements of the text that need to be highlighted. Moreover, these annotations enabled the creation of a dataset of labeled sentences, which is discussed later in further detail.

2.2. Linguistic Features

Many features were computed on the training set, and we searched for the ones with the highest discriminative power. We present part of these features in Table 3, with corresponding descriptives (mean—M and standard deviation—SD) for the three classes. Because most features were non-normally distributed, we employed non-parametric Kruskal–Walis H tests to observe which features exhibited statistically significant differences in their scores between different classes.

The distribution of the features, their complementarity, and their power to differentiate between classes led us to select six features for the rest of our work:

- Length of the content (number of tokens);
- Ratio of adverbs;
- Ratio of tokens that represent numbers;
- Ratio of terms expressing the modality;
- Flesch–Kincaid Reading Ease (FKRE);
- Number of expressive punctuation marks (question marks and exclamation marks) and parentheses.

Table 3. Relevance of linguistic features in descending order of the Kruskal–Walis H test.

Feature	Biased		Fake		True		$\chi^2(2)$	p
	M	**SD**	**M**	**SD**	**M**	**SD**		
Tokens from spaCy [25]	1095.068	1442.272	1374.710	1184.173	736.994	824.476	303.55	<0.001
Special punctuation marks	13.181	22.103	20.061	23.160	9.454	21.060	274.80	<0.001
Adverb ratio	0.052	0.016	0.059	0.018	0.043	0.017	266.56	<0.001
Modal verbs ratio	0.061	0.014	0.067	0.013	0.058	0.013	168.20	<0.001
Quotation marks	13.503	27.551	19.886	24.631	10.547	13.839	135.45	<0.001
First person pronouns ratio	0.008	0.012	0.008	0.009	0.005	0.008	114.48	<0.001
Conditional conjunctions ratio	0.003	0.003	0.003	0.002	0.003	0.004	61.51	<0.001
Sentence length	21.570	5.426	24.300	6.151	22.527	5.280	56.61	<0.001
Punctuation ratio	0.106	0.023	0.113	0.022	0.115	0.024	33.86	<0.001
Number ratio	0.027	0.012	0.028	0.014	0.032	0.017	23.73	<0.001
Parsing density	3.818	0.461	3.833	0.425	3.797	0.389	9.32	0.009
FKRE	55.748	10.435	53.837	9.787	55.214	9.836	7.24	0.026

2.3. Classification Models

We developed a series of classification models aiming at the maximization of recall, as we did not want to ignore potential fake news. The dataset was randomly divided into training, test, and validation sets according to the proportions 70%, 15%, and 15%, respectively.

2.3.1. SVM and MNB Classifiers

A first SVM was tested on the selected linguistic features by themselves in order to evaluate their power. A second SVM and a Multinomial Naive Bayes (MNB) classifier were tested on the bag-of-words representations of texts, whereas a third SVM considered the combination of bag-of-words representations and the six linguistic features.

2.3.2. Bert Encoding Applied at Different Granularities

In this study, we used CamemBERT [10], a pre-trained BERT-based model on the French OSCAR corpus, and applied it to different article granularities.

Article Level

The training was performed on the entire article, which was then truncated to 512 tokens without any loss of context.

Paragraph Level

Using paragraphs instead of articles increases the size of the dataset considerably, from 2300 articles to 35,000 paragraphs. However, there are two drawbacks. First, the label attributed to each paragraph (i.e., the one assigned to the entire article) is less precise due to the fact that not all paragraphs in a fake article are necessarily fake. Second, a significant amount of context is lost when paragraphs are treated independently.

Sentence Level

Next, we experimented with a sentence-level approach. In order to obtain meaningful labels, we built a dataset of sentences from the 2000 fake annotations, 1500 biased annotations, and sentences containing predefined keywords from the articles labeled as true. While the problem of the relevance of labels is solved thanks to the annotations made by hand during the labeling, the issue of content loss increases, as at the level of sentences there is almost no context left. Fake news, especially about climate change, is often part of a very specific context.

2.3.3. Text Fragment Annotation

For the text annotations in the dataset, we build additional baseline models in order to obtain a better understanding of the difficulty of the task. Considering the freedom of

the raters in annotating these specific text sequences, we slightly simplified the task by limiting the text fragments to sentences. For each sentence in the text, if it overlapped with an annotated fragment, then it was given the label of the fragment; otherwise, the sentence was labeled with "Other". The distribution of labels in this transformed dataset is presented in Table 4.

Table 4. Distribution of sentence labels.

Label	Number of Sentences
Fake	2853
Biased	2151
Irrelevant	4657
Other	63,291

The proposed classification model used CamemBERT for computing contextualized token embeddings, which were averaged to produce representations of each sentence. The class probabilities were then obtained by passing the sentence representations through two dense layers, the final one having a softmax activation. The full model was fine-tuned on this dataset.

This additional annotation and corresponding model is particularly useful for processing new articles, as it enables the automated highlighting of biased or fake sentences which need to be further checked by the reader.

3. Results

Table 5 presents the results of different models. As expected, the Transformer architecture outperformed the SVM and the MNB models. The best performance when considering the various granularities was obtained with CamemBERT at the paragraph level, arguably due to the significant increase in sample size; in contrast, the sentence classification performed poorly. The addition of linguistic features slightly increased the performance of both the SVM and CamemBERT models on the classification of entire articles.

Table 5. Comparison between different models (bold denotes the best performance in each category of experiments, i.e., classical machine learning models, BERT-based architectures at various granularities, and the concatenation of linguistic features to the BERT-based model at article level).

	Precision (%)	Recall (%)	F1-Score (%)
SVM—6 linguistic features	68.40	50.62	58.18
MNB—bag of words (k = 300)	76.42	**78.36**	**77.38**
SVM—bag of words (k = 300)	76.92	76.74	76.83
SVM—bag of words + 6 linguistic features	**77.16**	76.89	77.02
BERT on articles	**83.36**	84.45	83.90
BERT on paragraphs	83.21	**86.79**	**84.96**
BERT on sentences	64.31	64.19	64.24
BERT on articles + 6 linguistic features	**84.35**	**85.16**	**84.75**

Figure 1 introduces the normalized confusion matrix of the best model (i.e., BERT on articles with six linguistic features), as well as the distribution of classes across articles. As expected, the model struggles most with articles labeled as "biased", as these are the most difficult to identify, correctly labeling only 65% of test samples. The overall tendency of the model is to be more gullible and consider part of the biased and fake news as being true. Nevertheless, the distribution of the predicted labels is comparable to that of human annotation.

For the sentence classification task corresponding to the text fragment annotation task, the hyperparameters of the model were selected using Ray Tuning [26]. The training was performed for a maximum of ten epochs with early stopping. The loss function was weighted using the distribution of sentence labels to tackle the high class imbalance.
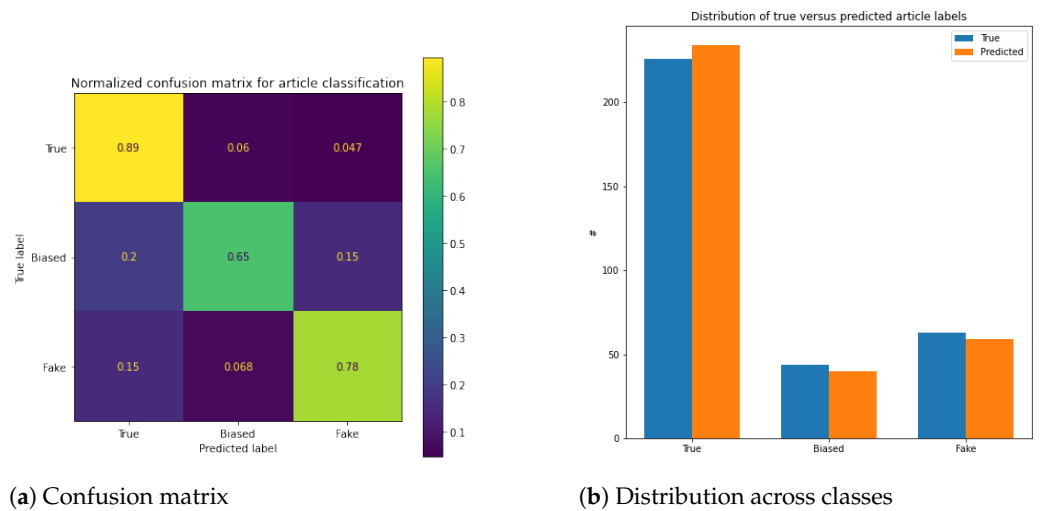
(**a**) Confusion matrix   (**b**) Distribution across classes

Figure 1. Comparison of true versus predicted article labels.

Two separate hyperparameter searches were performed. In the first, the best configurations were selected based on the unweighted validation loss, while in the second the weighted loss was used. Table 6 includes a selection of the best performing configurations in both runs, which were then evaluated on the test partition.

Table 6. Sentence classification results (bold denotes the best model).

Hidden	Activation	Learning Rate	Epochs	Macro F1 (%)	Micro F1 (%)
32	tanh	1.8×10^{-5}	8	42.78	71.12
64	tanh	2.1×10^{-5}	7	42.96	68.98
128	tanh	2.1×10^{-5}	10	**45.01**	**78.11**
256	gelu	5.6×10^{-5}	7	40.45	73.22

Figure 2 presents the normalized confusion matrix of the best model for sentence classification coupled with the distribution of classes across sentences. The model performs best at identifying the "Other" and "Irrelevant" labels, while it has problems with discriminating between "fake", "biased", and unlabeled sentences. However, an important finding is that the model spots potentially problematic sentences, which in return ensures interpretability and can be used to flag biased or fake news articles. These results are promising when considering the difficulty of the sentence labeling task and the highly imbalanced dataset.
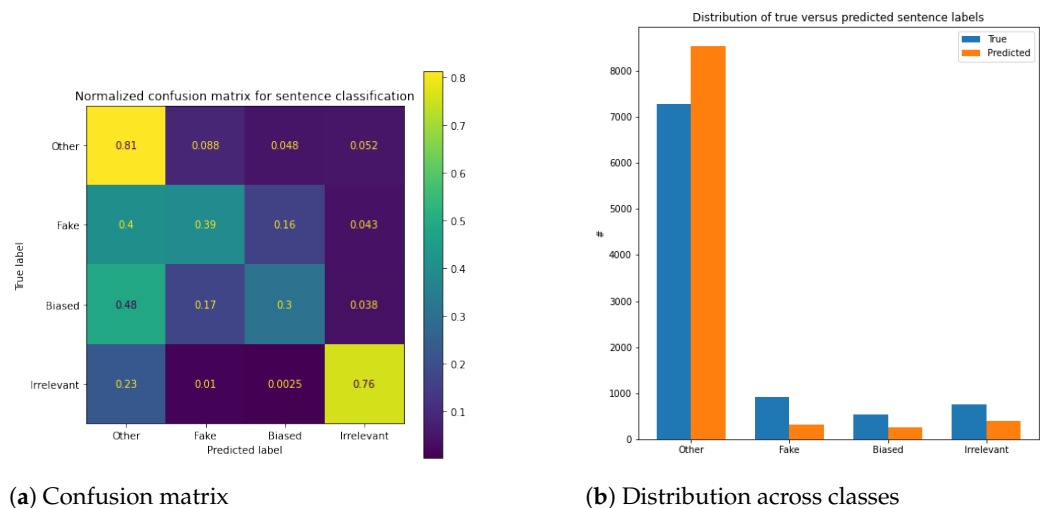

(**a**) Confusion matrix   (**b**) Distribution across classes

Figure 2. Comparison of true versus predicted sentence labels.

4. Discussion

Our BERT-based results are encouraging in terms of F1-scores, and 50 articles out of 59 fake entries from the test set were predicted as biased or fake. Our performance is comparable to other datasets and BERT-based baseline models for text classification; however, we must emphasize that the main goal of this paper is to introduce our dataset and establish a strong baseline that helps to assess the difficulty of the task and the quality of the dataset.

As we wanted to explore the limits of our dataset in terms of its bias, we first selected the most important words from the SVM support vectors for each class. Among the 200 most important words on average, none were specific to a single source. These words were consistent with the theme of the article, which denotes a low directly observable bias in our dataset.

Second, we applied cross-domain classification by training and testing a Naive Bayes Classifier on articles from different sources. We split the websites in two to create a training set and a test set with articles having no common sources. The difference in performance was considerable (see Table 7), indicating potential bias that is probably subtle and beyond the scope of human bias reduction. One way to reduce this bias further is to increase the number of annotated articles; another is to add new websites in order to diversify the sources.

Table 7. Cross-domain classification.

	F1-Score (%)
Regular dataset	76.83
Disjointed dataset	69.92

In addition, we explored the interpretability of our BERT-based model trained at the article level using LIME [27], which is a technique that approximates any black-box machine learning model to a local interpretable model in order to explain individual predictions. The words with the highest weights in the decision are marked as relevant. For example, pejorative vocabulary often influences the algorithm in favor of a "fake" prediction. Scientific vocabulary is often associated with positive weights for a "true" prediction.

Figure 3 is an example of BERT-based misclassification predicting that this biased article is fake. We can see how difficult it can be for the model to clearly distinguish between a biased article and a fake one, especially because the lexical fields used are often the same between these two labels (e.g., words such as "ideological" or "lobby" in this specific case). Moreover, BERT-based models are more likely to recognize the linguistic characteristics of fake news than to capture their argumentative structure.

However, this drawback does not lack utility, especially as it is consistent with findings made in the analysis of fake news in other languages; there, NLP models have difficulties in identifying the argumentative structure of fake news precisely because fake news is designed to mimic the argumentative structure of true news. Moreover, fake news imitates these properties in excess in order to appear "truer than the truth" and to hide its deceptive purposes [28].

For these reasons, even if NLP models cannot delineate the argumentative structure of fake news with satisfactory precision, they nevertheless reveal a series of its properties that readers cannot deduce by simply reading the text; when identified as such by NLP models, this can constitute triggers for more effective identification of fake news about climate change, which in turn indicates that our models can support better sustainable education. In addition, returning to the values from Table 3 that correspond to the six features integrated into the prediction models, we note that:

1. Fake news is, in general, longer than other types of news, and has a tendency to excessively describe or demonstrate the phenomena and ideas at issue;
2. Fake news frequently uses special punctuation marks and an excess of rhetoricity;

3. Fake news usually resorts to adverbs and modal verbs in an attempt to conceal unsubstantiated claims;
4. Fake news refrains from providing numbers, as these are harder to counterfeit;
5. Fake news has a more opaque discourse meant to hide its argumentative cracks.
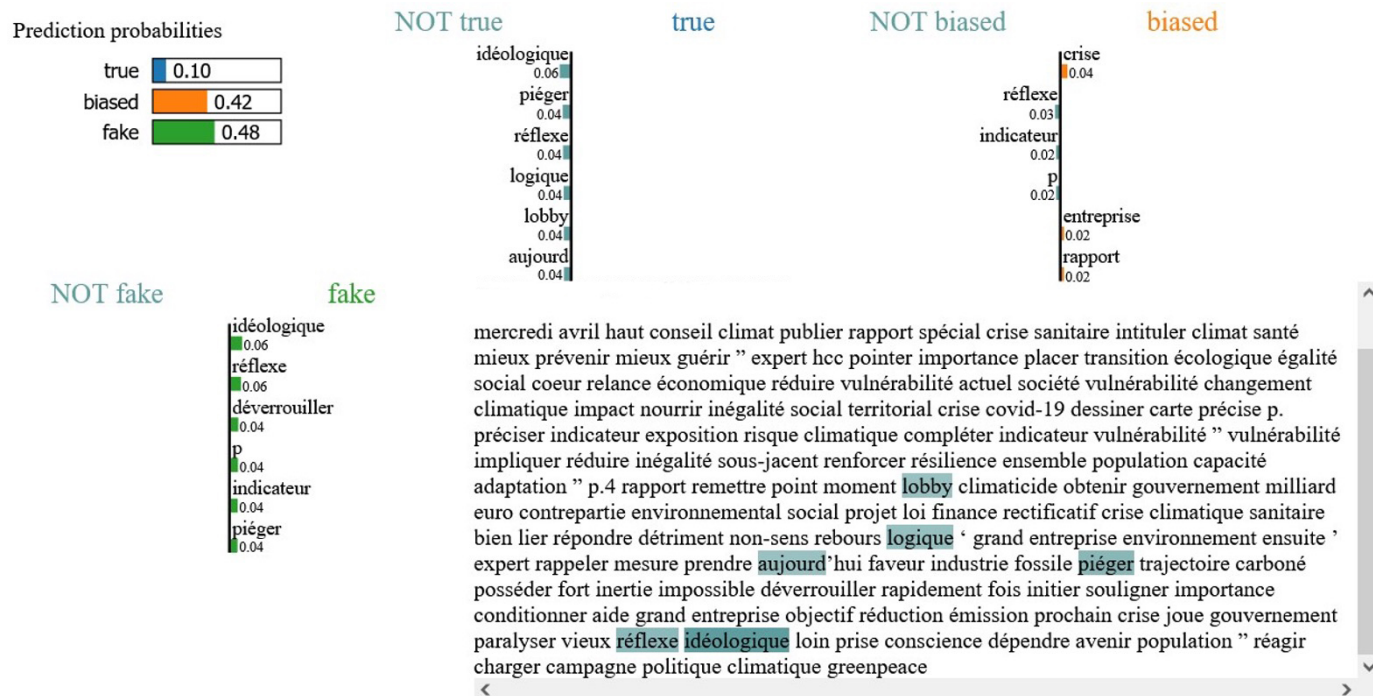

Figure 3. LIME interpretation of an article labeled as "biased" but predicted as "fake" by our best BERT-based model.

Even if these triggers do not guarantee the flawless identification of fake news, they can at least contribute to the education of readers by advising them to take a critical stance towards texts about climate change that manifest such properties.

5. Conclusions and Future Work

In this work, we introduced a novel publicly available dataset [7] and provided a comprehensive study to build a pipeline for predicting fake news in French on climate change. The data were collected from scratch through a first extraction step that allowed us to collect more than 11,000 articles on climate change from an initial list of 27 websites. We selected 6000 of these articles, then hand-labeled and annotated 3500 articles to create a robust corpus.

Afterwards, a strong baseline with various classification methods was created. First, we considered classical machine learning models such as SVM and Multinomial Naive Bayes as applied to both handcrafted linguistic features and bag-of-words representations. In the second step, we built and tested several prediction models based on the CamemBERT Transformer applied at various granularities, namely, entire articles, paragraphs, and sentences. The best performing model was the one operating at the paragraph level due to the larger number of samples, which reached 86.79% recall (the most important measure for our project) and 83% accuracy. Nevertheless, the difference with the BERT-based model when applied to entire articles while integrating the six most predictive linguistic features is negligible (i.e., R = 85.18%, and an F1-score of 84.75% instead of 84.96% due to a higher precision). In addition, we introduced a model for identifying biased, fake, or irrelevant sentences in articles that exhibited promising results (i.e., a Macro F1 of 45.01% and Micro F1 of 78.11%); this model is particularly useful for processing new articles, as it enables

the automated highlighting of problematic sentences which need to be further checked by the reader.

Attempts at interpretation, in particular with LIME, show that NLP models are not capable of understanding the argumentative structure of an article. The models seem to rely mainly on linguistic criteria, which nevertheless enables them to identify fake news remarkably well. In addition, NLP models highlight certain properties of fake news that can be identified perceptually (by mere reading), and can thus contribute to more sustainable education of the public. We are convinced that a larger collection of annotated articles and even greater diversification of sources in the training set would allow for even better generalization. In addition to the dataset, the open-source code used for crawling the news articles and building the classification models is available at [8].

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Abbreviations

The following abbreviations are used in this manuscript:

BERT	Bidirectional Encoder Representations from Transformers
CNN	Convolutional Neural Network
CSS	Cascading Style Sheets
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
LIME	Tool for Local Interpretable Model-Agnostic Explanations
MNB	Multinomial Naive Bayes
NLP	Natural Language Processing
SVM	Support Vector Machines

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Article

Online Learning, Mobile Learning, and Social Media Technologies: An Empirical Study on Constructivism Theory during the COVID-19 Pandemic

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Abstract: The study's main purpose was to discover the important factors that impact university students' online learning and academic performance during the COVID-19 epidemic, as well as their usage of social media throughout the pandemic. Constructivism theory was used and developed with constructs mostly linked to leveraging social media for collaborative learning and student interaction during the COVID-19 pandemic, given the context-dependent nature of online learning during the epidemic. During the COVID-19 epidemic, additional components such as collaborative learning, student participation, and online learning were implemented. The enlarged model, which assesses students' happiness and academic performance during the COVID-19 epidemic in connection to social media use, was validated using empirical data collected via an online survey questionnaire from 480 Saudi Arabian higher education students. AMOS-SEM was used to analyze the model's various assumptions (Analysis of Moment Structures-Structural Equation Modeling). The findings revealed that (1) using social media for collaborative learning and students' engagement has a direct positive impact on students' interactivity with peers and teachers; (2) students' interactivity with peers and teachers has a direct positive impact on online learning during the COVID-19 pandemic; (3) online learning during the COVID-19 pandemic mediates the relationship between students' interactivity and satisfaction; (4) online learning during the COVID-19 pandemic mediates the relationship between students' interactivity and satisfaction. Students, higher education institutions, and educational technology application suppliers would benefit greatly from the conclusions of this study, both theoretically and practically.

Keywords: social media technologies; online learning; COVID-19 pandemic; constructivism theory; academic performance

1. Introduction

In the worldwide COVID-19 epidemic, traditional or face-to-face schooling has encountered unprecedented obstacles. Countries have made attempts to limit huge crowd meetings and maintain physical social distance in order to regulate the virus epidemic. Therefore, most countries implemented quarantine periods, thus ending traditional education [1,2]. Similarly, governments have switched from face-to-face to online education for all subjects. During the COVID-19 epidemic, many undeveloped nations, such as Saudi Arabia, lacked digital channels, social media, or online learning to engage students and instructors. Moreover, during the COVID-19 epidemic, they were unable to provide complete online learning [3]. COVID-19 has forced teachers and students in many developing countries to connect online for the first time for academic reasons. Because many schools lack an online learning management system (LMS) for the COVID-19 pandemic, leveraging social media to engage students and promote online learning throughout the pandemic

might be advantageous [4,5]. During the COVID-19 epidemic, the study focuses on the participation of students and teachers on many social media platforms to drive online social interaction and generate successful online learning [6]. The interactive elements were interaction with group members or peers, interactivity with supervisors or lecturers, active collaborative learning, and engagement. Perception criteria included perceived ease of use, perceived utility, social media use, and research student delight. Therefore, both interpersonal and perceptual factors impact research students' academic achievement in higher education. Social media may boost collaborative learning and engagement by allowing individuals to work together to achieve a common goal [7]. Furthermore, study students' usage of social media suggests a positive relationship between academic success and satisfaction [8,9]; also discovered a relationship between academic success and student Facebook usage. It is uncommon for pupils to utilize social media for educational purposes [10]. Furthermore, students use social media to socialize rather than actively collaborate, participate, or achieve academic goals [8]. According to [11], a research model of social media antecedents and consequences was used; however, the results showed a higher perceived risk of using social media to waste time and a decreased willingness to learn. In addition, several research have found that the quantity of time spent on social media has a substantial influence [12]. It is likely that the majority of higher education students use social media and spend substantial time on it, and that the monitoring students' social media usage has a negative component. Excessive social media use is becoming more of a problem since it can lead to a lack of drive. According to experts, motivation might help a student's inner drive to succeed academically [10]. Students' strong desire to participate in active collaborative learning and study using technology may lead them to assume that social media may help them achieve this goal [13]. Thus, there is a negative impact on student interactions [14]. Social media has an influence on and can complicate a student's academic transfer from a college to a university level of education, jeopardizing research students' academic success [15]. The effects of social media in active collaborative learning environments were investigated, and it was revealed that using social media in these scenarios might help students learn more effectively. Thus, researchers should look at the interaction pattern that occurs during active collaborative learning [16]. Instructors do not use social media to educate or engage their students, despite their expertise with previous technology [17]. Professors are also lacking in social media abilities [18]. Students are not convinced by the existing platforms of teacher interaction, according to [19], so there is an excuse for effective active collaborative learning and understanding student–teacher communication regarding their training. However, students are receptive to new social media that will facilitate learning with teachers. According to educators, students seldom use social media networks for educational objectives [20]. Educators who utilize social media, however, have highlighted worries regarding the challenges it presents, as well as the insufficient evaluation and assessment [21]. According to an empirical study, students on campus demand more assistance in accessing additional social media active collaborative learning options than they do in face-to-face sessions. Lecturers can help students with quick inquiries, solutions, and coordination when it comes to using social media for active collaborative learning and involvement [22]. Teachers and students were given the opportunity to submit input during evaluative periods [23]. Experts claim that Facebook has a negative influence on school achievement in general, with male pupils being the most affected [24]. Therefore, the primary goal of this research is to identify and correct the flaws in a model that shows interactivity, social media use, active collaborative learning, engagement, and satisfaction of research students in higher education using the constructivism theor to evaluate academic performance during the COVID-19 pandemic [25]. As a consequence, this research is significant because it will disclose the characteristics and variables, the relationship between social media usage for active collaborative learning and engagement, and how these factors affect research students' academic advancement in higher education. "What are the interaction aspects that increase active collaborative learning and engagement, and hence academic success during the COVID-19

pandemic?" asks the researcher. This research will create a model of social media use for active collaborative learning and engagement by interactive factors, which will have an impact on academic performance in higher education institutions during the COVID-19 pandemic. It will also investigate the validity of constructivism for interactivity and social media use for active collaborative learning and engagement, which will have an impact on the academic performance of research students during the COVID-19 pandemic.

Social Media Use in Higher Education

Students in high school may utilize social media to evaluate and appreciate creative work, offer and receive educational assistance, and validate and enjoy creative work from classmates. Faculty usage [17,26], student engagement [27,28], and influence on, as well as related to, academic accomplishment are all researched in the context of higher education [29,30]. According to the researchers, university students who engaged in interactive blogs had a more favorable attitude toward peer interaction and academic achievement [31]. Students can use social media to communicate, cooperate, and interact in a social setting [32]. The use of social media curricula in higher education for teaching and learning has attracted the scholarly community's interest. Cognitive abilities and motivation for active collaborative learning in higher education, reflection, and metacognition are essential components of social media [33]. Several research have shown that using social media for student assignments results in higher levels of learning [34].

2. Interactive Variables Used with Theories

Students who were unable to achieve cognitive equilibrium and tried to become accustomed to achieving equilibrium cognition and supported learners in building knowledge can be found in social media networks to be interactive and with the perspective of the allotment of knowledge and information or discussion with others, according to the social constructivist theory [25]. As a consequence, constructivism [25] will be utilized to support the research's main thesis: learning is an active, creative process. The goal of this study was to fill in the gaps in the literature by examining how the use of social media for active collaborative learning and engagement affects the academic performance of research students during the COVID-19 pandemic. The constructivism theory was used to create the research model. As a consequence, constructivism was chosen in this research since it claims that engaging with classmates and lecturers leads to active collaborative learning [35]. Prior work has paved the way for the creation and refinement of a research model to investigate the influence of social media use in collaborative learning on academic achievement among research students. As a consequence of the investigation, seven operational themes of crucial factors on social media use for active collaborative learning and engagement that affect academic achievement were discovered and classified, see Figure 1.
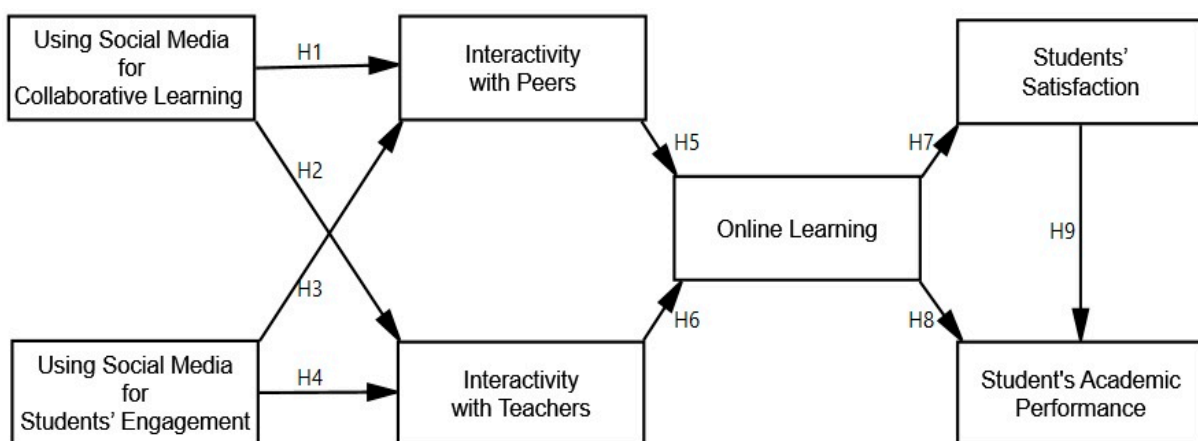

Figure 1. Research model.

2.1. Using Social Media for Collaborative Learning

In education, a social network is referred to as social media for allowing communication among research students, supervisors, professors, and experts, as well as enabling learners to grasp processes and participate in groups through the group process [36]. To support the learning processes required for the construction of a knowing society, new learning platforms that allow collaborative and constructive learning are required [37]. Students can utilize collaborative learning assignments on a wiki to discuss their work with others, receive feedback, and make changes before submitting the final version [38]. Students can utilize wikis to compile a collection of papers that represent the learning group's common knowledge. According to [39], active collaborative learning is more successful in diverse knowledge scenarios, and learners have strong cognitive abilities in this area. Several research looked at the possibilities of social media as a collaborative and cooperative learning tool [40]. To investigate students' perspectives of social media as an interactive learning tool, [41] created social media profiles for four university courses. Students who support using social media for academic purposes cited several benefits of using a social media course page as a useful learning resource, including increased interaction and engagement in discussions regarding course topics or research, as well as exposure to relevant media and learning materials. Several participants, however, were concerned regarding the necessity to stay on top of the social media course activities [42].

2.2. Using Social Media for Student Engagement

The engagement is centered on interactions between the person and the environment in order to ensure social and intellectual connections between study group members and the class in order to change student awareness and engagement [43]. Therefore, of the widespread usage of social media, individuals have incorporated online contact into their daily lives, demonstrating the various ways in which people interact with one another through information sharing [44]. Furthermore, a number of research that looked at the experience of utilizing social media networks revealed that it led to excellent learning outcomes and engagement [45]. One of the good aspects of social media platforms [46] is their influence on emotional components of the learning environment, as well as its impact on motivation and student engagement for active collaborative learning.

2.3. Interactivity with Peers

Learner involvement in the course has increased as well, as seen by social media activity logs, particularly with an evaluation task. According to recent research [46], virtual interactions are one of the most effective strategies to improve communication, inspire students to study, encourage them to take their learning assignments more seriously, and boost social network. While research on the use of social media for teaching and learning [17] is still in its early phases, these studies imply that it has the potential to be a transformative method for learning and teaching in higher education as a social networking tool. Before structuring their courses, selecting the pedagogical strategies they intend to employ and the sorts of evaluations they feel would increase their students' participation in the learning process, educators must first analyze their students' intellectual and social backgrounds. The usage of social media in higher education can help increase professor–student connection [47]. According to [48], social media use for learning is just as essential as learning objectives; thus, they must have a social presence, include interactive learning, and encourage active collaborative learning.

2.4. Interactivity with Teachers

Fluid interactions among research group members may be suffocated by traditional learning approaches [49]. Student participation has an impact on academic success [50]. Despite the relevance of the concept of integration, the integration of commuting students differs significantly from that of on-campus students, with socio-academic moments [51]. The traditional concept of engagement with peers and professors had more attraction

and importance for those students than the regularity with which these encounters took place or the depth of relationship between researchers and supervisors. By providing new opportunities to promote engagement, advanced technology has revolutionized the way students connect with one another, both inside and beyond the classroom. Facilitating relationships is crucial since it leads to more effective and better learning. Therefore, it is possible that it will become a need for academic achievement [52].

2.5. Online Learning during the COVID-19 Pandemic

This study backs up statements from [53], that using social media for online learning during the COVID-19 pandemic and academic communication, such as social media, can promote social learning and social presence. It also claims that by creating an interactive learning environment, encouraging social presence, and fostering social presence, using social media for formal academic communication might improve learning results. Various research have been produced that indicate the benefits of interpersonal connection because online engagement has been thoroughly examined in recent decades. Human involvement in online environments has been linked to student pleasure [54,55], faculty satisfaction [56], and student academic achievement [54,55,57].

2.6. Students' Satisfaction

Students from one cultural context may have various viewpoints on educational interventions based on their actions in another cultural environment [58]. This highlights the need of doing comparative research on online learner engagement as well as the impact of cultural variations on online student cooperation [59]. Furthermore, active collaborative learning environments, as well as students' happiness with them, is a hot topic that has spawned several research papers in the literature [60]. When it comes to user adoption and enjoyment with technology, perceived usefulness and ease of use are crucial elements to consider. They have been demonstrated to predict consumer happiness with websites and computers [61]. According to [62], while some studies have indicated that user entertainment has a significant impact on technology success, others have discovered that user perceptions of technology-provided entertainment are linked to IS systems and product adoption and satisfaction [63]. All forms of communication, according to [64], are important and should be incorporated in online courses since they promote students' learning and enjoyment. Furthermore, few studies have been performed on how students interact, communicate, negotiate, and cooperate in online classrooms [65]. This shows that students like connecting with peers who share similar interests, which boosts overall satisfaction with active collaborative learning in homogeneous groups [66].

2.7. Students' Academic Performance during COVID-19 Pandemic

Despite the fact that they mostly use it for social rather than academic purposes, the majority of respondents agreed that social media had a positive impact on their academic performance during the COVID-19 pandemic, according to a study on the impact of social media on students' academic performance during the COVID-19 pandemic in education [67]. It has been shown that there is a correlation between collaborative learning, engagement, and academic accomplishment [27]. The usage of social media in higher education has been recommended based on research [18]. Social media is viewed by learners and their communities as a means of disseminating fresh information. Facebook may be used to assist students or a specific group of people to communicate more successfully in a variety of ways [68]. The amount of time and effort students spend on educational activities is measured by student interaction and engagement [69]. The phrase "social media" encompasses a wide range of networked tools or technologies that highlight the Internet's social aspects as a conduit for communication, active collaborative learning to increase academic achievement, and creative expression in higher education [70]. They lead to the use of social media to increase educational access and engagement [71]. Social media platforms are widely used by students for both amusement and education. College

students utilize a variety of social media programs since it has become an important part of their daily lives for both personal and educational aims [8].

3. Research Methodology

We sent out 500 questionnaires for the study and 491 were returned by respondents; after human processing, 6 of the 491 questionnaires were incomplete ("students did not complete the survey") and had to be deleted, leaving 485. Outliers, defined as "data that differs abnormally from other values in a random sample," were found in 5 of the remaining 485 questionnaire copies put into SPSS, bringing the total number of acceptable surveys to 480 students. Hair et al. [72] argued for such exclusions, claiming that outliers might lead to erroneous statistical conclusions and should be removed. For the purpose of the study, we built a conceptual model based on constructivism theory to measure student satisfaction and academic achievement.

3.1. Instrument Development

Because Likert scales are widely used in information system (IS) research and have been thoroughly assessed in both marketing and social science, they were employed to examine the responses in this study [73]. This study's variables were all graded on a five-point Likert scale from 1 to 5: (1) Strongly disagree, (2) Disagree, (3) Undecided, (4) Agree, and (5) Strongly Agree were the five options. When choosing and creating a measuring scale, several aspects that affect the scale's reliability, validity, and utility must be taken into account. The study by Cooper and Schindlers [74] provided the foundation for these factors. The questionnaire looked at how students and researchers in higher education felt about using social media for active collaborative learning and engagement, as well as how it influenced their academic performance during the COVID-19 pandemic, was fine-tuned with the support of a pilot study with students, and tested beforehand. A questionnaire with 27 items was prepared after minor layout changes, and the online survey was administered toward the end of the semester in September 2021. Four items derived from [75] were used to examine the use of social media for collaborative learning in the questionnaire adapted from earlier studies. Students' engagement with social media was examined using three questions derived from [43]. A subset of six questions from [76] was used to assess interactivity with peers and teachers. Four questions derived from the questionnaire were used to assess online learning [77]. Students' academic performance during the COVID-19 pandemic was tested using four items from [78], and finally, student satisfaction was examined using four questions from [63].

3.2. Sample Size and Data Collection

Sampling is a statistical approach that includes picking a subset of individual observations from a population with the purpose of influencing student and researcher academic performance during the COVID-19 pandemic and satisfaction in higher education by employing social media for participation and active collaborative learning. The two types of sampling processes are random and non-random sampling. This study employed a random sampling technique because it assures that the research target group has an equal probability of being picked.

4. Data Analysis and Results

The current study's empirical analysis aims to explore how the interrelationships of many independent and dependent factors connected to using social media for active collaborative learning impact the academic performance during the COVID-19 pandemic of students and researchers. Structural Equation Modeling was the primary statistical tool employed in the data analysis for a variety of reasons (SEM). SEM is the most rigorous and powerful statistical research approach for dealing with complicated models, according to several specialists [72]. SEM is a set of statistical models aimed at explaining correlations between a large number of variables. After the measurement model has been confirmed, the researcher moves on to the second stage, which comprises estimating the structural model between the latent variables.

The one-step technique, on the other hand, estimates the measurement model and structural models at the same time [72]. The data are shown in Table 1.

Table 1. Adjusted goodness-of-fit index (AGFI).

Model	NPAR	CMIN	DF	*p*	CMIN/DF
Default model	80	839.735	298	0.000	2.818
Saturated model	378	0.000	0	0.000	0
Independence model	27	21,734.431	351	0.000	61.921
Adjusted Goodness-of-Fit Index (AGFI)					
Tucker–Lewis index		TLI		0.000	0.970
Incremental Fit Index		IFI		0.000	0.975
Comparative Fit Index		CFI		0.000	0.975
Root-Mean-Square Residual		RMR		0.000	0.027

4.1. Validity and Reliability

In this study, AMOS 23 was used to calculate individual item dependability. The item is deemed dependable if the squared multiple correlations in (R^2) of each item in the measurement model exceed 0.5. Individual item dependability is demonstrated if the standardized loading is equal to or greater than 0.70 [72]. The entire amount of true score volatility as a proportion of overall scale score variance is represented by composite reliability (CR) [72]. The consistency of a collection of variables in a measurement is determined using CR. The resulting coefficient is interpreted in the same way as Cronbach's alpha, with the difference that it accounts for true factor loadings rather than assuming that each item in the composite load assessment is equally weighted [72]. The average variance extracted (AVE) displays the total amount of variance in the indicators that the hidden construct accounts for [72]. Confirmatory factor analysis (CFA) can be used to explore this form of validity (see Tables 2 and 3).

Table 2. Relationship between factors (validity and reliability).

Relationship between Factors and Items			Estimate	Composite Reliability (CR)	Cronbach's Alpha	Average Variance Extracted (AVE)	Squared Multiple Correlations in (R^2)
SMCL4	<---	Using Social Media for Collaborative Learning	0.789	0.891	0.900	0.599	
SMCL3	<---		0.880				
SMCL2	<---		0.862				
SMCL1	<---		0.795				
SME3	<---	Using Social Media for Engagement	0.704	0.873	0.889	0.610	
SME2	<---		0.840				
SME1	<---		0.757				
INP4	<---	Interactivity with Peers	0.782	0.903	0.911	0.620	
INP3	<---		0.829				
INP2	<---		0.822				
INP1	<---		0.782				
INT4	<---	Interactivity with Teachers	0.773	0.887	0.895	0.587	
INT3	<---		0.843				
INT2	<---		0.778				
INT1	<---		0.792				
OL4	<---	Online Learning	0.826	0.907	0.881	0.633	
OL3	<---		0.825				
OL2	<---		0.814				
OL1	<---		0.813				
SS4	<---	Students' Satisfaction	0.795	0.890	0.864	0.641	
SS3	<---		0.785				
SS2	<---		0.793				
SS1	<---		0.804				
SAP4	<---	Students' Academic Performance	0.793	0.879	0.880	0.589	
SAP3	<---		0.744				
SAP2	<---		0.827				
SAP1	<---		0.766				

Table 3. Sample covariances reliability.

Factors	Code	SMCL	SME	INP	INT	OL	SS	SAP
Using Social Media for Collaborative Learning	SMCL	0.855						
Using Social Media for Engagement	SME	0.373	0.841					
Interactivity with Peers	INP	0.267	0.313	0.840				
Interactivity with Teachers	INT	0.369	0.425	0.287	0.837			
Online Learning	OL	0.292	0.348	0.287	0.288	0.853		
Students' Satisfaction	SS	0.308	0.363	0.376	0.340	0.293	0.903	
Students' Academic Performance	SAP	0.282	0.345	0.328	0.328	0.259	0.358	0.883

4.2. Measurement Model Fit

The total model measure, according to [72], may be that the fit is evaluated using a variety of goodness-of-fit metrics divided into three categories: absolute fit measurements, incremental fit measures, and parsimonious fit measures. As a consequence of this advice, the following indices were used in this investigation: RMR, lFI, TLI, CFI, RMSEA, and 2/df. The Root-Mean-Square Error of Approximation (RMSEA) was chosen for this study because it is one of the most often used metrics for correcting the GOF test statistic's propensity to reject models with a high sample size or a large number of observable variables [72]. As illustrated in Figure 2, many fit indices should be employed to evaluate a model's goodness-of-fit, with a value of 0.90 or above [72].
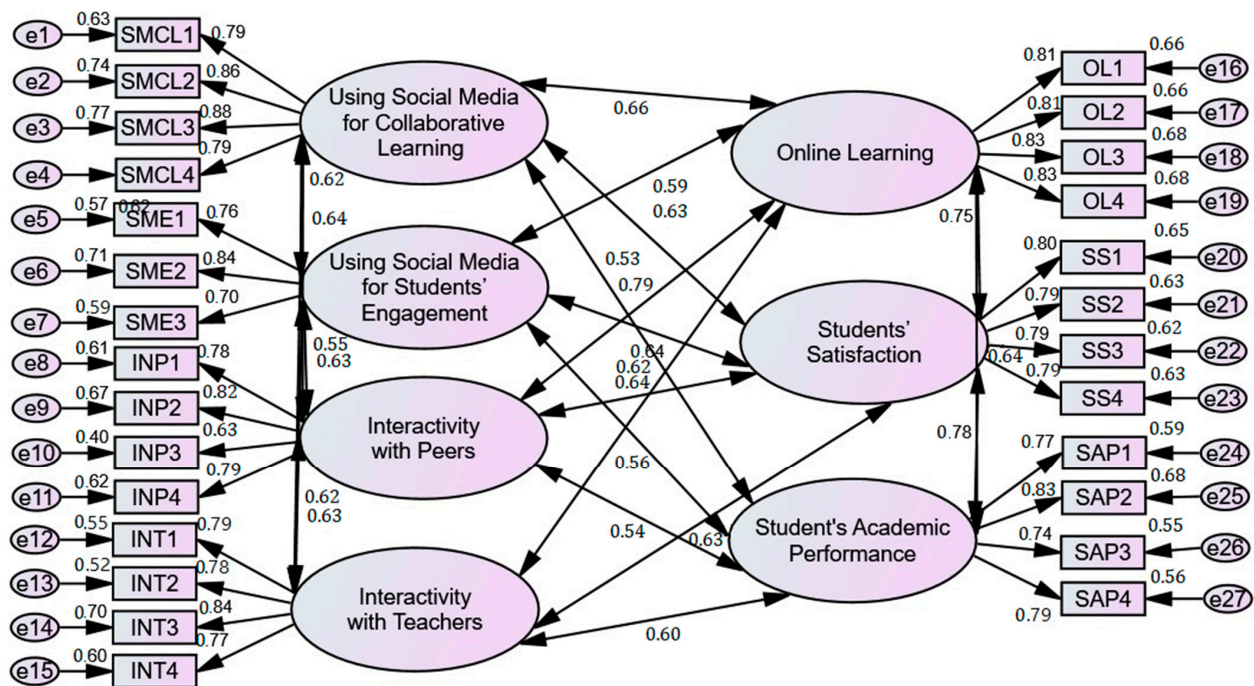

Figure 2. Measurement model.

4.3. Hypothesis Testing

Hypothesis testing is the penultimate step in the data processing process. The goal of this investigation was to look at the nine options listed in Table 4. The statistical significance of the parameter estimated by SEM was determined using the Critical Ratio (C.R.), which is defined as the parameter estimate divided by the standard error (S.E.) [72]. Smaller *p*-values (*p* 0.01) are frequently regarded as very significant since they suggest that the observed difference would only occur once in a hundred times if no genuine difference existed. To summarize, when sample sizes or the number of observable variables get larger [72], the statistical test or the resultant *p*-value becomes less relevant [72], as seen in Figures 3 and 4.

Table 4. Hypotheses relationships test.

| No	Hypotheses Relationships			Estimate	S.E.	C.R.	*p*	Results
H1	INP	<---	SMCL	0.422	0.026	16.147	0.000	Accepted
H2	INT	<---	SMCL	0.297	0.028	10.638	0.000	Accepted
H3	INP	<---	SME	0.361	0.023	15.953	0.000	Accepted
H4	INT	<---	SME	0.273	0.024	11.295	0.000	Accepted
H5	OL	<---	INP	0.278	0.024	11.606	0.000	Accepted
H6	OL	<---	INT	0.385	0.026	14.782	0.000	Accepted
H7	SS	<---	OL	0.530	0.022	24.179	0.000	Accepted
H8	SAP	<---	OL	0.131	0.021	6.235	0.000	Accepted
H9	SAP	<---	SS	0.634	0.022	28.691	0.000	Accepted
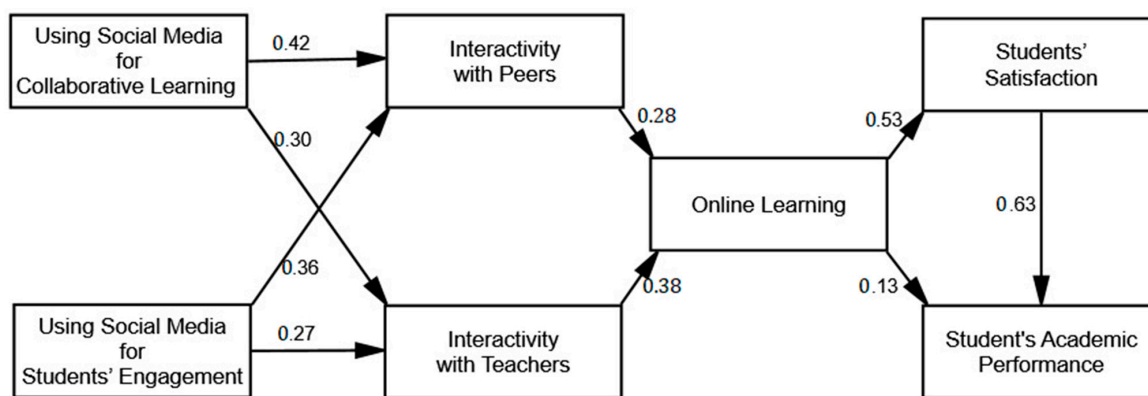
Figure 3. Structural model.
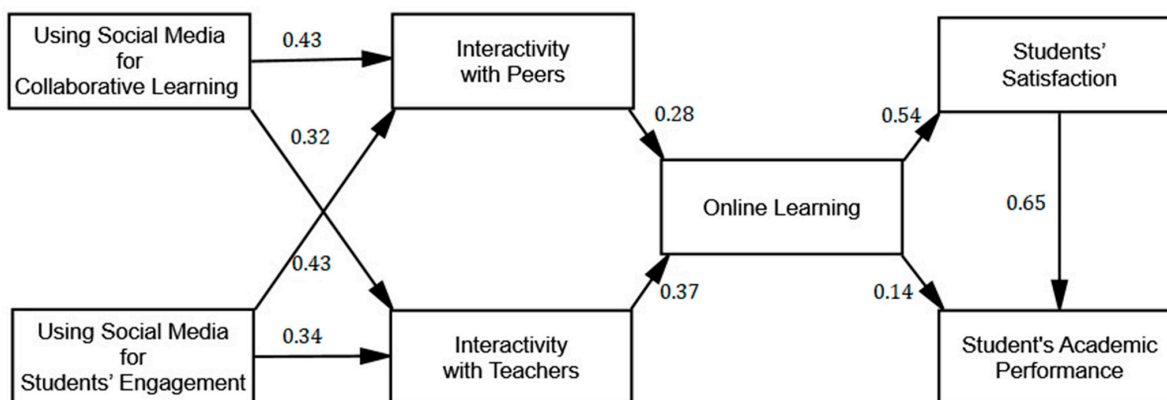
Figure 4. *p*-value results.

The hypotheses indicate the interrelationships between the components that may impact how higher education research students utilize social media for active collaborative learning and involvement, as well as their academic achievement. A two-step structural equation modeling technique was used to evaluate the assumptions. This technique was chosen for this study because it is more practical than other ways, such as the one-step method [72], as shown in Table 4.

5. Discussion and Implications

This research adds to the current literature by adding constructivism theory to better understand how students use social media for learning. Social media, along with the Internet, have revolutionized the way students interact, engage, and cooperate throughout the world. Collaboration and engagement on social media encourage a constructivist approach

to learning, in which students and teachers collaborate for mutual benefit [79,80]. They can discuss and share useful knowledge in a group environment through social media sites. In addition, effective social media use boosts participant engagement, collaborative learning, and learner performance. Social media-based learning systems, rather than traditional learning approaches, put online learning during the COVID-19 pandemic in the hands of students [81]. Students may foster healthy classroom conversations, student engagement, peer integration, and teacher integration by using social media. These findings corroborate those of [82], which discovered that social networks are simple to use and explore, as well as being beneficial for interactive learning. Previous research on social networking networks and their practical utility yielded similar results [9,83–85] and claims that using social media in the classroom encourages greater contributions and participation in active student collaboration and engagement. Therefore, these virtual community interactions foster the desired learning outcomes and student success. Employing online social media for collaborative learning and interaction with instructors and peers boosts student engagement, which improves academic achievement. Students' intellectual capacities should be developed on a platform provided by the higher education administration. Based on the outcomes of the empirical study, it can be stated that social media communication devices assist students in regaining knowledge and engaging with others in real-time while transferring educational materials' contents. Furthermore, modern communication devices would aid students who are shy in front of their peers; instructors might open up on the web for collaborative learning and teaching in a global setting; physically challenged students would benefit from such technology. It also stands to reason that the widespread use of advanced tools in practical training in higher education makes it simpler for professors and students to engage digitally through web-based learning, discussion groups, and other techniques. This research discovered that using social media for collaborative learning and engagement, as well as interactions with peers and teachers, has a positive impact on students' online learning during the COVID-19 pandemic and academic performance during the COVID-19 pandemic, implying that implementing such sophisticated technological tools in higher education would result in innovative, drastic changes in international collaborative learning and engagement. Here is a summary of the key research findings. Peer and teacher contact, as well as students' use of social media for educational reasons, enhance with collaborative learning and engagement. Students' use of social media enhances online learning during the COVID-19 pandemic, interaction and engagement, as well as student–instructor communication. The contact and participation of students have a favorable influence on online learning during the COVID-19 pandemic. Furthermore, online learning during the COVID-19 pandemic has a strong favorable effect on student satisfaction and academic achievement. Therefore, this research provides a framework for examining the influence of students' educational use of social media on collaborative learning and engagement. This model was created based on observations from the literature and then tested using structural equation modeling. Students' usage of social media for educational purposes was examined using constructivism theory basics. After that, the effects of students' usage of social media for online learning during the COVID-19 pandemic on student engagement, faculty member involvement with students, and student course participation were examined. Finally, the overall effects of student interaction, instructor–student relationships, and student course participation in collaborative learning were discovered to have an impact on students' happiness and academic achievement in online learning during the COVID-19 pandemic. According to this study, the indicators are well-representative of the constructs. When all goodness-of-fit criteria were approved, the measurement model was likewise judged to be adequate. The concept reliabilities and average variance extracted values were determined in the current study, which looked at both convergent and discriminant validity. The research model was found to be sufficient as a consequence of the data, and the study's nine hypotheses were confirmed and approved. The model was updated with additional correlations, and the model's validity was validated using the indices and goodness-of-fit indices. All of these findings imply that social media offers a number of benefits, including

the ability to improve collaborative learning and engagement with peers and instructors; all of which have an impact on online learning during the COVID-19 pandemic, student satisfaction, and academic achievement. This project provided a paradigm for harnessing social media for collaborative learning and involvement in order to improve students' academic performance during the COVID-19 pandemic. Students were most satisfied with the assistance offered by teaching staff and their universities' public relations during the global lockdown and shift to online learning, all of which are results of our research [86–88]. Here are the scientific contributions:

- By integrating social media into instructional practices, students' attitudes regarding technology and their enthusiasm for using it for digital learning can be improved. In order to improve their ability to study, succeed, and conduct research, instructors and mentors should encourage students to use social media to solve problems, share information, and trade expertise.
- It is recommended that colleges and universities support students who have used social media in the classroom in lieu of pressuring those who have not. With this method, students use elements and resources from social media in their educational process.
- Technology and resources have an impact on students' attitudes toward and intentions for using social media for digital learning. Digital learning choices based on social media should be used by students.

6. Conclusions and Future Work

The study's main goal was to look at the effects of a variety of factors on online learning during the COVID-19 pandemic and student happiness in order to help students improve their academic performance during the COVID-19 pandemic. Using social media for collaborative learning, using social media for student engagement, interactivity with peers, interactivity with teachers, online learning during the COVID-19 pandemic, student satisfaction, and student academic performance during the COVID-19 pandemic were all included in the proposed model for this study, which was based on constructivism theory. These factors were assessed using a structural equation modeling (SEM) technique and an online questionnaire comprising 27 questions. Both collaborative learning and engagement had a favorable impact on peer and instructor interaction, according to the findings; both factors affected online learning during the COVID-19 pandemic, which improved students' happiness and academic success. The use of social media as a platform for educational learning, cooperation, and student participation, as well as the use of social media as a platform for interaction and online learning during the COVID-19 pandemic, were all highlighted. These recommendations, when combined with a set of standards for using social media in higher education, would benefit both students and institutions. According to the findings of this study, future research could incorporate more characteristics to analyze the impact of various aspects on online learning during the COVID-19 pandemic and students' academic performance during the COVID-19 pandemic through the use of social media for collaborative learning and student engagement. Future research should look at additional studies and variables that influence the usage of social media for online learning during the COVID-19 pandemic, collaborative learning, and engagement to improve students' academic achievement (e.g., environmental and cultural). Regardless of the insights it offers, this study has its own limitations. The findings should be interpreted cautiously because this study only examined one university, and behavior at other universities (both private and public) may vary. This study's emphasis on quantitative data is another drawback; as a result, researchers should use qualitative data instead (such as observations or interviews) to avoid discovering inconsistencies between research themes. Future studies should repeat this investigation in several nations, regions, and cultures to correct its flaws and broaden the range of its conclusions. Due to the small sample size, it was not able to conduct moderator research, hence the effects of age and gender were not examined.

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Article

The Relationship between Cyberbullying and Mental Health among University Students

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Abstract: Background: The term 'cyberbullying' is linked to traditional bullying, and both refer to oppression. This study aimed to determine the overall effects of cyberbullying on mental health among university students of various ages, and to investigate the extent to which victims (students) directed less attention and focus towards their academic achievement. Methods: The participants in this study were 326 male and female students from King Faisal University in the Al-Ahsa Governorate. The researchers in this study employed the descriptive correlative approach. Results: The study's findings revealed that there were substantial variations in the categories of sex, academic specialty (medical and non-medical students), and family economic status, in relation to cyberbullying surveys. In addition, there was a significant negative relationship between cyberbullying and mental health. Conclusions: It is highly recommended that, in order to prevent cyberbullying, people of all generations need to be made aware of it via specific programs in different public areas, for example, in schools, colleges, and malls, and on social media.

Keywords: cyberbullying; mental health; university students; Al-Ahsa; Saudi Arabia

1. Introduction

Bullying is an aggressive behavior that is intentionally and repeatedly directed at individuals who have less power than the attacker does. Bullying may take many forms, including physical, verbal, and social bullying [1]. In its physical form, bullying includes hitting, pushing, spitting, and other physical acts. Bullying in the oral form includes mocking, name-calling, and threatening. In its social form, it consists of spreading rumors (slander), exclusion from peer groups, and other forms. When dealing with perpetrators, these three forms of bullying most commonly occur face to face [2].

Both cyberbullying and cyber victimization research have grown in popularity in recent years in various countries. Traditional forms of bullying, such as school bullying and school victimization, are still prevalent among children. The phenomenon of cyberbullying has gained scientists' attention because it is a new form of bullying in the digital era. Individuals can now use new media to intimidate others [3]. Bullying has also grown as information and communications technology has advanced [3,4]. This situation makes sense, because indirect intimidation is considered the safest and most convenient approach, compared to traditional bullying. Bullying victims can be easily intimidated without their names being revealed [5]. Even the perpetrators can use digital media to quickly publicize intimidation acts to the general public. Cyberbullying has a more dangerous effect than traditional bullying; it can even encourage victims to respond reactively to accidents and deaths. This type of cyberbullying often happens in the educational setting, particularly among students [3].

Cyberbullying refers to humiliation, threats, sexual harassment, or social exclusion using information and communication technology [6]. For example, posting pictures or embarrassing comments about someone, or posing as someone dangerous. Cyberbullies attack victims by sending demeaning or threatening messages, and delivering images using websites, instant messages, blogs, chat rooms, cell phones, e-mails, and personal online profiles [7,8]. As such, it can be understood that cyberbullying is different from traditional bullying. This situation creates new challenges for educators involved in the learning process in schools and colleges. Teachers must recognize changes in student behavior in the digital age. Additionally, teachers are faced with the challenge of keeping students safe in school both in physical space and in virtual space, which has become a hazardous environment. Until now, there has been no regulation and supervision of security in the virtual room.

Many studies have investigated the prevalence of cyberbullying and cyber victimization, the relationship of cyberbullying with other antecedent factors (such as personal and contextual factors), motives for participation in cyberbullying actions, and the practice of effective cyberbullying prevention and intervention [9]. In addition, bullying often occurs in an educational setting, and it is extremely disruptive to the learning environment. Teachers are concerned about the impact of cyberbullying, which has the potential to cause serious issues at school. Teachers realize that they are unable to oversee students' use of information and communication technologies on a one-on-one basis [10]. Students can bully without their names being revealed. Anyone, at any time, may view bullying content that is publicized by the perpetrators. Traditional bullying can have a more severe impact on mental health and academic issues than cyberbullying. In certain countries, fatalities such as suicide have occurred [3].

Victims of cyberbullying frequently suffer issues related to social skills and peer relations. Although information and communication technologies serve as a means of communication between users, students with offline relationship problems are more likely to be victims of cyberbullying [9]. This means that students need to be taught outstanding social skills at school/college. Thus, teachers need to understand the phenomenon of cyberbullying that occurs in the school environment. This includes how cyberbullying can occur, the impact that it has on students, and how preventive measures can be taken. Teachers may utilize this information to influence student behavior at universities. It also allows teachers to develop curricula and learning strategies to help students improve their social skills, both offline and online. This literature review study aims to discuss the definition of cyberbullying, its causes and impacts, and protective factors [11].

Cyberbullying is associated with the expansion of the internet. The phenomenon is growing in Italy and other European and non-European countries. Cyberbullying causes psychopathological symptoms of anxiety, sadness, and social phobia in young people, which can lead to extreme acts, including suicide [12]. The pressure, the experience of isolation, and the weaknesses that result from cyberbullying have an additional effect on the victim's family and their own circle of relatives. Cyberbullying is a form of bullying that takes place online, is generally anonymous, and attempts to harm and make fun of victims [13]. There are numerous types of cyberbullying, and each leads to particular responses and results. Even so, few types of research have centered on young adults' perceptions regarding cyberbullying. Teenagers regularly interact in competitive behavior, even by avoiding emotions and responses associated with victimization. According to several studies, the positive connection between exposure to violent video games and aggressive conduct among university students is moderated by the trait of anger. [14,15].

The technological ecosystems for adolescents and young adults have been altered, in the twenty-first century, by a dramatic shift in the technological environment. There are more mental health hazards associated with technological innovation. This research presents a narrative assessment of current cyber dangers confronting adolescents and young adults [16]. Not only that, but it also highlights the risks and consequences of cyberbullying, media platforms, cyber interpersonal violence, abuse of women, cybersex,

online harassment, online dating, cyberstalking, and phishing scams, with a focus on raising awareness and encouraging assertive initiatives to solve these societal problems as the digital era evolves [17].

After reading many literature reviews on cyberbullying in the age groups of 8–13 and 9–17, we decided to focus our study on college students, namely those aged 18 and above. This is a focus that differentiates our study from other, similar research. The goal of the current study was to determine the overall impact of cyberbullying on mental health. We also wished to investigate whether there was a substantial difference in mental health between males and females at King Faisal University, Saudi Arabia.

However, every generation has its view of cyberbullying, including teachers, some of whom are judged on their appearance, or due to racism and prejudice, among other things. Even when the bullying has ceased, cyberbullying can have long-term emotional consequences. Cyberbullying may also cause mental health problems, including tension and worry, sadness, aggressive behavior, and low levels of self-esteem.

The current research aimed to investigate the overall impact of cyberbullying on the mental health of college students of different age groups. Moreover, we also aimed to study the extent to which victimized persons (students) direct less concentration/less focus towards their academic performance.

Objectives:

1. To explore whether there is a relationship between cyberbullying and emotional mental health, i.e., depression, anxiety, and stress.
2. To evaluate the differences between males and females, as well as students at medical and non-medical colleges, with regard to the impact of cyberbullying on psychological disorders.
3. To explore whether there is a significant relationship between academic performance and mental health in relation to cyberbullying.

2. Literature Review

Today's teenagers are completely connected in their everyday lives. Aboujaoude (2015) refers to today's teenagers as completely wired, since they are constantly switching from one type of media to another [1]. Ongoing technological growth has brought about the continuous development of the concept of relationships. Non-mandatory entry to social networks and online communities suggests instant presence broadcasting over the network [18].

Cyberbullying, also known as electronic bullying, is a well-known risk of technological evolution; it involves purposed and repeated actions toward at least one individual, using electronic devices [19]. Cyberbullying, like traditional bullying, is dependent on an asymmetrical relationship between the person who make the cyberbullying and the targeted person [20]. The main feature of cyberbullying is the anonymity guaranteed by the internet, which makes victims feel weak and lonely. [21].

The rates of cyberbullying vary significantly across studies conducted in European and non-European countries, with values ranging from 6.5% to 72% for cyber victimization [22]. For instance, according to a 2017 Brazilian survey conducted in the United States, between 33.8% and 39% of adolescents have reported being victims of cyberbullying at some point in their lives. Rates of cyber victimization in China span from 14% to 57%, and cyber violence from 3% to 35%, according to research published between 2013 and 2018 [23].

2.1. Cyberbullying and Mental Health

Victims of cyberbullying use alcohol and narcotics more often than other students in schools, and are more likely to be absent from school (United Nations Children's Fund) [24]. In addition, they are more likely to perform poorly and have problems with self-esteem and health [25]. When it comes to cyberbullying, adolescents usually hesitate to confide in adults. Cyberbullying presents with the same symptoms as a post-traumatic stress disorder, and suicide can result from these symptoms [26]. Harassment and cyberbullying are frequently linked to anxiety and depression. [27].

2.2. The Psychological Effects of Cyberbullying

Cyberbullying has the potential to harm the victim's mental health. Victims experience increased levels of anger, helplessness, unhappiness, and fright [28]. The most significant emotional and non-physical results of cyberbullying include anger, helplessness, grief, and anxiety. Students who experience cyber victimization can develop symptoms of depression [29]. However, traditional bullying has a stronger link to depressive symptoms, as compared to cyberbullying [30]. Other research has revealed that victims of cyberbullying suffer from increased levels of depression than victims of traditional bullying [31]. In addition, cyberbullying has a stronger link to anxiety symptoms than traditional bullying [32].

When students do not know who is intimidating them, the negative impacts intensify, leaving victims feeling helpless and afraid. This is highly understandable, given that cyberbullying is often carried out anonymously by perpetrators [33]. In comparison to those instances when the victim knows who is committing the cyberbullying, anonymity generates heightened feelings of disordered anxiety: that is, in instances when the victim is unaware of the perpetrator's identity. The anonymity factor can make the victim feel less secure, resulting in a more pronounced power imbalance in cyber victimization than in traditional victimization [32].

2.3. Reactive Behavior

Cyberbullying victims may exhibit reactive behaviors, such as suicide attempts. This condition occurs due to ongoing depression, which eventually leads to the formation of suicidal ideation and attempts [34]. Several studies have found that cyberbullying has more severe consequences than traditional bullying. Cyberbullying has a greater incidence of depression, drug use, self-injury, suicidal ideation, and suicide attempts, compared to traditional bullying [35]. The researcher states that involvement in cyberbullying, whether as a bully or a victim, functions as a predictor for symptoms of depression and thoughts of suicide, in a way that traditional forms of intimidation (physical, verbal, relational) do not [35]. Victims attempt suicide, and cyberbullying has been shown to have a direct influence on suicide attempts [35]. Young individuals who experience traditional bullying or cyberbullying, either as perpetrators or victims, have greater rates of suicidal thoughts and are more likely to attempt suicide than those who have not experienced any form of aggression from their peers [36].

2.4. Difficulties in Social and Academic Development

Another problem caused by cyberbullying is the inability to make friends [37]. Cyberbullying enables victims and attackers to avoid facing social communications and building connections, which can have harmful emotional implications. [37]. Furthermore, perpetrators of cyberbullying have lower levels of conscience [37]. Additionally, cyberbullying can also obstruct students' academic development [37]. Feelings of pressure and shame discourage students from focusing on educational activities. Victims find it challenging to develop their academic, social, and emotional capacities [37].

2.5. The Role of the School Environment

Cyberbullying must receive serious attention from school stakeholders and must be addressed by teachers, parents, and peers [38]. Various protective strategies may be implemented to avoid cyberbullying, and education is an important component of cyberbullying prevention and response. Educators must devise innovative techniques to engage young people in meaningful discussions regarding the use of accessible technology. In this context, they can create lessons that teach students to express their opinions appropriately on social media [39]. An encouraging school environment plays a vital role in reducing the occurrence of cyberbullying [40]. Previous studies have revealed that a positive school climate [3,37] and school safety [3] can protect children from the victimization and oppression of cyberbullying [41].

2.6. The Role of the Family

Cyberbullying victims frequently have the lowest level of family support [42]. Parents can assist in anti-cyberbullying interventions by providing: (a) emotional and practical support for students, (b) knowledge of ICT safety, and (c) a structured environment, characterized by warm involvement and control of behavior, combined with discussions of and participation in children's online lives, to promote critical thinking, respect, and finally autonomy [5]. Some types of social support can protect against cyberbullying. Specifically, perceived social support from the family and teacher reduces the likelihood of depression and anxiety symptoms, and a higher level of social support from the family increases the probability of a greater level of subjective well-being among children who are victims of cyberbullying [43].

2.7. The Role of Peers

A positive community can protect children from cyberbullying. Information and communications technology may be used as a medium for communication between users [6]. However, students who have offline relationship problems are more likely to become victims of cyberbullying [9]. Therefore, the role of positive interaction and peer support is vital to reducing the incidence of cyberbullying [43]. Previous studies revealed that positive peer influence and peer support are linked to decreased cyber victimization [3]. Furthermore, choosing a positive community is a significant factor in reducing the occurrence of cyberbullying.

2.8. Individual Role

Protective measures against cyberbullying not only rely on situational factors but also on personal factors [6]. Students are thought to play a vital role in protecting themselves against cyberbullying. Prosociality is expected to prevent cyber victimization and cyberbullying by lowering the frequency of technology usage, among other individual factors [3]. Additionally, social competence, intelligence, and problem-solving can protect against victimization [3,6].

Furthermore, the ViSC Social Competence Program is also proposed as a cyberbullying prevention program [44]. ViSC is a primary prevention program, with secondary prevention features to minimize violent behavior and intimidation in schools, as well as to promote social and intercultural competency [45]. Given that cyberbullying harms students, the findings of this study provide further evidence that teenage peer aggression must be addressed seriously both at school and at home. In addition, in programs that respond to cyber victimization and cyberbullying in the school setting, both the prevention of and intervention in cyberbullying are critical components [46].

All technological developments provide various benefits and unexpected losses. This includes impacts on the school environment and the way students learn. The downside of technological development is that it might have a bad influence: for example, when technology is used as a tool for cyberbullying [47]. The development of technology has had a significant influence on this new form of bullying. The ease with which people can use the internet, and other technical gadgets such as cell phones, has also contributed to the emergence of new forms of bullying. Individual relationships have been altered by the increased use of technology. Rapid changes in communication and social interaction have significant effects, both positive and negative, including encouraging the emergence of cyberbullying [3].

Cyberbullying refers to humiliation, threats, sexual harassment, or social exclusion using information and communications technology [6]. Perpetrators attack victims by sending demeaning or threatening messages and images using websites, instant messages, blogs, chat rooms, cell phones, e-mails, and personal online profiles [7,8,48]. As a result, it is clear that cyberbullying is different from traditional bullying. This situation creates new challenges for educators in the school/college learning process. In the digital era, teachers must be aware of changes in student behavior. Furthermore, they face the challenge

of keeping students safe at school, both physically and virtually, which has become a hazardous environment. Until now, there has been no regulation or supervision of virtual room security [12].

3. Materials and Methods

Study type: IT Cross-sectional design.

The sample size consisted of 326 students from different colleges of King Faisal University. All the respondents (males and females) were aged 18 and above, and came from different socio-economic backgrounds.

Hypothesis 1 (H1). *There is a significant difference in mental health between males and females, with regard to cyberbullying.*

Hypothesis 2 (H2). *There is a significant difference in mental health between students at medical and non-medical colleges, with regard to cyberbullying.*

Hypothesis 3 (H3). *There is a significant difference in mental health between victimized students and non-victimized students with regard to cyberbullying.*

Hypothesis 4 (H4). *There is a significant relationship between poor academic performances/diminished concentration/poor mental health, and cyberbullying.*

Tools: Two main questionnaires were used. The first of these was the Cyberbullying Scale, which was developed by the Cyberbullying Assessment Instrument [36]. This questionnaire focuses on assessing cyberbullying among college students, and consists of 20 items. The second questionnaire, "Mental Health Questionnaire", was developed by DASS 21, and consists of 21 items that focus on depression, anxiety, and stress.

Procedure: The study was carried out among university students at King Faisal University, Saudi Arabia. The sample size was 326 students, aged 18 and above, and the study was conducted using valid questionnaires through online surveys. The target was focused on students with different levels of socio-economic status, male and female students, and students from both medical colleges and non-medical colleges, at King Faisal University. Two questionnaires were used: DASS-21 and the Cyberbullying Assessment Instrument. The collection of questionnaires was carried out between January and March 2022, during the academic year.

Analysis of data: The data was entered and analyzed using the SPSS program, version 26, with the help of different statistical techniques such as Chi-square, Pearson correlation, and frequency. Chi-square was used to assess the significance level of various factors such as sex, age group, academic level, academic specialty (medical and non-medical students), and the economic level of the family, with regard to the cyberbullying questionnaire. The Pearson correlation was used to determine the existence of a significant relationship between cyberbullying and mental health. Likewise, the frequency technique was used to determine the significance of sex, socio-economic status, and academic level and specialty (non-medical colleges) for mental health.

Ethical Approval: The ethics committee of the university granted and informed IT, giving the researchers consent to carry out the research. The ethical principles were considered with respect to research with human beings.

4. Results

Table 1 shows the demographic percentages: 311 students (95%) were aged 18–25, the highest percentage of the age groups; 2.1% of students were 26–30 years of age; and 2.5% were above 30 years of age.

Table 1. Description of demographic variables.

Variables	Categories	*n*	%
Age	18–25	311	95.4
	26–30	7	2.1
	More than 30	8	2.5
Sex	Female	139	42.6
	Male	187	57.4
Academic year level	1st	77	23.6
	2nd	158	48.5
	3rd	52	16.0
	4th	12	3.7
	5th	9	2.8
	6th	18	5.5
Specialty	Medical colleges	255	78.2
	Non-medical colleges	71	21.8
Family socio-economic level	SAR 5000–10,000	77	23.6
	Less than SAR 5000	56	17.2
	Greater than SAR 10,000	193	59.2

With regard to sex, males comprised 42.6% of respondents and females 57.4%. In terms of different academic levels, 23.6% were in first year; 48.5% second year; 16% third year; 3.7% fourth year; 2.8% fifth year; and 5.5% sixth year. The percentage of students at medical colleges was 78.2%, and the percentage of students at non-medical colleges was 21.8%. In terms of family socio-economic level: SAR 5000–1000, 23.6%; less than SAR 5000, 17.2%; greater than SAR 1000, 59.2%.

Table 2 shows that there is a significant difference level in sex, academic specialty (medical and non-medical students), and economic level of the family, among respondents to the cyberbullying questionnaires.

Table 3 shows that there is a significant negative (−0.687) relationship between cyberbullying and mental health.

Table 4 shows that 15% of the participants mentioned that cyberbullying is a significant/big problem at their college. The majority (84%) of the participants agreed that cyberbullying is on the rise. About one-half (49.1%) of the participants have been cyberbullied in the past three years.

Table 2. Chi-square test results.

Variable	Items	*p*-Value	In Favor of
Sex	Bullying always occurs when you are in which place?	0.000	Females who chose society.
	Bullying is a very big problem in your college.	0.000	Females who are not sure about that.
	How often do you think cyberbullying occurs through cell phone use during school hours?	0.047	Females who think it occurs from time to time.
	I found it hard to wind down	0.009	Females who sometimes found it hard to wind down.
	I experienced breathing difficulty	0.024	Males who never experienced breathing difficulty.
	I found it difficult to work up the initiative to do things	0.016	Females who sometimes found it difficult to work up the initiative to do things.
	I experienced trembling	0.017	Males who never experienced trembling.
	I felt that I was using a lot of nervous energy	0.005	Males who never felt that they were using a lot of nervous energy.
	I felt that I was rather touchy	0.000	Males who sometimes felt that they were rather touchy.

Table 2. *Cont.*

Variable	Items	*p*-Value	In Favor of
Academic year level	Bullying occurs through what place?	0.001	Third-year students who mentioned it occurs through personal profile pages.
	Should we leave the student on the internet without watching him, directing, or guiding him?	0.039	Sixth-year students who mentioned that we should not leave the student on the internet without watching him, directing, or guiding him.
	If the student took a photo of someone else, should he have the right to publish it with permission?	0.006	Third-year student who mentioned that we should take permission to publish the photos.
	I could not seem to experience any positive feeling at all	0.036	Fourth-year students who sometimes could not seem to experience any positive feeling at all.
	I felt I was close to panic	0.031	Fourth-year students who sometimes felt they were close to panic.
Specialty	Bullying always occurs when you are in	0.005	Non-medical students who mentioned that bullying always occurs when they are in college.
	Bullying occurs through	0.000	Medical students who mentioned that it is occurs through personal profile pages.
	Should we leave the student on the internet without watching him, directing, or guiding him?	0.042	Sixth-year students who mentioned that we should not leave the student on the internet without watching him, directing, or guiding him.
	Did they tell their parents about the cyberbullying? Did you tell your parents about bullying via the internet that happened to you?	0.002	Medical students answered that they did not tell their parents about bullying via internet happened to them.
	I tended to overreact to situations	0.026	Non-medical never tended to overreact to situations.
	I found myself getting agitated	0.011	Non-medical students never found themselves getting agitated.
	I was unable to become enthusiastic about anything	0.022	Non-medical students were never unable to become enthusiastic about anything.
Economic level of family	How often do you think cyberbullying occurs through cell phone use during school hours?	0.038	Students who have a family economic level of SAR 5000–10,000 think that cyberbullying occurs through cell phone use during school hours.
	I found it hard to wind down	0.023	Students who have a family economic level of SAR 5000–10,000 found it sometimes hard to wind down.
	I found it difficult to relax	0.016	Students who have a family economic level of SAR 5000–10,000 sometimes found it difficult to relax.

Table 3. The correlation between cyberbullying and mental health.

Variable	Test Name	Mental Health
Cyberbullying	Pearson correlation	−0.687
	p-value	0.001

Table 5 shows the assessment of the mental health of the participants related to different issues, such as anxiety, stress, and depression. The results show that (58.6%) of participants found it hard to calm down after any kind of stress; (20%) reported that this was never an issue; and the remaining (9%) answered 'almost always' in relation to mental health issues. The results show that it is difficult for the participants (university students) to return to a normal mood after experiencing stress. Moreover, regarding the

questions related to overreactions and difficulties calming down quickly in situations such as cyberbullying, (9.5%) of the participants showed overreactions; (31.6%) of respondents reported that tended to overreact to situations was 'never' an issue; (16.6%) of participants responded that it was 'often' the case; and (42.3%) responded 'sometimes' regarding mental health issues.

Table 4. Frequencies and percentages of important items of the cyberbullying questionnaire.

Items	Categories	*n*	*%*
How many times have you been cyberbullied in the past 3 years	More than 10 times	28	8.6
	1–5 times	118	36.2
	5–10 times	14	4.3
	Never	166	50.9
Cyberbullying is on the rise	Disagree	52	16.0
	Agree	274	84.0
Cyberbullying is a significant/big problem at our college	Disagree	144	44.2
	No	133	40.8
	Yes	49	15.0

Table 5. Frequencies and percentages of important items from the mental health questionnaire.

DAS 21 Items	Categories	*n*	*%*
I found it hard to wind down	Sometimes	191	58.6
	Never	68	20.9
	Almost always	16	4.9
	Often	51	15.6
I tended to overreact to situations	Almost always	31	9.5
	Never	103	31.6
	Often	54	16.6
	Sometimes	138	42.3
I found it difficult to relax	Almost always	31	9.5
	Never	82	25.2
	Often	66	20.2
	Sometimes	147	45.1
I felt down-hearted and blue	Almost always	40	12.3
	Never	123	37.7
	Often	42	12.9
	Sometimes	121	37.1
I felt I was not worth much as a person	Almost always	19	5.8
	Never	228	69.9
	Often	21	6.4
	Sometimes	58	17.8
I felt scared without any good reason	Almost always	29	8.9
	Never	145	44.5
	Often	38	11.7
	Sometimes	114	35.0
I felt that life was meaningless	Almost always	39	12.0
	Never	156	47.9
	Often	49	15.0
	Sometimes	82	25.2

5. Discussion

The present research aimed to assess the overall impact of cyberbullying on mental health, and the extent to which victims (students) paid less attention to their academic performance.

In terms of cyberbullying, the results of the present study revealed that there was significant differences according to the following variables: sex ($p = 0.0001$), academic

specialty ($p = 0.039$), medical ($p = 0.0001$) and non-medical ($p = 0.005$) students, and family economic status ($p = 0.038$). In relation to mental health, surveys demonstrate that females ($p = 0.009$) are more stressed than males ($p = 0.007$) when it comes to cyberbullying. When we analyzed the data at different academic levels, we found that third-year students ($p = 0.006$), fourth-year students ($p = 0.036$), and sixth-year students ($p = 0.039$) were more fearful of cyberbullying than first-year and second-year students. This might be due to students gaining experience and maturity as they progress through their academic years. However, aside from demonstrating a major difference between students at medical and non-medical colleges, one unexpected finding from this study is that students are not willing to discuss any problems with their family members. The students imply that no matter what transpired in their social lives, they would never tell their parents about their problems. As a result of the bullying they endure, students are constantly stressed, anxious, and depressed [37].

According to the results of the present study, about one-half of university students (49.1%) say they have been victims of cyberbullying, with the percentage being greater in the case of aggressors. Prior empirical investigations have indicated that prevalence rates for both victims and aggressors are similar [24]. Data have demonstrated that various emotional issues are predictors of being a victim of cyberbullying. Higher percentages of anxiety and stress, in particular, indicate a higher likelihood of being a victim of cyberbullying, although higher depression rates among students predict a greater likelihood of becoming a cyberbully [12,24,37], proving hypotheses 2 and 3 of this research.

Unfortunately, few studies have investigated whether these high levels are the outcome of predictors of cyberbullying in the college environment, making comparisons of the findings of this research very difficult indeed. Even so, the distinctive features of this transition phase may predict psychological issues in the college population as a whole [49]. Moreover, it has been demonstrated that these issues increase the chances of being a victim.

Results of the recent study revealed that there was an overall significant negative relationship between mental health and cyberbullying. These results clarified that cyberbullying has a negative impact on students' well-being, academic performance, and mental health. The results clearly show that victims of cyberbullying experience emotional problems, such as worry, tension, and sadness. Bullies' violent and domineering behavior [12] is associated with sad emotions, dissatisfaction with life, depression, and high levels of irritation. [44,48]

Results of the recent study show that (58.6%) of participants found it hard to calm down after any kind of stress; (20%) responded that this was 'never' an issue; and the remaining (9%) answered 'almost always' in relation to mental health issues. From these results, it is shown to be difficult for participants (college students) to return to a normal mood after experiencing stress. Moreover, with regard to questions related to overreactions and difficulties calming down quickly in situations such as cyberbullying: (9.5%) of the participants overreacted; (31.6%) of participants responded that this was 'never' an issue; (16.6%) of participants responded 'often'; and (42.3%) responded 'sometimes' regarding mental health issues. Here, the results show that there is an anxiety among college students who are victimized.

However, we can also identify from the results based on mental health questions that respondents who are victimized suffered from depression. Questions related to "I am not a deserving/a worthy person" received affirmative responses from (30.1%) of respondents; question based on "meaningless life" from (12%); and questions related to not being able to cope for trivial reasons from (8.9%). These results show that the participants thought that it was useless or of no value to live, felt discouraged by society, experienced discrimination, and felt desperate and lonely. Similar studies also support these results [28,45].

Similar studies were also supported [46], which concluded that there was relationship between victimization and the internalization of problems, whereby being a victim of bullying predicted future emotional problems. At the same time, depression, anxiety, anguish, insecurity, and low self-esteem all predisposed the student to become a victim.

Students who experience cyber-victimization are at greater risk of depressive symptoms [29]. Additionally, traditional bullying has a stronger relationship with depressive symptoms, as compared to cyberbullying [30]. This finding does not follow other studies, which found that victims of cyberbullying have higher rates of depression than victims of traditional bullying [10].

In addition, the present study shows how some university adjustment factors are predictors of becoming a victim. Specifically, personal-emotional adjustment and social adaption were discovered to be predictive factors of becoming a target of bullying, with higher levels of individual and interpersonal adaption reducing the likelihood of becoming a target. Previous research has indicated that students who are victims of cyberbullying experience internalized issues such as stress, discomfort, fear, aloofness, depression, shame, indifference, and low academic performance due to mental health problems [12]. This has a negative impact on university students' academic performance, which supports hypothesis 4 of our study. According to Egeberg (2016), bullies have poor academic performance and a lack of integration in academic and scholastic dynamics [50]. As a result, making positive academic adjustments (the desire to fulfil educational obligations, educational hard work, and educational satisfaction) protects against participating in violent behavior toward peers.

Several types of research have found that victims have poorer social adaptation than non-victims, experiencing challenges interacting with peers, and social difficulties [51]. As a result of the findings of this research, excellent psychological and community adaptation appears to be a preventative measure against being a target of mockery, insults, or bullying via online technology [43,52].

Emotional skills can help students to feel a greater level of understanding for their schoolmates. However, one of the characteristics that cyberbullies frequently mention is a lack of understanding for victims, as they do not seem to feel distressed or guilty as a result of their aggression, and thus are unable to empathize with the victim's emotions or feelings [12]. Bullying is also associated with poor scholarly performance and a lack of collaboration in scholarly interactions [53].

We believe that future studies should focus on determining which factors might aid in a better understanding of cyberbullying. Other variables include social support [54], impulsivity or other features of self-regulation [5], aggressiveness [55], sexual orientation [31], and coping style [56]. As a result, experimental strategies in cyberbullying should be aimed at increasing the levels of these protecting factors [54].

6. Limitations of the Study

Two notable limitations affected the recent study:

1. There was a time limitation.
2. The results would have been better if we had assessed a larger sample size for both males and females.

7. Conclusions

The present research aimed to study the connection between online bullying and psychological health in college students. There was a significant negative relationship between mental health and cyberbullying with regard to gender, age, economic level, specialty, and academic level. Furthermore, this study showed that the higher the educational level, the more likely students were to deal positively with cyberbullying issues. It is highly recommended that, in order to protect them from cyberbullying, people of all generations need to be made aware of it via specific programs in different public areas, for example, in schools, colleges, and malls, and on social media. Moreover, this study gives us a foundation to conduct more studies on cyberbullying, which is understudied in many Arab countries owing to cultural and societal factors.

8. Recommendations

The researchers recommend the following:

1. Providing awareness programs about cyberbullying in order to prevent this behavior in younger generations.
2. Giving counseling to people who have been exposed to cyberbullying.
3. Constructing special units in educational institutions to provide support for people who have been exposed to cyberbullying.
4. Conducting further studies about the relationship between cyberbullying and mental health among different populations, such as high school students.
5. Conducting the same research but using a bigger sample size.
6. Conducting similar studies over longer periods of time.

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Article

Developing Resilience to Disinformation: A Game-Based Method for Future Communicators

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Abstract: This paper analyzes the outcomes of a game-based educational process aiming to strengthen resilience to fake news. An innovative approach that considers linguistic choices as bases for manipulating information is used in an online classroom environment, students in communication being invited to understand, explain and reflect upon framing and information credibility, using as a topic of inquiry the refugee crisis of 2021 in Romania. Cognitive learning outcomes as well as learning dynamics were assessed using pre- and end-of game surveys. The results of the game are discussed in relation with the instructional goal to facilitate the understanding of communicative social actions, learning about disinformation that is deliberately misleading, as well as finding ways to break the disinformation code. The debriefing discussions after each stage of the game encouraged students to reflect upon their newly gained insights and increase their critical thinking capacity, in the effort to ensure a sustainable education in communication studies. The paper has the potential to enrich the educational strategies with innovative methods helping future professionals navigate the complex world of media messages.

Keywords: disinformation; fake news; serious game-playing; CRAAP test; resilience; media literacy; sustainable education

1. Introduction

Students are heavy users of social networks, and active and significant participants to the digital public sphere, as a place of information, contestation, organization, discussion and political, social, educational and ethical struggle. They are also the most vulnerable target categories to disinformation and propaganda since they have not fully formed critical thinking skills and are prone to confusion and gullibility. A sustainable education equips them with critical skillsets that allow swift identification of fake news, disinformation and propaganda. In a turbulent informational ecosystem and in a participatory media culture, news literacy becomes a pivotal skill.

1.1. Background and Importance

Disinformation and false information, often referred to as fake news do not constitute a novel phenomenon. Media literacy initiatives to enable the general public to critically evaluate media messages formally date back to UNESCO's declaration of 1982, known as the Grünwald Declaration on Media Education [1]. Ever since, a variety of international organizations, universities and media outlets called for the necessity to raise people's capacity to access, understand and critically evaluate media via reducing the deficit in media literacy across the world, either in formal educational programs or in an informal context. The diversification of media, the advent of digital extensions of communication, the multiplication of platforms that carry information led to the necessity of developing new tools to foster independent critical thinking and build resilience against false information, as underlined by UNESCO in the 2020 Seoul Declaration on Media and Information Literacy for Everyone and by Everyone. It bluntly states that "media and information literacy

(MIL) is a core competency for addressing the disinfodemic" [2]. While the term "media literacy" means different things for different countries and stakeholders, as recognized by the specially created expert group of the European Commission [3], it is an evolving concept that aims to develop the critical thinking of the users of media, be it traditional, digital, social—or whatever new form it may take in the future. To fight the spread of fake news, a variety of strategies have been developed, from fact-checking procedures and networks to software apps or moderation tools [4].

In the context of the health crisis of 2020–2021, the interest towards combating disinformation and fake news grew exponentially, bringing new topics and tools for deception detection to the fore. The World Health Organization warned that the infodemic, understood as a significant increase in the volume of information associated with a specific topic and whose growth can occur exponentially in a brief period of time due to a specific incident, spreads farther and faster just like the health-affecting pandemic [5]. In a country like Romania, where the interest towards the MIL topic is uneven, with mild initiatives to educate the public, critically analyze media messages and detect fake news, in 2020 the Civic Labs program from the Code for Romania in partnership with the Authority for Romania's digitalization created browser extensions for Chrome and Firefox, to help users fight pandemic-related disinformation [6]. However, resilience against disinformation is not systematically dealt with on a large scale. And while the pandemic dominated media content throughout 2020 and 2021 [7], other socially relevant events happened and needed proper interpretation, such as electoral processes or the flow of refugees in Europe. Against this background, the research team for the present study worked on building the capacity of future professional communicators to identify and dismantle fake news related to the refugee crisis, independent of the pandemic topic, in a university city of Romania. The task was complicated by the fact that the research was conducted during emergency remote learning in higher education imposed by pandemic-related measures, a period marked by students' fatigue with Zoom-facilitated classes, anxiety, work overload and loss of the feeling of the community of learning [8]. Thus, the educators aiming to develop media literacy skills in students, appealed to innovative pedagogical strategies in the form of game-based learning to assist future professional communicators—students in communication sciences—strengthen resilience against disinformation, develop deception detection skills and enrich their learning experiences with role-playing in a serious game environment.

1.2. Study Aims

Educating future communication specialists is challenging because it is a complex issue, rooted in multidisciplinary knowledge and for an ongoing changing social environment. The repertoire of skills and abilities is expanding at a high rate. Employers propose new tasks and responsibilities for their communication experts, ranging from media relations to social media management and from content production to developing relations with a variety of stakeholders, via multiple platforms. The core of the profession remains, however, the mastering of media literacy at an expert level, above the general skill listed by the European Framework of Key Competences for Lifelong Learning [9] (p. 23). The primary objective of this article was to analyze data collected during the fall semester of 2021 and verify whether students in communication studies perceive value in serious game playing as a pathway towards stronger resilience to disinformation. Another important objective was to test the serious game method to ensure a sustainable education of future communicators.

2. Literature Review
2.1. Research on Fake News and Media Literacy

Fake news is not a new phenomenon, but it has gained interest in the last several years, due to the magnitude, the multimodality and the multiplicity of its manifestations and consequences in the digital post-truth era. Because the term fake news itself is problematic

and open to abuse, other different concepts have been proposed for describing the phenomenon: disinformation, information manipulation, information disorder, information influence, etc. There is a distinction concerning fake news types [10] among false information without the intention of causing harm (mis-information), false information with the intention of causing harm (dis-information) and real information with the intention of causing harm (mal-information). Fake news can be considered a form of disinformation, comprising, cumulatively false or misleading information and the intention of causing harm to individuals, social groups, organizations or countries.

Fake news is created and disseminated with increasing speed, expertise and effectiveness in the digital context [11], thus being more difficult to detect and resist. The fake news exploits the gullibility of media users, who frequently are not only biased, but also irrational and lazy. Framing (selecting some aspects of a perceived reality and making them more salient) is a particularly effective discursive device of fake news, because it is hardly discernible. It is difficult to differentiate on digital and social media among true, misleading, or false content. One important way of addressing this problem is media literacy, which equips individuals with powerful tools and strategies of resilience and resistance to fake news [12]. Media literacy creates and develops an adaptable and critical toolkit for detection of the fake news and protection from the harm they may cause [13].

Media literacy comprises a set of critical skills and competencies, which enable users to find, analyze, evaluate and interpret various forms of media messages [14]. The main media literacy skills are: analysis, evaluation, grouping, induction, deduction, synthesis and abstracting [15]. Media literacy stimulates the understanding of the methods of message construction and framing, of the different types of media genres, of the various ways of experiencing the messages, of the embedded values and perspectives in media messages, and of the purposes of media producers, whether profit, power or some other aim. Media literacies (digital, visual, textual, aural) promote critical thinking applied to messages and awareness of the media processes and impacts. One important component of media literacy is news literacy [16]. News literacy is the ability to analyze and critically assess news, from the sources of information to the final form with which news stories are presented. It enables users to evaluate the credibility of information and to examine the structure of that information. Young people's lack of interest in news and their disconnection from politics increases their vulnerability to fake news. As the fake news repertoires are ever-increasing, so are the counteracting techniques [16].

Media literacy education (MLE) can be construed as a sustainable remedy to the contemporary disruptive media content, which provides users of all ages (especially college students) with lifelong critical tools for analyzing and assessing information and images [17]. Sustainability is a multidimensional concept, which can be understood or framed differently across the various higher education disciplines. Sustainable education provides enduring solutions by academic participation concerning societal and environmental issues. Sustainable teaching guides individuals, through aligned efforts and connected interventions, to be able to acquire new skills and adapt continuously during their lives [18]. In the media studies field, this diversity of focus involving sustainable education upholds complex cultural practices and forms of knowledge [19]. The principles of sustainability, as empowerment action tools, have permeated the media education on different levels, but the research in this area is rather scarce. Sustainable education in a mediated world is a crucial aspect in the development of savvy, informed and engaged citizens as consumers of multimodal media messages [20]. The habit of critical interrogation of media messages can be formed via sustainable education methods. Media coverage and filtering of different issues is a major factor in framing and responding to them as risks, threats or crises [21]. Sustainable media education expands the ability of individuals to interpret and construct dynamic representations of the real-world processes and to access and evaluate information across multiple media platforms and engage actively and critically in a turbulent media environment [22].

2.2. Game-Based Learning

Game-based learning gained momentum due to Johan Huizinga's "Homo Ludens" [23], which brought to public attention the fact that adults picking up narrations, game metaphors and game elements succeed to better understand culture and society, understand complex issues and deal with uncertainty or conflict. Another line goes outside gaming and playfulness, into Erving Goffman's theory that each social interaction remains, in and of itself, a type of performance, each person enacting a prescribed role on the stage of social expectation, shifting one's sense of identity as demanded by circumstance [24]. The assumed role brings changes in posture, lexical choices, attitude, etc. Most of the time, individuals shift from one social role to another without a conscious effort, mimicking consecrated types of behavior for a given situation. Role-playing is, on the other hand, not only a learned activity, but a path towards personal and/or professional success. Role-playing games are viewed as forms of cultural rituals, appealing either to fantasy, or to non-fictional strategies, depending on the stake and purpose of the game. In the effort to innovate educational practice and re-ignite people's appetite for learning, gamification was proposed, in the last decade, as a process capable of motivating individuals to stay committed to lifelong learning, although the outcomes of game-based learning are not always enduring [25,26]. Nevertheless, game-based learning tools and gamification are perceived as effective ways of transferring knowledge on complex topics not only to students, but to broad audiences and such tools are proposed in a variety of packages and durations. Literature on the topic [27] mentions frameworks on gameful design such as RECIPE (Reflection, Exposition, Choice, Information, Play, Engagement) and playful design such as TANC (Theme, Activities, Narrative, Components), alongside emphasizing the meaningfulness of playing and memorable experiences that win the intrinsic interest of students. Sarah Lynne Bowman makes a compelling case towards using role playing in a variety of contexts, mentioning business, education, military training, improvisational theater, drama therapy, health care and leisure. In her view, role-playing enhances a group's sense of communal cohesiveness by providing narrative enactment within a ritual framework, encourages complex problem-solving and provides participants with the opportunity to gain experience, while being capable of offering participants a safe space to enact alternate personas [28]. She demonstrates that role-playing encourages creativity, self-awareness, empathy, group cohesion and "out-of-the-box" thinking. For the specific case of combating fake news and raising resilience against disinformation, Jon Roozenbeek and Sander van der Linden [29] propose the fake news game, explaining how the inoculation theory proves effective for developing participants' ability to recognize and resist fake news. The game is freely accessible on the internet under the title "Bad news game," with brief indications regarding the inoculation theory—a "vaccine against fake news"—role playing in producing fake news messages and guidance to post-game debriefing, to reflect upon the experience. Other models and games are described in literature [30], but the one developed and studied by Roozenbeek and van der Linden seems to be a forerunner.

3. Design and Methods

To facilitate students' learning experience through game-based learning, the teaching and research team designed an experiment in the form of a serious game, incorporating learning goals specific for Romanian second-year students in communication studies, who take classes in media relations and in producing content for communication campaigns. The usefulness and value of game-based learning is advocated for and appraised in educational literature, as shown by Qian and Clark [26]. Role-playing games may take place in a variety of different formats, both in-person and online. The present study is based on the assumption that critical thinking on media consumption is enhanced by active learning methods, such as experiential learning and serious games, putting learners in a "hands-on" paradigm, instead of the spectators' role, which is so easy to adopt in traditional education. Since the educational process was carried out online, due to pandemic-related restrictions, accessible tools and communication platforms were identified for virtual encounters, and

scenarios for the two gamification stages were developed. All activities were carried out in Romanian, but for the purpose of this study relevant examples have been translated into English.

Communication students supposedly have a good level of media literacy, after the introductory course in media and communication (first year level), where the principles of MIL are taught. As an overarching theme of the exercise, the refugee crisis was selected, due to the fact that the topic is sensitive in Romanian media [31]. Also, the university city where the research was carried out proved to be in the center of media attention because of the waves of refugees from Asia and Africa in the fall and winter of 2021. The pre-game test served as a starting point for unfolding the gamified experience, each stage being followed by debriefings and debates both on the method, and on the content and outcomes of the experience. The pre-game stage used Sarah Blakeslee's CRAAP test [32] to measure students' ability to fact-check media messages and detect potential points of distorting the meaning of the message. Media literacy literature, however, warns that working with real-life media materials is not enough for developing resilience to misinformation [13]. Additional efforts are needed, and the research team authoring this study selected, out of the available tools, the path of gamification [18]. Hence, the next stage, role-playing in text production, aimed at unveiling the capability of students to apply the theoretical knowledge in practice and to adapt the content-production to expected style indications, preparing them for the game-playing as such. The subsequent two game-playing activities placed students in the roles of media monitors, analysts and critics, building abilities to detect the various manipulative intentions behind media messages. The debriefing stage between the two gamification stances targeted a corrective, teacher-led deciphering of the issues raised by the game. The discussion and comment-collection planned for this stage served as a test validating the acceptability of the game method by the participants, who could terminate the experience, or express their interest in moving to the second (and last) stage of the game. In the last and final stage, the whole experience was offered for appraising and extracting takeaway lessons. A more detailed presentation of the news game is presented further in the article.

Isondaje.ro, a Romanian free online platform was used for all three testing activities, while Zoom was used for presenting the topics, role-playing and debriefing. Additionally, the virtual campus (https://cv.upt.ro/last accessed 20 January 2022), supporting the educational process in the university was used to collect texts produced by the participants, testimonials and post-game feedback. The game was inspired by Roozenbeek and van der Linden [29], but the teaching and research team developed a new scenario for the game, entitled "The refugee crisis seen from Timisoara", designed the playing cards, ensured guidance and monitored the game while it unfolded from October to December 2021. A synthetic presentation of the flow is provided in Figure 1 below.
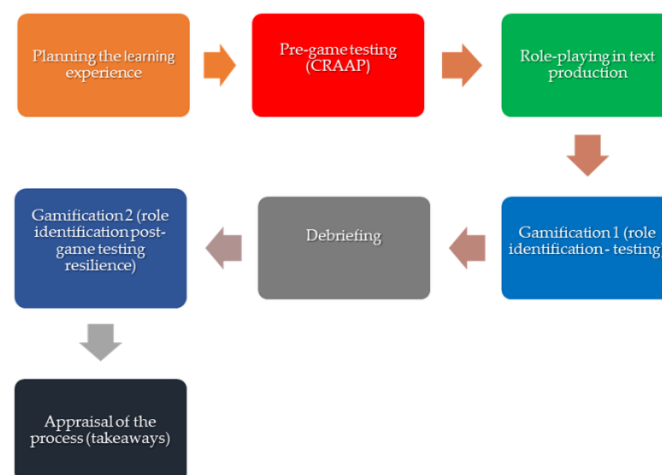

Figure 1. Learning experience design.

Fifty second-year students in communication studies from Politehnica University of Timisoara, Romania, took part in the experience. Measures were taken to ensure the participants' anonymity and voluntary participation. The median age of the sample was 21.9. Each of the three surveys (the CRAAP test, gamification 1 and gamification 2) contained four closed questions and four questions inviting for free comments. Students were invited to write testimonials and a template was provided, to steer them towards reflecting not only upon the experience (I liked/I did not enjoy the game), but also upon the lessons learned from participating in the activity.

While the CRAAP test was applied individually, using a real media piece of news, all subsequent activities were assigned as group work. The basic structure of the game is as follows: players are randomly divided into groups of four people. These groups are then randomly assigned one of four key roles, developed to reflect ways in which facts can be distorted and presented in a misleading manner. In the Roozenbeek and Van Der Linden's version of the game, the goal of each group is to produce a news article that reflects their character's unique goals motivations. The four characters are: (1) the denier, who strives to make a topic look small and insignificant, (2) the alarmist, who wants to make the topic look as large and problematic as possible, (3) the clickbait monger, whose goal is to get as many clicks (and by extension ad revenue) as possible, and lastly (4) the conspiracy theorist, who distrusts any kind of official mainstream narrative and wants their audience to follow suit. Each group is given a so-called 'source card' that explains the background of the article that the players are assigned to produce. In the version presented in this study, the teaching and research team felt that the text-production, while rich in information, is not sufficient for equipping future communication professionals with tools to detect deception and dismantle disinformation. The teaching and research team produced, based on factual information, four variants of a media message on the refugee topic, written in the key of the four roles: reductionist, who strives to make a topic look small and insignificant, alarmist, who wants to make the topic look as large and problematic as possible, sensationalist, in whose presentation the desire to stir awe is obvious, and conspirationist, who distrusts any kind of official narrative and wants their audience to detect hidden cues of dark motives. These four roles cover the most common and frequent disinformation tactics [29].

Understanding that interpretation lays in the eye of the beholder [33], students were invited to identify media frames and comment upon the issues that lead them match the texts produced for Gamification 1 and Gamification 2 with the roles of media producers, mentioned in the cards. The roles and the cards are presented in Figure 2 below.
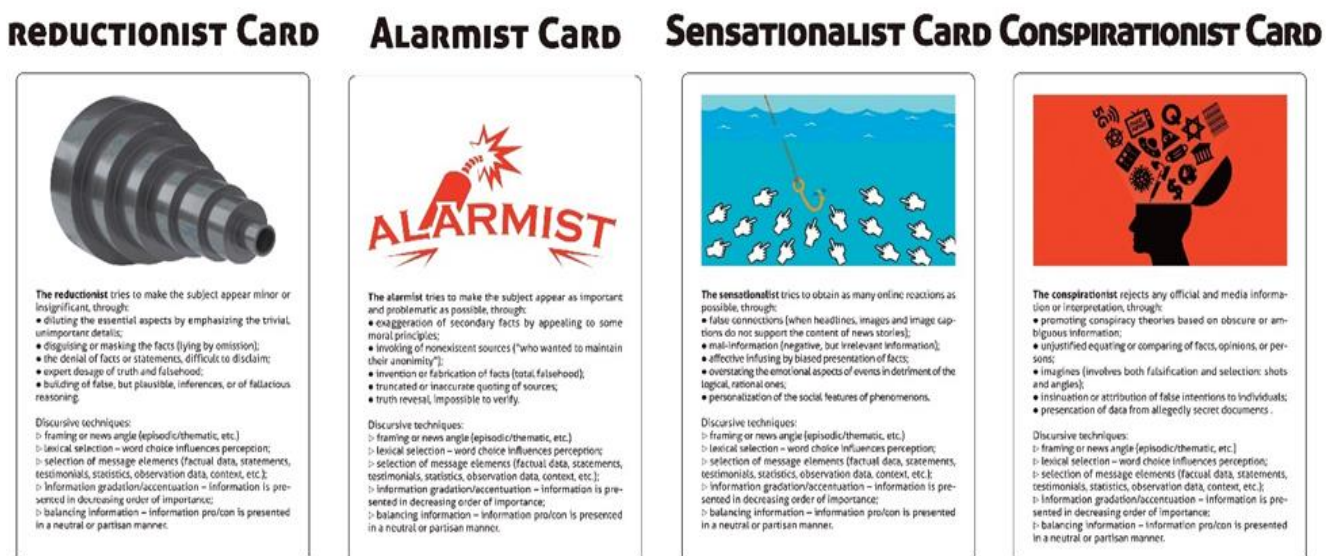

Figure 2. Role cards developed and used in the game.

The cards were available to students throughout the game, facilitating a deeper understanding of the meaning of each role. Students could verify their assumptions, check the items that identify each role and experiment with discursive techniques to produce and/or deconstruct media messages.

4. Game Playing and Results

The experiment was launched on 18 October 2021, with pre-game testing. Students were reminded that the CRAAP verification tool was a reliable fact-checking drill to deconstruct media messages, and a link to a real media story on the refugee crisis was provided via Isondaje.ro, accompanied by a set of closed questions regarding the Currency, Relevance, Authority, Accuracy and Purpose of the article (https://www.tion.ro/eveniment/perchezitii-la-timisoara-pentru-destructurarea-unei-retele-de-trafic-de-migranti-1505181/ last accessed 20 November 2021) and an invitation to provide the proofs in the media message that support their choices. The number of participants in the game ranged from 34 to 57, a core of 50 students fulfilling the greatest amount of the tasks. Fifty participants responded to the questionnaire, 93% of them offering correct answers. The test served both as a reminder of the MIL principles applied to interpret media, and as a nudge to deal with the subsequent tasks from the position of (future) professional communicators.

In the second step, students were given a fact sheet with data on the topic, and were invited to create media-like content, under one of the assigned roles (described in the cards, see Figure 2), in randomly created groups of four. In the post-mortem debate, students were invited to describe their collaborative strategies and reflect on the experience in the form of testimonials. The debate highlighted that a variety of strategies were adopted by the teams to solve the task, the most popular one being Zoom sessions (72% cases), followed by Whatsapp groups (13%) and Google docs (11%). The remaining responses up to 100% were inconclusive. Comments on the experience, posted individually by the participants on the special space allocated on the virtual campus platform led to 53 testimonials. The comment collection was used by the teaching and research team as a test validating the method, students being invited to respond whether the game experience is perceived as useful and meaningful, experience building or not and to express their willingness to continue the game or terminate it at that stage. All the respondents found the experience exciting and enriching, a novelty compared to the habitual academic experiences and declared readiness to repeat the game or move along similar proposals. The testimonials offered insights into the way students appraised: (a) teamwork, (b) experimenting with strategies aiming to manipulate audiences, (c) the importance of the style/framing for content production and editing and (d) the usefulness of critical thinking and issues to look for in understanding and deconstructing a media message. Table 1 below presents some of the most relevant examples, along the four criteria of appraisal.

The next stage of the experience, designated as Gamification 1 was launched on November 1st and proposed a fact sheet, followed by four versions of media articles, written in the key of the four exercised roles: reductionist, alarmist, sensationalist and conspirationalist. Students were asked to read the articles and decide what role corresponds to what message and offer examples from the text leading them to assigning the respective role. As a debriefing strategy, correct answers were presented and commented on by the teachers. The game ended with Gamification 2, launched on December 12, to test participants' resilience to fake news, their competence in deception detection and identification of the already drilled four roles. Once again, the teachers team proposed a fact sheet, followed by four versions of media articles, framed differently and written in the key of the four exercised roles: reductionist, alarmist, sensationalist and conspirationalist, on the same refugee crisis topic, but with new elements compared to the previous text. Results of student responses are presented comparatively in the table below:

Each article could be placed into one of the four categories, but respondents failed to notice that each had a single correct variant, which, once exhausted, was not repeated at

the next ones. Within each category, responses are calculated at 100%, the percentage in the table representing the proportion of correct answers for each variant of the articles.

Table 1. Student comments on the game-playing experience.

Teamwork	"Working with people is not easy, especially when the team is made up of different people and who inevitably have different views on certain aspects. But these differences of opinion can be constructive, so it is important to listen and communicate, so the relations between us are important too". "I have noticed that I like to coordinate a team. Also, work is much easier and more enjoyable when several people collaborate". "Overall, it was nice to be part of the team, although at the beginning we had to overcome small organizational obstacles; ultimately we were able to meet and bring the task to the end". "I learned that a team works well if there is collaboration, empathy, and good communication". "The game helped me realize that teamwork is easier than individual work, due to the fact that the tasks are divided, and you have someone to counsel with, so that the outcome is better (than in individual work)".
Experimenting with strategies aiming to manipulate audiences	"It was interesting, because I was not acquainted with these strategies until the time of the game, and the dynamic experience made me understand the issue much easier than during academic lectures". "Manipulation strategies have always been used, either to shed a positive light on a villain or to bury the career of others. Regardless of the subject, each communicator has his/her own principles, needs, and so on. It is not new for certain communicators to manipulate audiences against or towards something in a particular topic". "Given that you can control your audience through that article, it requires a series of strategies that can either capture attention in a positive sense (arouse curiosity) or misinform your audience about important news." "I learned many new things about the roles that a news story plays and (I understood how) to observe the manipulation".
The importance of the style/framing for content production and editing	"I have noticed that the style of writing is sometimes more important than the elements communicated in a material". "I noticed how much the style chosen for writing alters the result; I think we need to be much more careful, because by writing in the wrong register, our intentions may not be correctly understood". "The editorial style is a very important one, because it determines whether the audience perceives the information reported, in the way in which it should be understood". "The game made me aware that news can be written in many ways, and those who write it may have other intentions/agendas than those to present the truth as it is".
Issues to look for in understanding and deconstructing a media message	"The game helped me better understand what the competence of critical thinking means". "We learned how manipulation/disinformation can be dismantled". "It is very important to get to know ourselves first what criteria to check information to apply, before believing absolutely everything we see, hear or read". "In order to understand a news story well, you need to know how to pass it through certain filters, these being the critical grids".

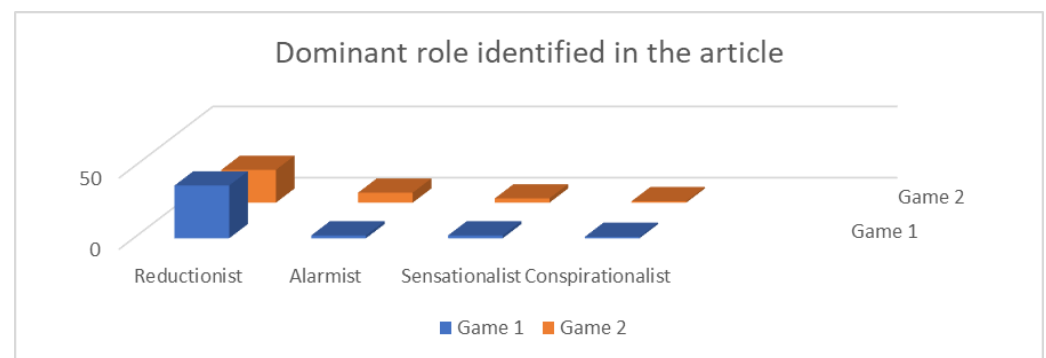To illustrate students' choices, the results for the reductionist role are presented in Figure 3 below.

Figure 3. Role identification (Gamification 1 vs. Gamification 2) for the reductionist variant.

The expected result was that students consolidated their capacity of correctly identifying the intentions behind the sets of articles. However, in Game 2 there was a drop in the correct responses for the reductionist variant, as seen in Table 2 and Figure 3. A similar situation is encountered for the conspirationalist variant. The second round of the game showed improvements only in the identification of the sensationalist and alarmist roles, but at lower rates by comparison to the other two roles.

Table 2. Comparison between the two stages of the game, identifying the role present in the article.

Role	Gamification 1 (% of Correct Responses)	Gamification 2 (% of Correct Responses)
sensationalist	31%	38.2%
reductionist	88.1%	67.6%
conspirationalist	76.2%	47.1%
alarmist	38.1%	47.1%

After allocating the roles to each article variant, students had to motivate their choices. Here are the dominant motivations:

- Title of the article;
- Lexical choices (selection of words by which articles induce a state of alert or, on the contrary, try to "anesthetize" the audience);
- Data manipulation—by exaggeration, falsification, (in)existing connections;
- Ambiguity in expressions.

Interesting to notice is the fact that in the analysis of the articles, the resource offered by the photo and the photo caption illustrating the text was not exploited at all, even though the 21st century students are perceived as highly sensitive to visual clues. The main confusion persisting in the participants' minds is between the alarmist and the sensationalist roles, present in both phases of the game.

In the debriefing discussion, students were presented the analysis of the results, the correct variants, and the activities they could follow, to consolidate and increase their critical thinking and resilience against fake news and disinformation.

5. Conclusions

Throughout the experiment, students were exposed to two main methods to interpret and/or produce media messages: media literacy interventions [32] and inoculation strategies [29], out of a larger repertoire of possibilities, amply discussed by Guan et al. [34]. Also, due to the difficulties encountered by students in the virtual environment for learning

purposes [8], the teaching and research team adopted a procedure described in the nudge theory [35], according to which the presence of a positive stimulus helps participants in the activity develop favorable attitudes, gain confidence and concentrate on task solving, rather than on memorizing theoretical issues. At all stages of the experience, pretesting, game-playing and post-game debriefing students had the verification criteria and grids, guiding them to understand and analyze, produce and deconstruct media messages.

Resonating with Roozenbeek and van der Linden's findings, we conclude that inoculation lessens in power and needs reinforcement, until the desired behavior is consolidated in the participants and becomes part of their way of reasoning. It was somewhat disheartening to understand that only some six weeks apart from having completed the task of interpreting the potential of fake news in offered examples participants actually did not encounter progress in combating misinformation. While the gaming experience stirred students' interest and enthusiasm, their resilience against fake news seems to need repeated and more complex efforts. As future professionals in the field of communication studies, participants in the educational experience confessed to encounter an "aha moment" when they saw that the same factual items can be spun and treated differently by the media, according to adopted styles, hidden agendas, bias or other, undetectable at first sight, criteria. In a (future) capacity of spokesperson, reputation counsellor or media monitor, students understood the importance of framing, the necessity to carefully chose the style in content production and the pressing issue of linking content distribution to some means of fact-checking mechanism (automated or not) to enhance the chance of fighting the proliferation of fake news in relation to their area of activity. These considerations became evident during the post-game debriefing, when participants, after voicing enthusiasm with role-playing and games, started reflecting on the core of the issue, namely the takeaways for their chosen profession. Serious game playing proves to be a powerful tool for educational purposes, but one-time playing (even throughout a semester) is not enough to consolidate the desired behavioral change. It definitely offered a variety in the context of remote emergency learning, where students confessed to suffer from Zoom-phobia after more than a year of isolation. The goal of helping re-build community ties in the group of participants, promised by the promoters of gamified education, was reached [28]. But the findings of this research resonate with the careful appraisal formulated by Dichev and Dicheva [25] that there are areas of uncertainty concerning the success of game playing in education not related to the process itself, but the consistency of skills development and cognitive acquisitions. It becomes clear from the findings that the effort to build resilience against fake news requires additional strategies and targeted interventions, in formal and informal settings, to equip the young generation with the much-needed critical thinking and genuine media literacy skills and ensure a sustainable education in communication studies.

The authors of this study recognize the limitations of the endeavor: the size of the sample does not offer enough ground for considering that the results can be extrapolated to the educational system. Also, the game should be repeated, to analyze whether the results replicate or not. Hence, it is to be treated as an exploratory study, a step towards developing practical roadmaps with concrete milestones towards reaching the goal of educating a media literate, resilient, competent generation of communicators, capable of identifying and fighting disinformation (in the traditional or in the new media alike) with communication tools.

Data Availability Statement: Data are available, upon request, from the corresponding author.

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Learning from Each Other—A Bibliometric Review of Research on Information Disorders

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Abstract: Interest in research connected to information disorders has grown considerably in recent years. The phrase "information disorders" refers to three different notions: dis-, mis-, and malinformation. It is difficult to pin down this new and dynamic phenomenon of informational disruption and to assess its impact on society. Therefore, we conducted a bibliometric analysis on the complexity of information disorders using the Web of Science Core Collection database from 1975 to June 2021. We analyzed 8964 papers with the goal to have an overall picture of the topic, clarify the knowledge framework of research in this field, examine the development dynamics, identify future research directions and increase the understanding of the research on information disorders. The following are our main findings: the number of publications, authors, and journals has increased; research on information disorders has earned considerable attention in multiple academic fields; there are more and more works written in collaboration by scholars from different parts and cultures of the world. This paper makes important contributions to the literature, not only by providing researchers and practitioners with a coherent and perceptible intellectual basis to find answers, but also by bringing valuable insights for further investigation and future research directions.

Keywords: information disorders; fake news; disinformation; misinformation; infodemic; bibliometric review

1. Introduction

With the development of contemporary social technology, we are witnessing a new phenomenon: global scale *information pollution*. Sometimes called *infollution* [1], one of the biggest challenges of our time is defined as the presence and spread of unwanted messages in human society, in large enough quantities to cause significant negative effects on human and social activities [2]. Other authors [3–5] refer to it as the contamination, with irrelevant, inaccurate, redundant, noisy, excessive, unsolicited and low-value information which distorts reality and prevents the process of understanding.

Information pollution can be of several types: direct manipulation, ideological manipulation, propaganda, fake news, online disinformation, conspiracy theories, psychological contamination, memes and memetic warfare, etc. According to Meel and Vishwakarma these "are not mutually exclusive but at the same time also have some heterogeneity that brings them under a specific category" [6] (p. 3).

Information pollution has affected both society and human nature itself. As Wang et al. [7] mentioned, the consequences of infollution include wasted time, physical health issues, informational stress or addiction problems. Yet the most devastating

consequences are represented by the *disruption of information* in digital communication environments: we live in the post-truth age, we are exposed to alternative facts and fake news, we suffer from distress caused by information overload [4,8,9]. It is clear that we live in an age of disruption whose direct and indirect impacts are difficult to quantify and, as Wardle [10] has observed, the long-term implications of disinformation campaigns are the most worrying.

Pollution of the information ecosystem is frequently associated either with disinformation or with the term "fake news". As Wardle and Derakhshan [5] have shown, it is a vague term, misused and "widely ab(used)" [11] that is not at all suitable to describe the extent of information sharing practices that result in nothing other than questionable or manipulative information. Thus, in order to capture this new reality, Wardle and Derakhshan [5] do not consider that the term "fake news" has a simple, widely accepted meaning, for at least two reasons: (1) it is inadequate to describe "the complexity of the information pollution phenomenon" and (2) it has been picked up by some politicians who use it to label media organizations that do not endorse them (the most conspicuous example being Donald Trump, who stated that CNN, *The New York Times* and other media outlets produce "fake news").

The authors of the already cited article [5] suggest using the term *information disorders* (ID) which refers simultaneously to three different notions: *"mis-information"* (false information, but which is not intended to cause harm), *"dis-information"* (false information intentionally spread in order to cause harm) and *"mal-information"* (genuine information that is manipulated in order to produce harm). The three types of ID can take different forms: satire or parody, misleading content, imposter content, fabricated content, false connection, false context and manipulated content [5] and "have their own actors, motivations and rhetoric", as Frau-Meigs [12] (p. 16) explains. There are also other terms that attempt to pin down this new informational disruption, the changes, even malformations the information ecosystem goes through nowadays as a result of the endless possibilities offered by technology: narrowcasting, viral autobots, like factories, algorithms that generate content, troll armies, computational propaganda, clickbait headlines, deep fakes, etc. [13,14].

The impact of information disorders is often downplayed despite the huge risks they entail. For instance, since the beginning of 2020, large amounts of disinformation regarding COVID-19 have been spread [15], including fake studies, phony-testing and ineffective prevention methods. Consequently, the World Health Organization on the 2nd of February 2020 has described this overabundance of information generated by the COVID-19 pandemic as the first massive *infodemic* spread both online and offline, which brings about significant health risks [16,17].

This phenomenon is clearly worrying, thus any discussion regarding information disruptions and their effects might start from the following questions:

- How many types of information disorders exist? Is there a taxonomy in scientific literature?
- What sources produce and spread information disorders? Who are the main actors in this field and what expertise do they have?
- How much of the digital content is organic and how much is distributed by bots?
- How do information disorders evolve over time? What common experiences and knowledge about information disorders exist on a global scale?
- Has the complexity of the problem been discussed/explored publicly?
- Which approaches could contribute to an informed and resilient society in a pandemic context?

Researching information disorders is a challenging task and any study has limitations. If Hansson et al. [15] identify six types of harmful information during the pandemic in Europe, Kapantai et al. [11] (p. 1) reported that, although there is rich scientific literature on diverse topics, it does not address ID in a unitary way. It only deals separately with its elements, with "no commonly agreed typology framework, specific categorization criteria". Basically, as Wardle and Derakhshan [5] have observed, ID is a research field that is too

complex. If some of its aspects could be described as low-level information pollution, others are sophisticated and deeply deceptive. Most of all, in the literature, we encountered varied definitions and dimensions of ID and its manifestations, which makes it difficult to understand the concept unequivocally [18]. That is reason enough to undertake a thorough analysis in order to identify the most interesting research directions of the concept of ID. In fact, as far as we know, there are no publications presenting the results of a literature analysis covering the breadth of the field of ID. We identified some papers that focus on general results on fake news in different areas, but they need to be updated and extended due to a significant increase in the number of recent publications. Therefore, our paper is focused on filling this gap.

The structure of the current paper is as follows: After the introduction and an overview of how ID topics are reflected in the literature from a bibliometric perspective, we describe the methodology, and in the Section 4 we analyze the data. The Section 5 discusses the results, provides limitations and suggestions for further research. Finally, at the end, we draw several conclusions.

2. Literature Review of Bibliometric Studies on Information Disorders

Bibliometric studies analyze scientific production from a quantitative perspective and it has become well known among researchers. It is considered a very good tool for analyzing the dynamics of science as it provides an overview of research trends in general or in a particular field [19]. At the moment, bibliometric indicators are the main elements that evaluate the quality of work and the effectiveness of scientific research, scholars, research teams, research institutions (universities or other organizations) and countries in general [20]. More specifically, bibliometric tools are used to study the flows of scientific publications, to rank the quality of work in a particular field, to assess the pace of development and to identify specialists, institutions and countries recognized worldwide for their contribution to the development of science by calculating the number of publications and citations. For example, networks of citations are built by taking into account citations. They can be interpreted in many ways: the degree of international collaboration between researchers can be determined, the "centrality" or "periphery" of a journal can be established, the trajectory over time of a certain journal can be tracked down, and so on. The analysis of citations can also help to establish the links between articles and based on them, thematic networks can be formed, links between disciplines and many others can be visualized [21].

The bibliometric analysis of ID has been less covered by scientific publications and the conversation surrounding fake news is still relatively centralized. Moreover, they do not look at ID globally, but choose either a research field (media and communication, politics, health, etc.) or just a topic (fake news, post-truth, propaganda, etc.). Sometimes, they are limited to only one database (Web of Science or Scopus), but they do not study in-depth co-citation, for example, or they do not perform science mapping. Therefore, previous bibliometric studies provide the foundation for understanding the ways bibliometrics might be applied to the evaluation of scientific output from the ID domain.

One of the first bibliometric studies on the effects of fake news and misinformation was carried out by Ha et al., who examined 142 journal articles. They focused on mapping development in scholarship on fake news and misinformation between 2008 and 2017, paying special attention to how the "surge in social media and mobile media use and the election of Donald Trump affected the research on misinformation and fake news" [22] (p. 2). The authors suggested more research was needed on other topics "to cover areas such as the responsibility in the information creation and dissemination process, identification of fake news or misinformation in different types of content, and practical strategies to use in real life" [22] (p. 22).

The study of Dalesandro et al. [23] was similar to the approach of Ha et al. [22] and consisted of mapping the fake news topic in the scientific literature based on 325 papers indexed in the Scopus database between 2005 and 2018. The authors assessed the scientific

production related to fake news to better understand this phenomenon and its causes and/or motivations and pointed out the fact that the theme was aligned with international policy (Brexit and Presidential Elections 2016 in the USA). They concluded that fake news was related to other themes such as social networks, misinformation, post-truth, informational competence, journalism and the internet, and there was a need to further explain the most common issues linked to this theme.

Park et al. [24] came to the same conclusion. They conducted a comprehensive study of 479 academic articles indexed in Web of Science (WoS) in the last 20 years on fake news and related concepts, such as truthiness, post-factuality and deep fakes. Based on their findings the authors developed a conceptual fake news framework classifying fake news into misinformation, disinformation, malinformation, and non-information. However, the authors explored only some of the topics from the large spectrum of information disorders and concluded that malinformation and non-information should be investigated more closely. Lee and Nah [25] also confirmed that the theme of misinformation became more critical to academia. Similar findings were reported in [26]. The authors empirically examined 103 peer-reviewed articles published between 2000 and 2018 on fake news. Their study focused more on content analysis of the field of journalism, and it took into consideration the United States more than any other country.

Alonso Garcia et al. focused on the impact of fake news on the scientific community. They took into consideration 640 scientific articles from WoS, excluding other types of documents. Their findings suggest that, although this is "a line of research whose assent is emerging at the same time is vertiginous" [27] (p. 14), there is a keen/intense need to "continue on a path that combines the eradication of the phenomenon, as well as education for the prevention of its consumption". In the same vein, the purpose of the research carried out by Wang [28] on 387 articles indexed in WoS was to identify the different forms of fake news and other related concepts and to explore the recent trends of research in this field. The author concluded that not all research on disinformation is related to the investigation of fake news. Some papers just discussed errors and disinformation in their fields of research. However, this study limited the publication year to 2019 and earlier.

Other studies have explored "how fake news is taking over social media and putting public health at risk" [29] (p. 143) and, more recently, the infodemic effects. Wang et al. [30] conducted a systematic literature review on 57 articles from different databases about the spread of health-related misinformation on social media. The authors argued that there have been fewer studies on misinformation about infectious disease or vaccination and a more targeted approach was needed on research topics such as psychological responses and social contexts where misinformation spread.

Between January–April 2020, Naeem et al. made a content analysis of 1225 COVID-19 fake news stories in English taken from fact checkers, myth-busters and COVID-19 dashboards. The authors concluded that the "COVID-19 infodemic is full of false claims, half-baked conspiracy theories and pseudoscientific therapies" [29] (p. 148). Therefore, researchers, scholars, scientists and journalists should "exercise their professional responsibility to help the general public identify fake news stories".

Along the same lines, Pool et al. carried out a bibliometric study in order to map the infodemic literature. After analyzing 414 records indexed in WoS published between 1993 and 2021, the authors proposed an infodemic research platform based on research nodes such as coronavirus (COVID, pandemic, disinformation, lockdown), post-truth, fake news, fact checking and social networks (Facebook, WhatsApp). However, one of the limits of this study was that it did not explore the "effective use of social media in the context of pandemics misinformation" [31] (p. 768).

More recently, Kapantai et al., conducted a systematic literature review on disinformation with a clear objective "to identify and define the various underlying content types in the information disorder ecosystem and organize them" [11] (p. 17). They proposed a unified typology framework for disinformation to be validated in the years to come. The authors reached a consensus, namely that ID was a complex, dynamic and broad research

field that had to be analyzed continuously and periodic research was necessary to update the literature.

Other authors made bibliometric reviews in conjunction with information disorders on topics such as propaganda or rumor. For example, the study of Chaudhari and Pawar [32] analyzed propaganda in social media and offered evidence that it was related with fake news, political astroturfing, terrorism or radicalization. Similar findings were reported earlier by Tal and Gordon [33] who argued that, although propaganda plays a very important role in our lives, it cannot be considered an autonomous field of research. Wang et al. [34] carried out a bibliometric analysis of 970 articles indexed in WoS between 1989–2019 and found that the research on rumor propagation dynamics was directly linked with online social networks, social media and Twitter.

What the authors of the current paper noticed is that the profile of scientific production related to this subject can be described as something recent given the few studies mentioned above. There is a need to further understand how the conversation surrounding information disorders is evolving and how its practice is changing, not only in politics or public health but also in other strategic domains, such as digital communication channels, the environmental field or education. To the best of our knowledge, this is the first bibliometric study that covers an extensive period from 1975 to present and thus provides a wider coverage.

3. Methodology

This study follows the guidelines set by Andres [21], Ball [20], Gutiérrez-Salcedo et al. [19], Oliveira et al. [35] and Grosseck et al. [36].

3.1. Methods and Tools

The main goal of this paper is to conduct a bibliometric analysis on information disorders research. In order to achieve this goal, we set four objectives:

- *Establishing a descriptive structure* through content analysis for documents, authors, journals, institutions and countries: Which authors are the most productive? What is the annual scientific publication growth? Which journal do scholars mostly publish in?
- *Determining the impact scientific publications have on generating new knowledge* through citation and co-citation analysis on publications, authors, journals, institutions and countries: Who are the most cited scientists and scholars? What is the academic performance of the ID theme in the WoS database? Is there a certain level of authors' contribution that follows a particular pattern?
- *Tracing collaboration patterns* through co-authorship analysis for authors, countries and institutions: Which countries collaborate in information disorders research? What is the specific contribution pattern of authors who researched this topic?
- *Identifying key research areas and emerging trends* through co-occurrence analysis: What is the conceptual structure of the research field? What are the most relevant topics in the research developed on ID? How has ID research progressed over the past 40 years?

In order to quantify scholarly communication, we worked with Biblioshiny (a bibliometric software package web-based on R language) and with VoSViewer to analyze and visualize the research status and trends in the field of ID. Both software programs are freely available online and effective in performing bibliometric research [37].

3.2. Sources and Data Collection

The documents were extracted from the Web of Science Core Collection which is considered one of the most important and comprehensive collections of scientific resources worldwide for detailed bibliometric analysis [38]. WoS gives researchers the opportunity to access and analyze information in order to form an opinion on the various research trends and models and the possibility to have an overview of the worldwide research phenomenon through a single platform and search sequence [39]. WoS has a complex structure and includes several indexing databases which differ according to the range of

subjects they cover. Hence, what makes WoS the most well-known and recognized scientific and research platform in the world is, on the one hand, the large volume of information it contains and, on the other hand, the ease and very short time in which correlations can be established between articles based on citations or other information on a given study topic.

The topics used as search criteria to retrieve papers in the field of ID are depicted in Table 1.

Table 1. Search criteria.

Criteria	Details
Database	Web of Science Core Collection
Citation Index	SCIE (Science Citation Index Expanded) and SSCI (Social Sciences Citation Index)
Topics	"disinformation", "dis-information", "misinformation", "mis-information", "malinformation", "mal-information", "fake news" and infodemic*
Time span	1975–June 2021
Document type	Articles, books, book chapters, proceedings papers, reviews
Language	Any language

We based our search on PRISMA guidelines [40]. As a result, on 6 June 2021, we extracted a total of 10,195 papers which were downloaded in a tab separator format. Figure 1 shows the refining process until the final set was obtained.
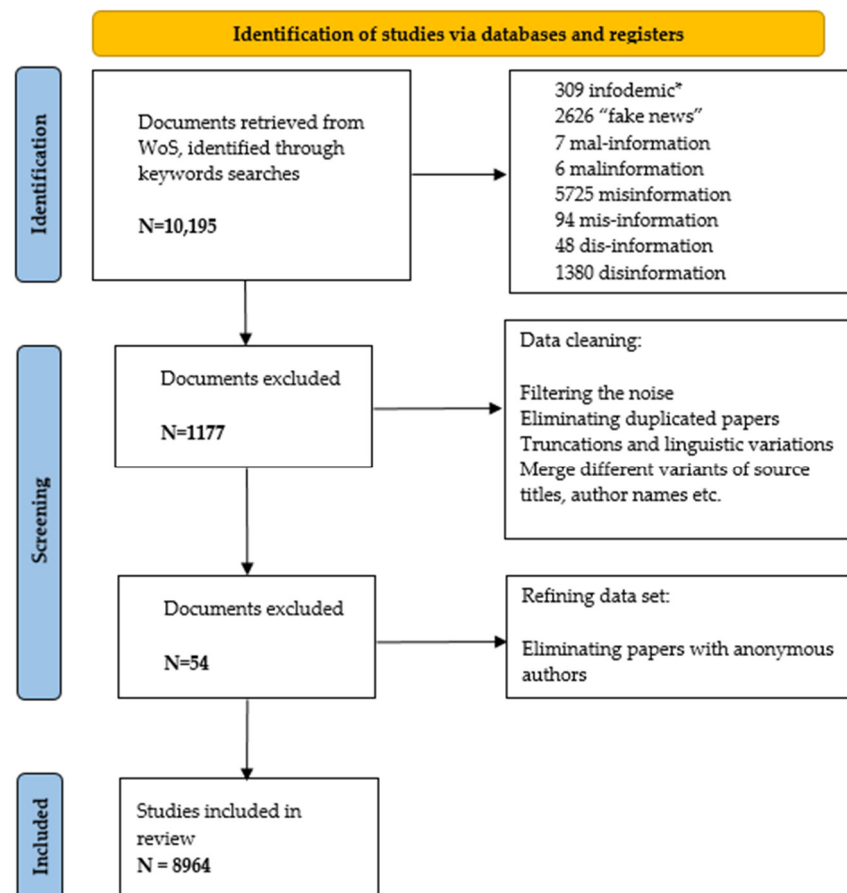

Figure 1. PRISMA guidelines.

The final data set consists of 8964 documents, which represents, as far as we know, the largest dataset for this type of analysis on information disorders.

4. Data Analysis and Results

4.1. Content Analysis—An Overview of the Collection

Content analysis uses the following terms (Figure 2):

- A document (or a citing document) is a scientific paper (article, review, conference proceeding, etc.) included in a bibliographic collection. In our collection, we have 8964 documents in 4108 sources (journals, books, etc.).
- A reference (or cited reference) refers to a scientific document included in at least one of the reference lists (bibliography) of the document set. Then a reference is cited by one or more documents. In our collection we have 239,719 references included in the 8964 documents.
- A cited document is a scientific document included in a bibliographic collection and, at the same time, it is cited in at least one other document of the collection. Cited documents belong both to the Document and the Reference set. We have 2283 cited documents.
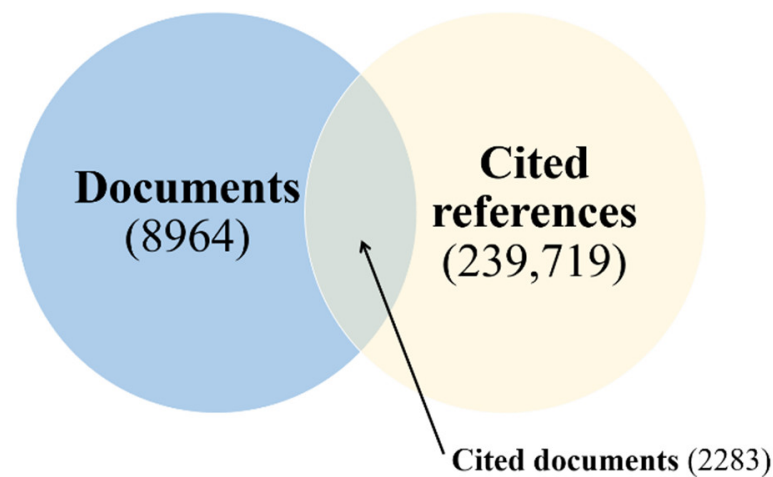

Figure 2. Cited documents.

4.1.1. Document Types

We retrieved 26 types of documents. The most frequent are the articles, including early access (5678) followed by proceedings papers (1211), editorial materials (660) and reviews (360). Other document types were letter (223), book review (177), meeting abstract (106) and news items (46). The remaining documents are present in a very small number. The majority of the papers (8299) are written in English. When it comes to other languages, the number of papers written in Spanish is 254, Portuguese (101), German (83), French (64) and other languages make up fewer than 50 papers (Russian—49, Italian—37, Turkish—22, etc.).

4.1.2. Papers in Different Subfields/Categories

Counting published documents is one of the several possible units of analysis. Categories and research areas are worth considering as well. The publications in WoS are included in more than 250 subject categories and are considered peer-reviewed literature (both traditional or open access). A paper can belong to several categories. The highest number (1053) is associated with the category Communication (11.74%) followed by Computer Science Information Systems (7.02%), Public Environmental Occupational Health (6.99%), Psychology Experimental (6.25%) and Computer Science Theory Methods (6.19%). Next, with a much smaller percentage, we found Information Science Library Science (4.63%), Computer Science Artificial Intelligence (4.19%), Political Science (4.06%), Engineering Electrical Electronic (3.83%) and Psychology Multidisciplinary (3.80%). The remaining WoS categories (such as Medicine General, Educational and Educational Research, Law, Social Sciences, etc.) have a share of under 3%.

WoS has 156 research areas, with each category being mapped to one research area. The five broad categories of research areas are Arts and Humanities, Life Sciences and Biomedicine, Physical Sciences and Social Sciences and Technology. The first ten research areas covered by our data set are Psychology (14.16%), Computer Science (14.14%), Communication (11.74%), Public Environmental Occupational Health (6.9%), Government Law (6.57%), Engineering (5.34%), Information Science Library Science (4.63%), Education Educational Research (3.79%), General Internal Medicine (3.77%) and Business Economics (3.55%).

4.1.3. The Annual Trends of ID-Related Publications

Research on ID can be placed in a timeframe that can be divided into three categories of scientific stories (Figure 3): initial stage (1975–2009), steady rise (2010–2016) and high growth (2017–present).
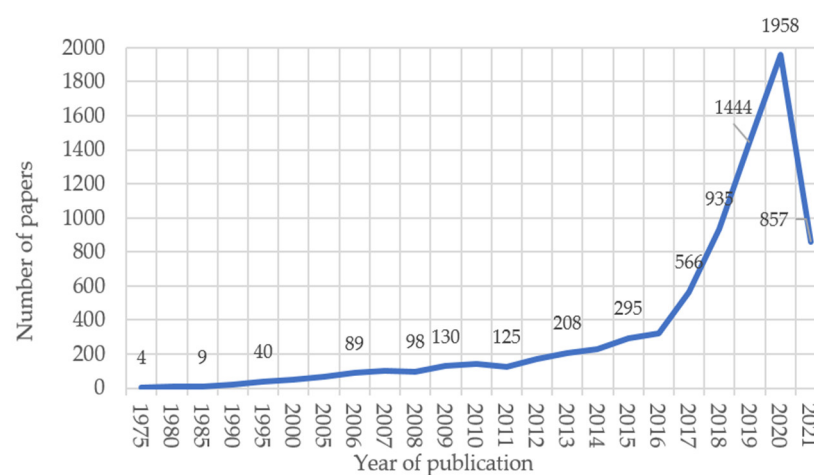

Figure 3. Temporal evolution of scientific productivity. Information disorders research papers published from 1975 to June 2021.

The growth of scientific production is exponential, with an annual growth rate of 12.38%.

4.1.4. Authorship

For the period 1975–June 2021 we identified 26,242 authors. The "top 10" authors published 321 papers (3.58%) in total and include the following scholars: Elizabeth Loftus (54 papers), Stephen Lewandowsky (40), Ullrich K. H. Ecker (35), Daniel Wright (26), Emily Vraga (25), Henry Otgaar (24), Garry M. (22), Hill J.A. (21), Paterson H.M. and Pennycook Gordon (19).

4.1.5. Keywords

Bibliometric analysis uses two types of words:

- Author Keywords are short informational structures which the authors use believing that they best represent the major concept of their works.
- Keywords Plus are sets of words that are automatically generated from an existing database and that we find in the titles of bibliographic references of the paper, sometimes without being present in the title or keywords established by the authors.

Comparing keywords plus and author keywords, Garfield and Sher [41] claimed that the first terms are able to grasp an article's content with greater depth and variety. As Zhang et al. [42] suggest, although keywords plus are important to investigate the knowledge structure of a scientific field they are "less comprehensive in representing an article's content".

There are 14,489 authors keywords and 7380 keywords plus. Word TreeMap representations (Figure 4) are useful for quickly spotting the most prominent terms and for locating a term alphabetically to determine its relative prominence. Most of all, de Bellis [43] says it reflects both the topic and the direction of writing articles in the field in a more concise and intuitive way.
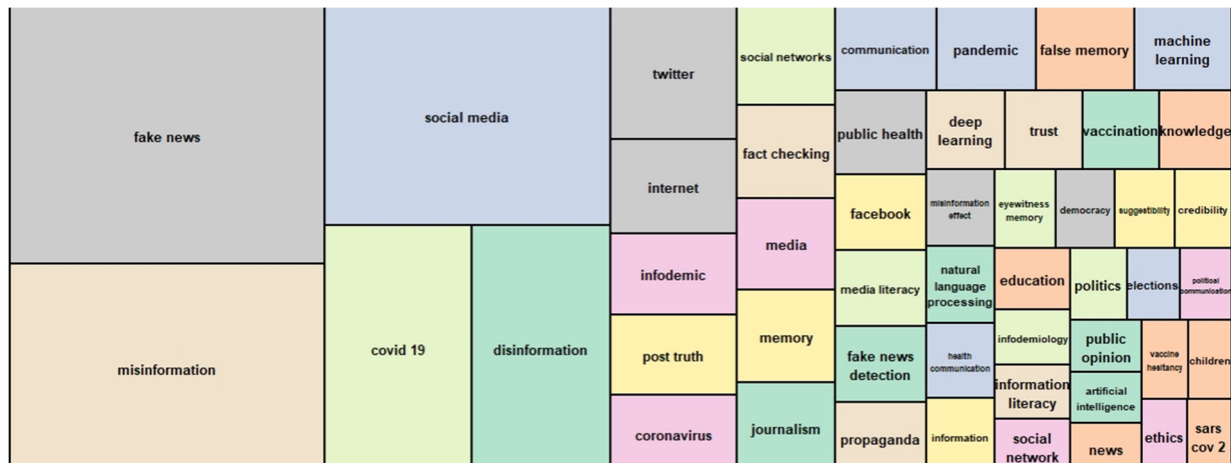
Figure 4. Word TreeMap of high-frequency authors keywords.

The top 20 authors keywords occurrences are fake news (1106 papers), misinformation (899), social media (852), COVID-19 (499), disinformation (467), Twitter (229), internet (164), infodemic (141), post truth (137), coronavirus (136), social networks (132), fact checking (125), media (123), memory (123), journalism (122), communication (116), pandemic (114), false memory (113), machine learning (112) and public health (103).

The dynamic of authors keywords is shown in Figure 5.

Figure 5. Dynamic of authors keywords in the information disorders literature.

4.1.6. Countries or Regional Distributions

We took into consideration the country where the authors work, which may be different from the country of birth or country of citizenship (Figure 6).

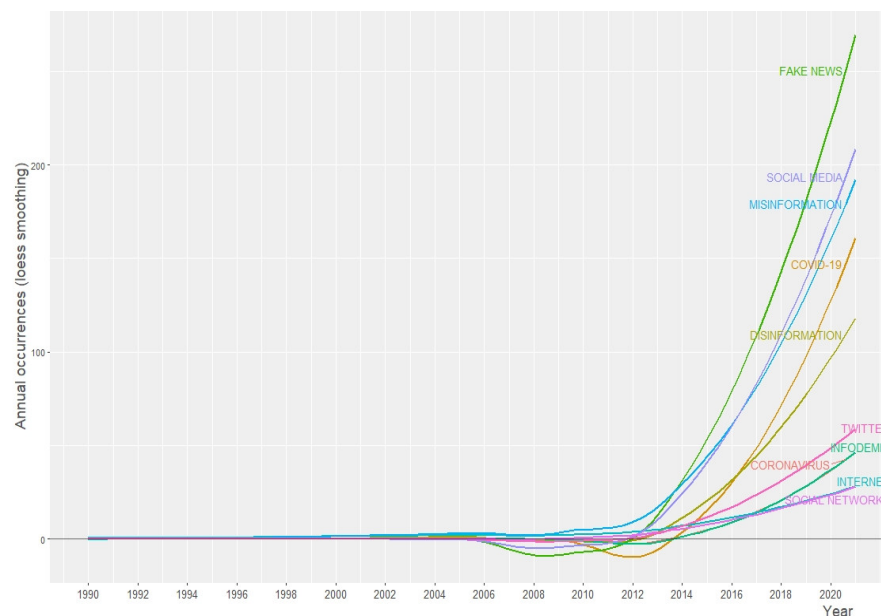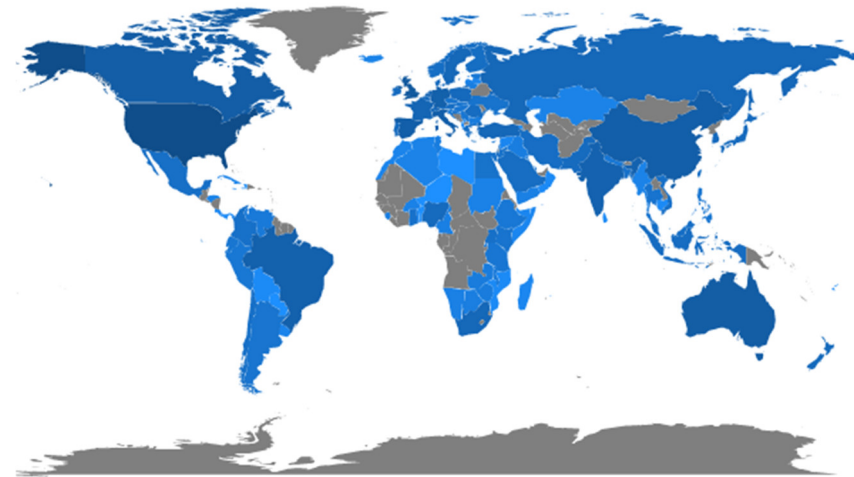**Figure 6.** Visibility of scientific production. Legend: The color intensity is proportional to the number of publications.

Out of 136 countries identified, the USA dominates the classification with 3670 papers, followed by England (819) and Australia with 525. In the top 10 most productive countries we can also find Canada (455 papers), Spain (416), China (363), Germany (361), Italy (342), Brazil (245) and India (224).

4.1.7. The Distribution of Institutions

Our data set includes 5368 institutions. The highest number of ID-related documents belongs to Harvard University with 134 papers. It is closely followed by the University of North Carolina with 118 papers and Oxford University with 108 papers. In the top 10 most productive affiliations of authors, we also find Michigan University (101), The University of Sydney (101), University of Pennsylvania (99), University of Toronto (96), Washington University (95), University California Irvine (84) and University of Illinois (81). The top 10 institutions amount to 11.34% of the total publications.

4.1.8. The Distribution of Sources of Publications

Scientific papers are usually included in journals, books or conference proceedings, which in addition to knowledge claims, offer relevant information on various aspects of the organization of research (such as authors, institutions, collaboration between groups of researchers, etc.). Therefore, the distributions of sources of publications can be a powerful tool of investigation at the crossroads between different analytic dimensions. The 8964 papers from our data set were published in 4108 sources. The first 20 publication sources comprised 950 papers.

To establish a quantitative relationship between the publication sources and the documents from the bibliography set, we took into consideration Andres' [21] advice to use Bradford's law (Figure 7).

Thus, we identified three journals as a "core" source: *Journal of Medical Internet Research* (887 papers), *Applied Cognitive Psychology* (119) and *PLoS ONE* (91). In the top 10 most productive journals we find *Memory* (75 papers), *Social Media + Society* (50), *International Journal of Communication* (48), *Media and Communication* (44), *International Journal of Environmental Research and Public Health* (43), *Profesional de la informacion* (40), *Proceedings of the National Academy of Sciences of the United States of America* (37), *American Journal of Public Health* (36), *Memory & Cognition* (36) and *New Media & Society* (35).
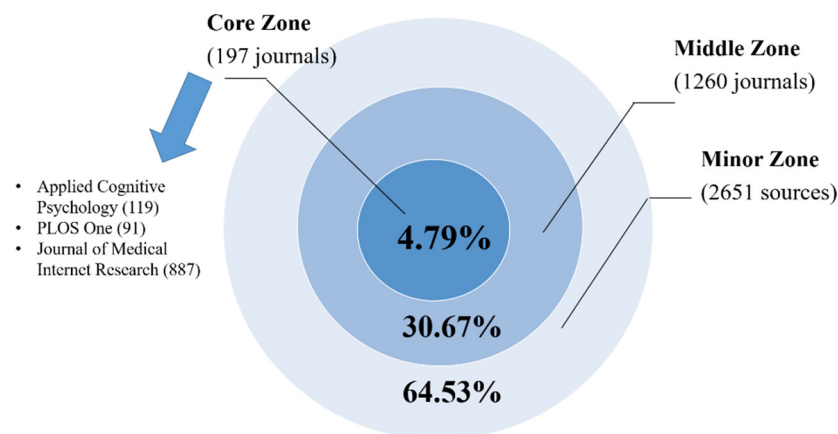
Figure 7. Bradford zones regarding the distribution of publishing sources productivity.

4.2. Conceptual Structure of Knowledge Analysis

The conceptual structure of knowledge refers to what sciences talk about, the main themes and trends, and it is based on relations among concepts or words in a set of publications. Aria and Cuccurullo [44] indicate it can be carried out on three levels:

- Co-occurrence analysis (sometimes called *co-words network*) to understand the *research front* (what topics and issues are the most important and recent, what is the evolution of research subjects over time and what are the trends).
- Factorial analysis (data reduction techniques) is helpful *in identifying subfields*. Aria and Cuccurullo [44] show that clustering algorithms can also be used in cases of both network and factorial analysis.
- Mixed approach. Starting from a conceptual network, one can identify thematic networks that plot on a bi-dimensional matrix, where axes are functions of centrality and density of the *thematic network*. Dividing the timespan in time slices, it is possible to represent the *thematic evolution* within a specific research field through an alluvial graph.

4.2.1. Co-Words Analysis

As de Bellis [43] stated, the best-known technique to detect associations of scientific concepts for delineating subject areas, growing subfields or disciplinary patterns is to run a co-word analysis. The analysis with VoSViewer revealed the most used terms by authors [45]. In the visualization featured in Figure 8 each term is represented by a bubble. Alonso Garcia et al. [27] explained that the size of a bubble is directly proportional to the number of publications which contain the term analyzed. Usually, terms co-occurring often tend to be located close to each other.

The highest frequency was clearly fake news (1999). Other topics studied in the literature were effect (1381), participant (1037), news (848), user (819), COVID (778), event (732), experiment (617), health (614), patient (594), pandemic (541), education (525), condition (520), accuracy (499), memory (494), network (489), attitude (477), population (470), child (456) and feature (448).

Cluster analysis is an additional method of co-word analysis to visualize the evolution of scientific fields and to reveal patterns, research hotspots and development trends in scientific discourse. This method measures the association strength between representative terms in documents. As depicted in Figure 8, the research front is condensed in four major clusters.
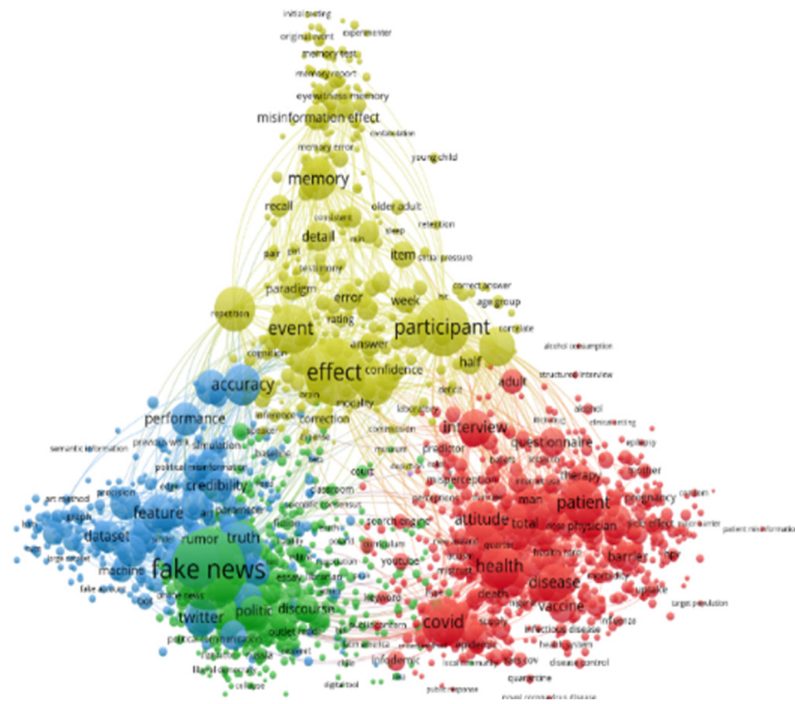
Figure 8. Map of key descriptors about information disorders (Of the 117,029 terms, 3228 meet the threshold (minimum number of occurrences of a term is 10).

- The green cluster is important throughout the entire period and it focuses on political research topics, with studies on how fake news is constructed and propagated in various electoral contexts or other approaches (climate change, for example) in the media, etc., especially with the help of new technologies. Moreover, in this cluster we find topics related to media education, the impact of fake news being even more worrying in countries where civic and media education are still weak.

- The blue cluster encompasses research on critical perspectives of technology and social networking as enablers of fake news, mis- and disinformation, and contains topics about the role online and digital technologies play in creating, promoting, detecting, tracking, signaling and combating fake content, about social media as disruption technologies for truth and trust, and about the major contribution of algorithms in amplifying the phenomenon.

- The yellow cluster is oriented more toward the cognitive processes involved in accepting, sharing and correcting false information. Mainly, we find topics about false memory, exposure to misleading content and their devastating effects on mental health.

- The red cluster includes specific topics related to the effects of disinformation on public health, especially in the context generated by the coronavirus pandemic, but also topics that address certain national contexts (Philippines, Saudi Arabia, South Africa, Thailand, Vietnam).

Figure 9 provides a temporal view of what has been studied over the years. For example, the lighter the yellow color, the newer, more recent the themes after 2016, such as propagation—especially through online networks such as Facebook and Twitter, source credibility and legitimacy, fact checking, US presidential elections (Donald Trump), civic engagement, media and information literacy, deep fake, natural language processing or how blockchain can help in assessing the news credibility and in building trust in news posted online, and also in preventing the spread of disinformation. In 2020, we have come across research topics such as those related to the pandemic caused by SARS-CoV-2 (COVID, coronavirus, outbreak, quarantine, infodemic, vaccine, etc.).
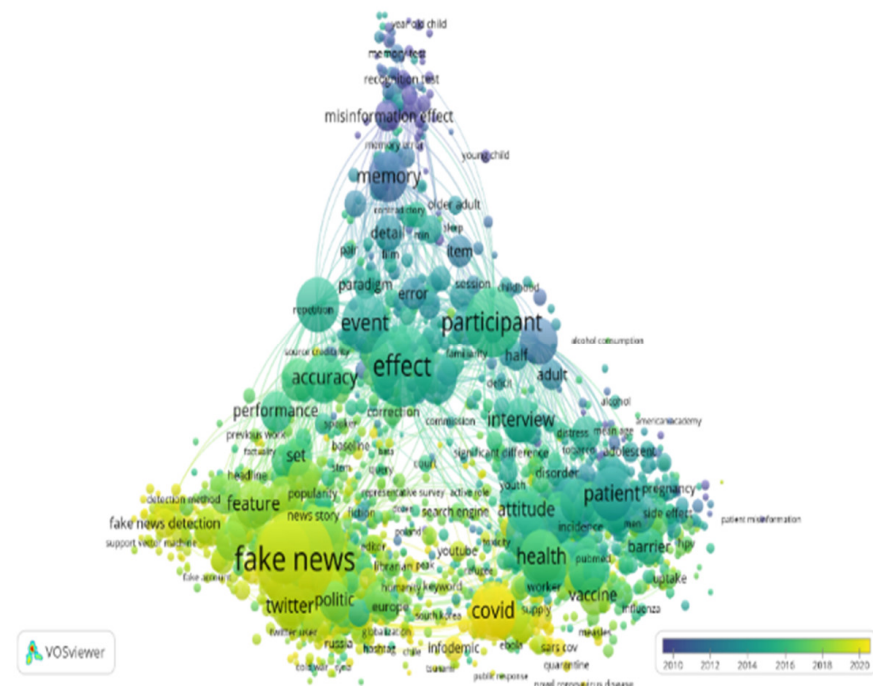
Figure 9. Overlay visualization of the scientific landscape.

4.2.2. Thematic Map

The thematic map is also used to highlight different themes and to depict hidden patterns. It is obtained by applying a clustering algorithm to the keywords network, with each cluster represented as a *strategic or thematic map*, a two-dimensional graph generated by Biblioshiny, according to their density and centrality:

- Centrality corresponds to the importance of the theme in the entire research field.
- Density depicts the degree of the theme's development.

By combining the high and low levels of density and centrality, the thematic mapping allows a visualization of four different typologies of themes (Figure 10):

- *Motor themes* (high/strong centrality and density): The driving force themes are reflected in the upper right quadrant.
- *Basic and transversal themes*: The lower right quadrant frames the fundamental and cross-cutting issues. Although significant, these themes are basic, general and transversal.
- *Emerging or declining issues* (low centrality and density): The topics are marginal and underdeveloped.
- *Highly developed and isolated themes*: These are marginal topics due to their highly specialized nature.

In order to understand how the ID area of research developed over time and to identify the evolutionary relationships, paths and trends, we relied on thematic evolution analysis. Such a representation of the data is useful because it can be applied to data that changes over time and helps us to better understand the flow conditions of different themes in the field. The analysis made by Biblioshiny is based on a Sankey diagram (Figure 11), a specific type of flow chart which is an important tool for visualizing energy and material flows.

4.3. Intellectual Structure of Knowledge Analysis

Citation analysis is an efficient way to study communication within the academic community, the structure of a science from an interdisciplinary point of view, as well as the mechanisms of creating new knowledge. We look at the most cited authors, documents, countries, journals and institutions.

Bibliometric analysis also makes use of citation networks based on the links between documents that cite and documents that are cited. Two documents are in a co-citation relationship when both are cited in a third document. Thus, when examined over time, co-citation analysis is helpful in detecting a shift in paradigms and schools of thought [20,21]. We looked at cited authors, references and journals.
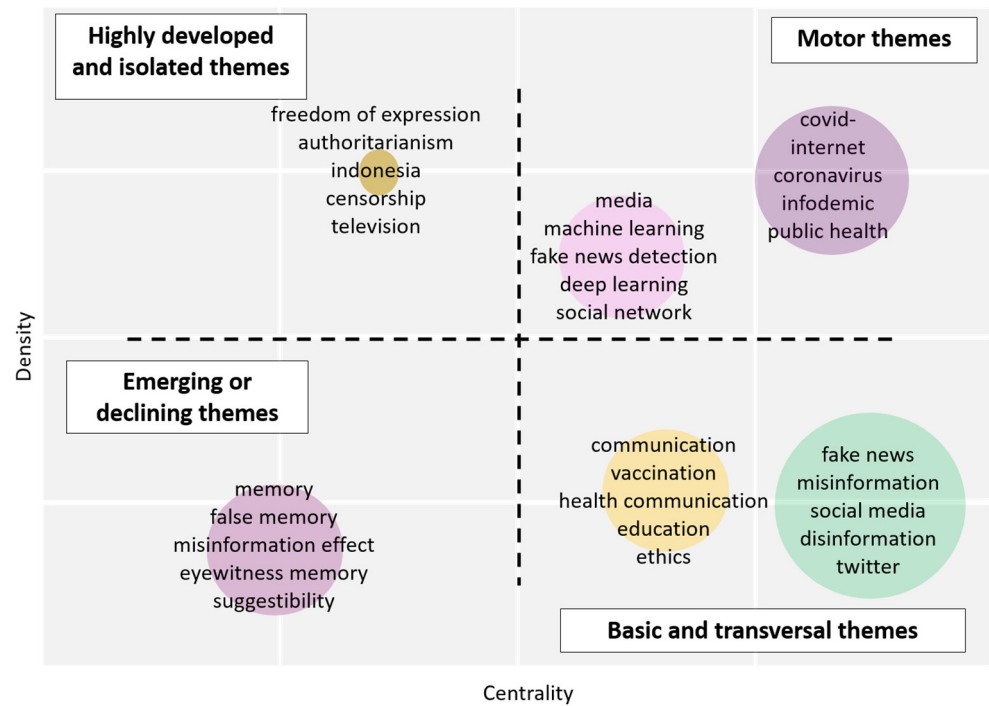
Figure 10. Strategic diagram depicting the performance of ID research themes. Legend: The volume of each bubble is proportional to the number of documents containing each keyword.
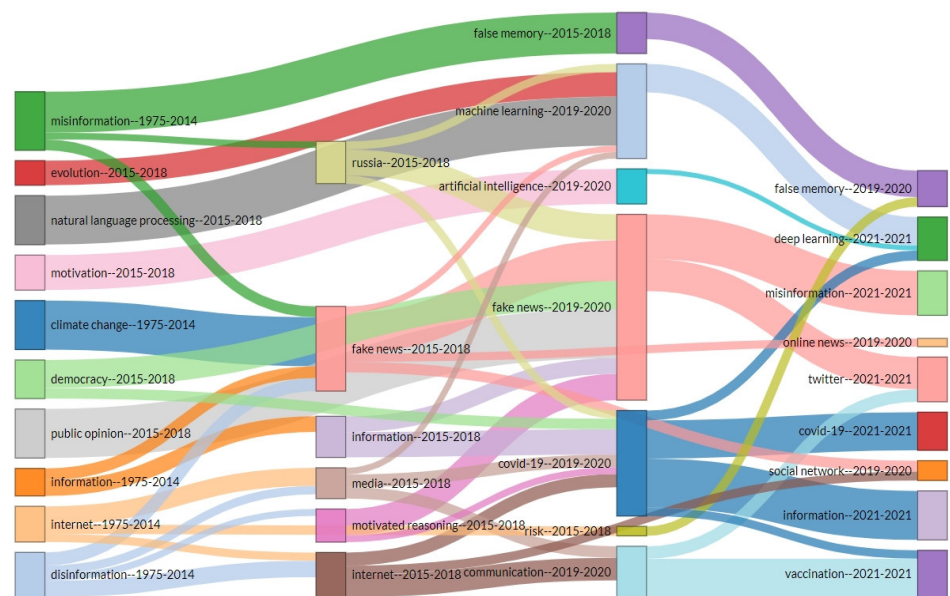
Figure 11. Thematic evolution of the ID research over time (1975–June 2021). Legend: node = topic; size = number of keywords included in the theme; colors = to distinguish different research themes; width = to indicate the number of shared keywords. The thicker the line, the higher the relevance of the two themes.

4.3.1. Citation Context Analysis

Global citations are used in order to identify *the highly cited papers*, to measure the number of citations a document received from documents in the entire database. Local citations are used to measure the number of citations a document received from the documents included in the analyzed collection.

Regarding direct citations corresponding to our dataset, WoS indicators point out that the 8964 publications were cited 98,681 times, 75,290 of them being bibliographic references, without counting self-citations. The number of papers citing these articles is 66,366, out of which 62,068 are articles without bibliographic self-citations. The average citations per item is 11, while the Hirsch index is 118.

Figure 12 shows that the average citations per item experience several fluctuations, but generally the trend is upward. The period between 2005–2010 is the research time slot with the biggest number of highly cited papers. The highest average citations per item reached 3.46 in 2010 (over a period of 11 years). However, the most citations were received by the 42 articles from 1997 (52.61%) with an average of 2.19 per article and the longest citation period (32 years) is detected in the articles from 1989.
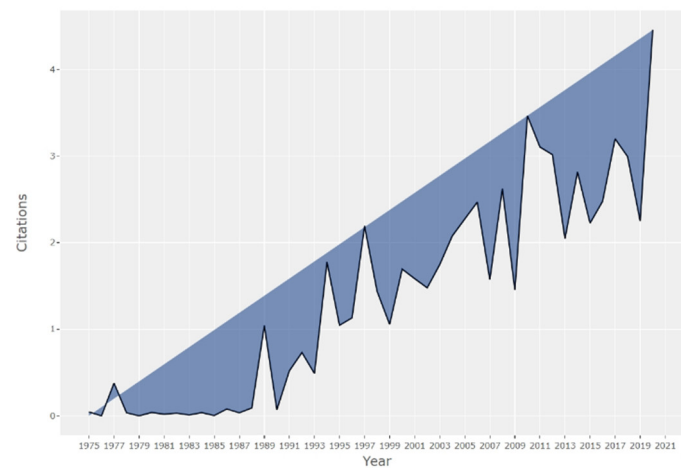
Figure 12. Citation dynamics. Average article citation per year.

The next logical step was to find who are the authors who contribute most to the advancement of ID knowledge and what are the most cited documents. The authors who have brought important contributions to the advancement of ID are included in Table 2. The most cited author is Brendan Nyhan, a professor of Political Sciences at Dartmouth College, USA, followed by Stephan Lewandowsky, a professor of Psychology at University of Bristol, Ulrich K. H. Ecker, a professor of Psychology at University of Western Australia, and the professor of Psychology, Elizabeth F. Loftus, from the University of California, Irvine.

Table 2. Top 10 most cited authors.

Author	h_Index	g_Index	Citations	Documents
Nyhan B.	12	18	2513	18
Lewandowsky S.	20	40	2510	40
Ecker U.K.H.	17	35	2031	35
Loftus E.F.	21	44	2012	54
Pennycook G.	9	19	1345	19
Quattrociocchi W.	13	18	1096	18
Wright D.B.	15	26	1023	26
Vraga E.K.	9	22	504	25
Garry M.	13	22	491	22
Bode L.	9	19	459	19

Table 3 identifies the highly cited papers as reported by Web of Science. The papers from the top 10 locally cited documents received 2739 citations, meaning 14.48% of the total number of local citations belong to the first ten most influential papers.

Table 3. Top 10 most local cited documents.

Document	DOI	LC	GC
Allcott H., 2017, J. Econ. Perspect.	10.1257/JEP.31.2.211	570	679
Lazer D.M.J., 2018, Science	10.1126/SCIENCE.AAO2998	387	648
Lewandowsky S., 2012, Psychol. Sci. Publ. Int.	10.1177/1529100612451018	377	771
Loftus E.F., 2005, Learn Memory	10.1101/LM.94705	282	601
Tandoc E.C., 2018, Digit. Journal	10.1080/21670811.2017.1360143	272	362
Nyhan B., 2010, Polit. Behav.	10.1007/S11109-010-9112-2	264	846
del Vicario M., 2016, P. Natl. Acad. SCI. USA	10.1073/PNAS.1517441113	193	480
Lewandowsky S., 2017, J. Appl. Res. Mem. Cogn.	NA	152	266
Johnson H.M., 1994, J. Exp. Psychol. Learn.	10.1037/0278-7393.20.6.1420	124	214
Kuklinski J.H., 2000, J. Polit.	10.1111/0022-3816.00033	118	337

Legend: LC = local citations; GC = global citations.

According to [43], citations do not simply link documents, they link ideas and arguments. Therefore, the citation analysis can be also used to quantify the impact of different actors, such as countries, universities, research institutions or journals, on the research stage and to monitor the variations of their performance over time.

Following are the top 10 most cited countries (the number of total citations is written in parentheses): USA (52,015—far ahead of the others), UK (9170), Canada (6274), Australia (5471), Italy (2675), Germany (2116), China (1745), Spain (1595), Netherlands (1571) and Israel (1110).

Table 4 shows the institutions with the best performances in terms of citations received by papers authored by people affiliated with them.

Table 4. Top 10 most cited institutions.

Organization	Documents	Citations
University of Michigan	75	5019
Harvard University	112	3806
The University of Western Australia	62	2635
University of Pennsylvania	68	2471
MIT	43	2310
NYU	62	2101
University of Toronto	69	1913
Yale University	50	1901
Stanford University	59	1769
Georgia State University	26	1733

In addition, Table 5 features the top 10 most cited journals (with high impact factor) attracting most researchers in search of high-quality papers.

Table 5. Top 10 impact sources.

Source	h_Index	g_Index	TC	NP	IF
Applied Cognitive Psychology	27	48	2725	119	2005
PLoS ONE	20	48	2424	91	3.24
Proceedings of the National Academy of Sciences of the USA	14	37	1393	37	11,205
Vaccine	14	29	1332	29	
Organic Geochemistry	1	1	1294	1	
Memory	21	33	1260	75	2.09

Table 5. *Cont.*

Source	h_Index	g_Index	TC	NP	IF
Journal of Medical Internet Research	16	33	1175	87	5428
Psychological Science	16	22	1141	22	
Memory & Cognition	19	33	1122	36	2272
Political Behavior	5	10	1092	10	

Legend: TC = total citations; NP = number of papers; IF = impact factor.

4.3.2. Co-Citation Analysis

The co-citation analysis allows us not only to draw the intellectual boundaries of the research field, but also to highlight its articulation into subareas and emerging research fronts and its connections with other specialties.

Figure 13 uncovers the relationships between authors in five clusters. In the visualization made by VoSViewer each circle represents a researcher. The larger the circle, the more publications meeting the analysis criteria were authored by these researchers. The closer the researchers are, the more strongly they are linked to each other.
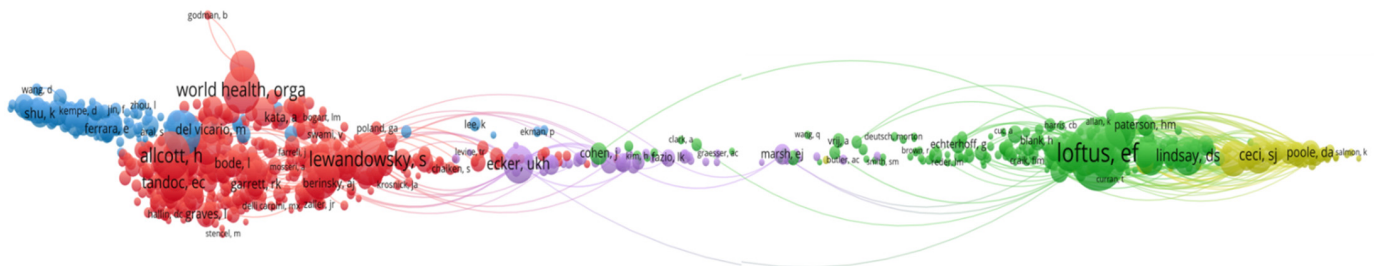

Figure 13. Co-citation networks of authors.

Of the 144,918 authors, 1568 meet the threshold, with a minimum number of citations of an author = 20.

The most influential authors prove to be Loftus (1750 citations), Lewandowsky (862 citations) and Allcott (750 citations), scholars whose works center on identifying information disorders and its most common form—fake news, including the ways in which fake news spreads and produces damage. In the top 10 co-cited authors follows the World Health Organization—WHO (701), Nyhan B. (681), Vosoughi S. (665), Pennycook G. (624), Roediger H.L. (557), Lindsay D.S. (526) and Ecker U.K.H. (487).

The next step was to identify the most influential papers by doing a co-citation analysis with VoSViewer on 239,719 valid references (751 met the threshold with a minimum number of 20 citations of a cited reference) (see Table 6).

Table 6. The top 10 most co-cited publications.

Cited Reference	Citations
Vosoughi S., 2018, Science, v359, p1146, doi 10.1126/science.aap9559	610
Allcott H., 2017, J. Econ. Perspect., v31, p211, doi 10.1257/jep.31.2.211	425
Lazer D.M.J., 2018, Science, v359, p1094, doi 10.1126/science.aao2998	425
Lewandowsky S., 2012, Psychol. Sci. Publ. Int., v13, p106, doi 10.1177/1529100612451018	405
Loftus E.F., 1978, J. Exp. Psychol.-Hum. l, v4, p19, doi 10.1037/0278-7393.4.1.19	317
Tandoc E.C., 2018, Digit. Journal, v6, p137, doi 10.1080/21670811.2017.1360143	310
Nyhan B., 2010, Polit. Behav., v32, p303, doi 10.1007/s11109-010-9112-2	286
Loftus E.F., 2005, Learn Memory, v12, p361, doi 10.1101/lm.94705	285
Johnson M.K., 1993, Psychol. Bull., v114, p3, doi 10.1037/0033-2909.114.1.3	276
Kai Shu, 2017, ACM Sigkdd Explorations Newsletter, v19, p22, doi 10.1145/3137597.3137600	246

The visualization of co-citation networks of publication sources is presented in Figure 14. Each circle represents either a journal, a book or a conference proceedings volume. The dimension of the circles is proportional to the number of papers citing the

corresponding publication. Based on co-citations, the closer they are, the stronger they are related.
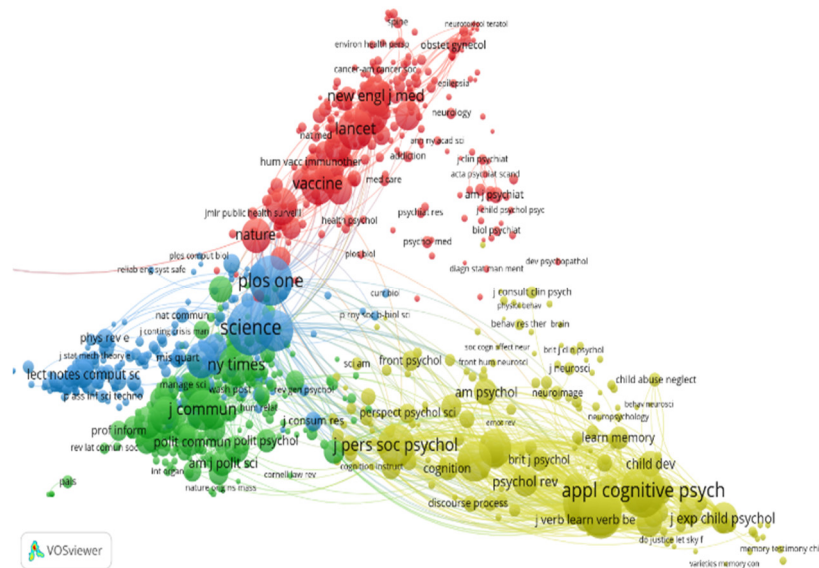
Figure 14. Co-citation networks of publication sources.

Of the 99,481 sources, 2004 meet the threshold, with a minimum of 20 citations of a source.

4.4. Social Structure of Knowledge Analysis
Co-Authorship and Collaboration Patterns

The most common kind of social structure is a co-authorship network. Gutiérrez-Salcedo et al. [19] stressed that co-authorship networks allow the discovery of groups of regular and influential authors, hidden communities of authors, relevant institutions in a specific research field, regional collaboration, research hotspots, etc. The map presented in Figure 15 shows the network of co-authorship links between authors of publications or those that have co-authored with them. Colors indicate clusters of authors that are quite strongly connected by co-authorship links.

Figure 15. Map of authors with collaborative links.

Collaborative patterns were analyzed for countries as well. In Figure 16, each node represents a country. There are connecting lines between the nodes, indicating that there is a cooperative relationship between the countries. The thicker the link between countries, the stronger the collaborative relationship and vice versa. The USA has an outstanding performance in international collaboration: UK–USA (179 papers), Canada–USA (119), USA–Australia (113), USA–China (112), UK–Australia (90), USA–Germany (65) and USA–Italy (58).
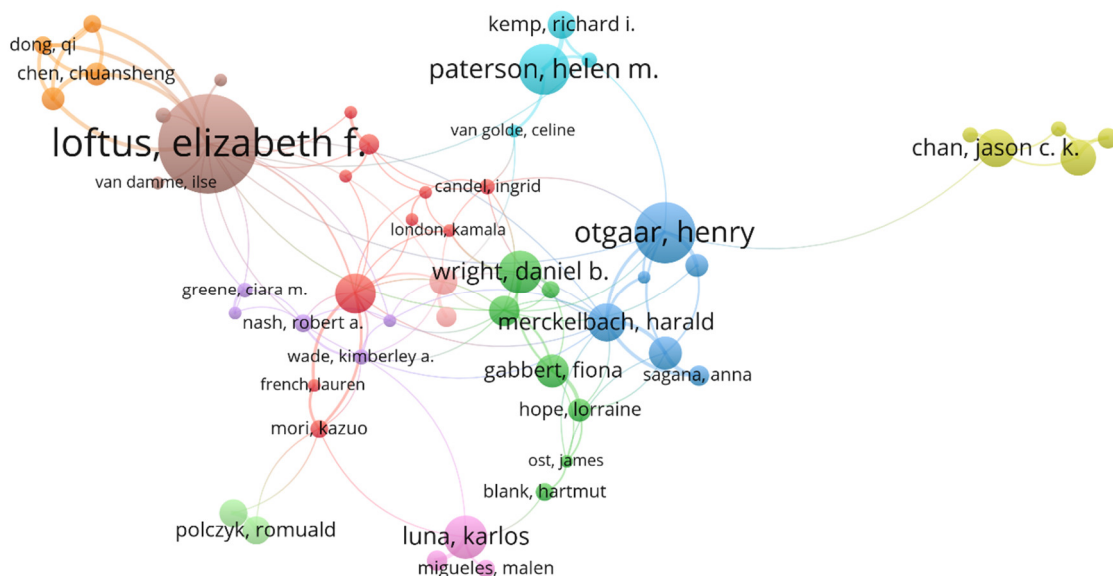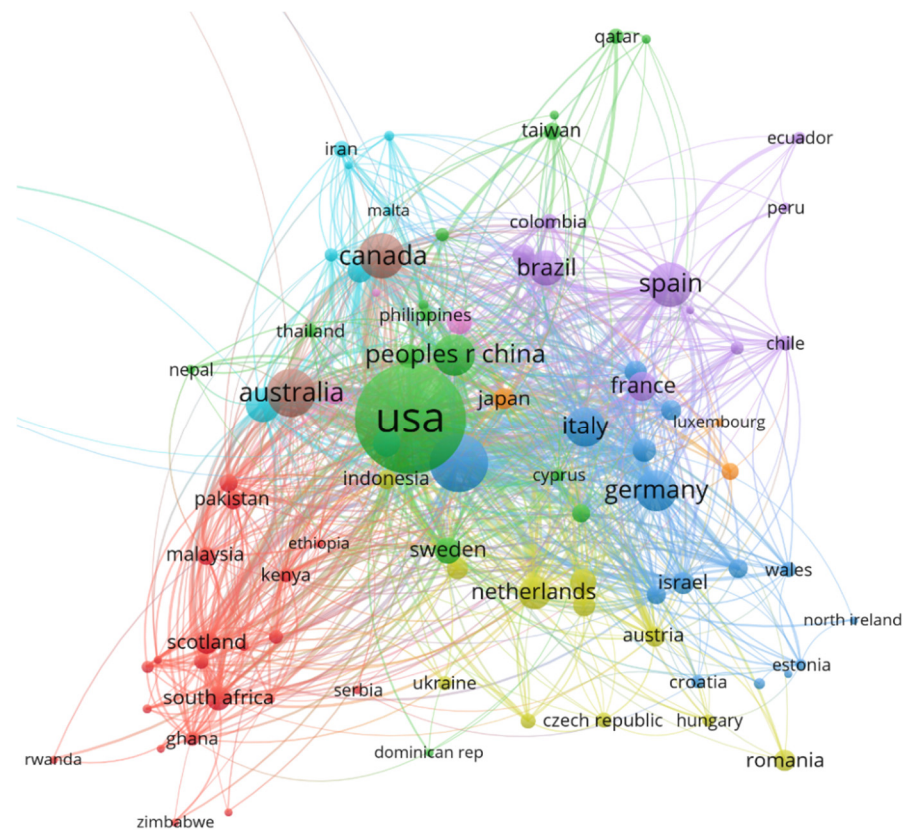

Figure 16. The dynamics of international collaboration between countries in the field of ID.

And regarding the corresponding author, the ranking is approximately the same (Table 7).

Table 7. Most relevant countries by corresponding author.

Country	Articles	Freq	SCP	MCP	MCP_Ratio
USA	3235	0.38724	2691	544	0.1682
United Kingdom	669	0.080081	447	222	0.3318
Australia	378	0.045248	266	112	0.2963
Spain	356	0.042614	302	54	0.1517
Canada	346	0.041417	245	101	0.2919
Germany	269	0.0322	193	76	0.2825
China	260	0.031123	156	104	0.4
Italy	250	0.029926	183	67	0.268
Brazil	209	0.025018	186	23	0.11
India	186	0.022265	158	28	0.1505

Legend: MPC = multiple country publications; SCP = single country publication. MPC indicates for each country the number of documents in which there is at least one co-author from a different country. MCP measures the international collaboration intensity of a country.

Concerning the collaboration between institutions, Figure 17 shows that regional cooperation predominates. Nevertheless, global international collaboration seems not to be missing either.

Figure 17. The institution co-authorship. (**a**) North American universities; (**b**) universities in the Asian and Oceanian space.

5. Discussions

The current study focused on providing answers to the following questions: What are the main areas and themes, the most current a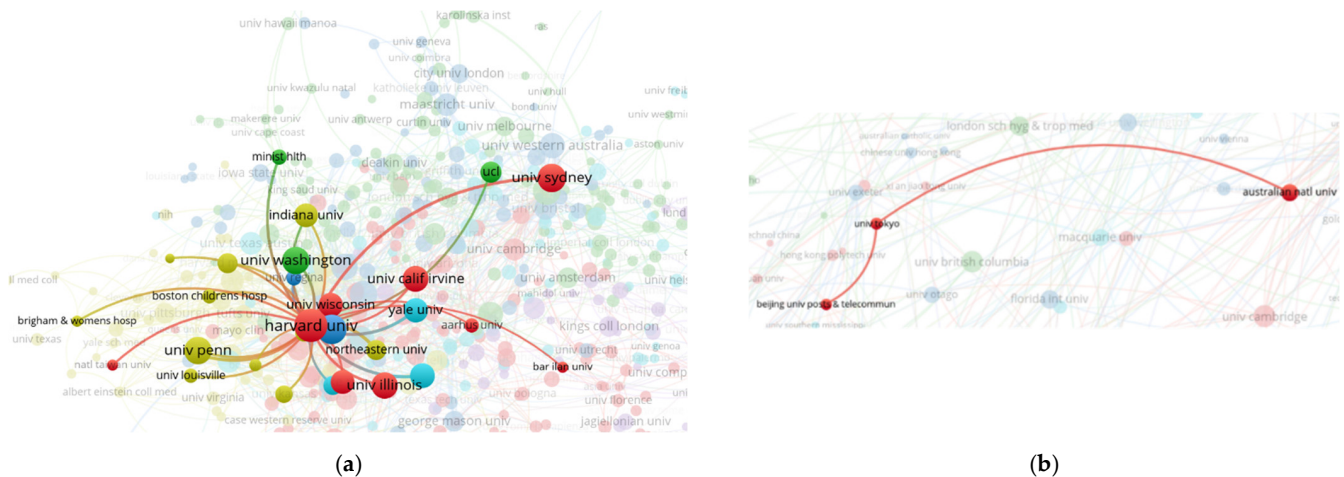nd "trending" topics in the ID field? What are the most cited works and authors? Which are the most influential scientific journals? Which human communities (institutions, regions, groups of countries) have the biggest influence on the development of this field? How does interest in certain scientific results evolve over time? As we have shown in the previous section, we retrieved some interesting results. In what follows, we will present our findings associated with the four research objectives.

5.1. Content Analysis

First, we looked at the document growth, counting the number of documents on ID in each year, in order to grasp the trend of scholars' attention on the domain as a whole. The analysis of document types indicated that journal articles constituted the most important channel for formal scientific communication, approximately 63% of the total number of documents, although proceedings papers (13%) also played an important role. The proportion of other types of documents (editorial materials, reviews, etc.) was much smaller. The majority of the papers (92.5%) were written in English, which reinforced what Hallinger and Chatpinyakoop found, namely that "the coverage of documents in other languages remains quite uneven" [36] (p. 5).

We chose not to focus on a single descriptor (e.g., fake news) because, as mentioned earlier, discussions about today's information ecosystem should cover more comprehensive concepts, such as disinformation, digital misinformation, malinformation, information pollution and even informational pathologies (see Table 1). Basically, we are dealing with a multitude of concepts which, as EU expert Alina Bârgăoanu [14] said, starts from relatively innocent forms of misinformation but also includes hostile propaganda from state or non-state actors with economic, political or geopolitical interests. This wide range covers lies, rumors, propaganda, manipulation, conspiracy theories, sensational or contextual information, but also almost fake or almost true news (the most dangerous type because it is difficult to distinguish between them). As a result, our work differs from and complements previous bibliometric studies.

Then we analyzed the categories and domains in which papers were included in WoS from the point of view of their value and contribution to the development of the field. We

found that research related to ID entailed great efforts on the part of professionals from various scientific areas and disciplines, such as Communication, Computer Science Information Systems, Public Environmental Occupational Health or Psychology Experimental.

It should also be mentioned that a paper can be recorded in more than one research field, with many papers being interdisciplinary. ID research practically brings contributions to all scientific fields, which opens up new paths of integrative research. In truth, ID is too complex to be fully covered by accessing a single research domain.

The next step was to see how the academic conversation evolves over time and concerns publications directly related to the ID, such as documents where the terms disinformation or fake news appeared as the publication topic or as part of the title. Based on the annual trends of ID related publications analysis, we divided the evolution of research into three stages (Figure 3):

- From 1975 to 2009, the initial stage, with a low-production exploration period of over 35 years. An early stage with slight fluctuations in the number of publications, amounting to less than 100 per year. Abu Arquob et al. [26] reported that prior to the 2000s, few studies in this field were conducted (an increase in scholarly attention to the topic can be seen after the 2000s). Starting in the 1970s, authors have explored misinformation and disinformation [46], and have written about how "even after misinformation is corrected, false beliefs can still persist" [47], how "people are more likely to accept misinformation as fact if it's easy to hear or read" [48] or about how people can be influenced by information after an event has happened, and the nature of false memories [49].

- Between 2010 and 2016, we are in a stage of rapid development. Starting with the year 2011, a rapid increase can be noticed in the number of publications. Papers are usually oriented towards spotting trends and phenomena related to the impact of fake news, such as anti-intellectualism, antiscience or agnotology [50]. According to Jankowski [51], works from this period generally focus on a particular type of ID and Abu Arquob et al. agrees that they "do not generally reflect the theoretical grounding expected from academic research" [26] (p. 6). We should also note that the proliferation of the ID phenomenon that has led to the increase in the number of publications and research related to ID since 2010 is closely related to the affordances of social media platforms, the most popular being launched around this year: Facebook (2004), YouTube (2005), Twitter (2006), WhatsApp (2009). In this period, one can see underlined the paradox of trust, where the crisis of confidence in governments, politicians, journalists, scientists and experts is riposted by trust in anonymous messages on social media platforms. If in the early years of web 2.0 and social media the technology was saluted for its potential for innovation, positive change and democratization of information within the social world, this optimism slowly collapsed into exhaustion and suspicion of online discourse and business practices on social media platforms.

- From 2017 to present we are talking about an explosive period. The literature volume is abundant, it increased sharply and attracted the attention of scholars from various countries, reaching 1958 papers in 2020 compared to 141 in 2010, with a burst in publications in the pandemic year of 2020. The year 2016 marked the publication of the first scientific research on the role of digital technologies in important recent and very recent events, such as the Arab Spring, the crisis in the Ukraine, Brexit, the popularity of Donald Trump, the war in Syria, etc. Most such research relates to digital disinformation or fake news. In fact, Jankowski [51] suggests that fake news has become a serious topic for empirical research after 2016, when public discourse tried to make sense of Brexit and the US presidential campaign. Moveover, after 2016, more studies on the psychological aspects of disinformation were published. In fact, in a meta-analysis, Chan et al. [52] singled out almost 7000 studies focusing on these aspects.

For the future, we can expect the production of literature on ID to grow constantly, as we are witnesses to a significant development in a range of disciplines: history, media and communication, education, psychology, philosophy, health, economics, environment, etc.

Between 1975 and June 2021, contributions to research were made by 26,242 authors, 2380 of whom are authors of single-authored documents and 18,255 are authors of multi-authored documents, which means 0.418 documents per author and 2.39 authors per document. Psychology professor Elizabeth Loftus from the University of California, Irvine, specialized in cognitive psychology, human memory, psychology and law and is the author with the most publications. Since the mid-1970s, Professor Loftus has conducted a series of innovative research on how semantic memory works, focusing on relatively unknown theories, investigating how complex memories change, how discoveries can be applied in the legal system and striving to understand the circumstances in which an honest eyewitness may have misidentified an innocent defendant.

At the same time, each author from the top 10 most productive authors developed and conducted research on different aspects of ID. For instance, Australian researchers Stephan Lewandowsky and Ullrich Ecker wrote about the way in which some "misinformation" "sticks" in the public consciousness, about how people continue to believe untrue things, even after it turns out they were lies, about conspiracy theories and how to avoid being fooled by the media and about the worrying effects that fake news can have on democracy [8,53].

Going further to find out the productivity of authors on the scientific subject of ID, we used Lotka's law (Figure 18). Alfred Lotka observed that there is a "small group of experts that carry out a greater scientific production and the rest of them make only a minimal contribution to the field of knowledge in question" [21] (p. 23).
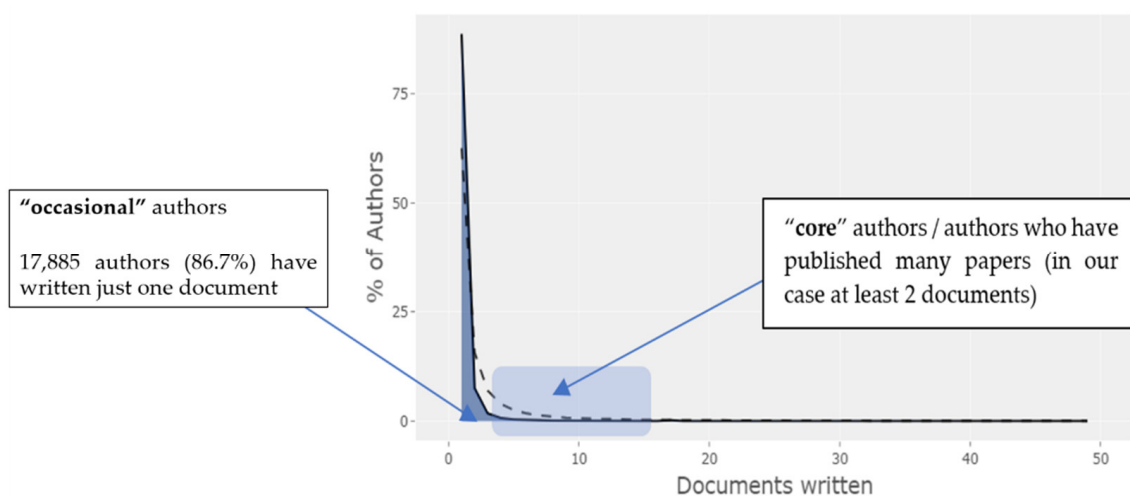
Figure 18. The frequency distribution of scientific productivity.

Results from the authors who contribute most to the development of the research in the field of ID are presented in Figure 19.

Fake news and disinformation are topics that have been covered a lot in recent years. They are not a new phenomenon, but specific to the times we live in is that this phenomenon now has the means to spread instantly to a huge number of people through social networks and social media applications. Hence, the concept has become a challenge for researchers all over the world who are trying to identify, fight, fact check and reduce the negative effects of disinformation and fake news at individual and social levels.

The co-word analysis is an indicator of the different poles of interests that shape the structure and the dynamics of a research field [43]. Figure 4 presents a synthesis of research topics in the ID spectrum such as fake news, disinformation, manipulation, but also other forms of influencing public opinion (persuasion, propaganda, etc.) in various fields

ranging from politics, economics, medicine, public health and journalism, to education or science. Current topics such as the infodemic generated by the COVID-19 pandemic are also present. With the rapid development of technologies and the diversification of mass communication and of data transmission channels, we are witnessing the magnitude and development of the phenomenon. Therefore, researchers have the responsibility to keep exploring, investigating, analyzing and debating the issues typical of this vast, constantly developing field.
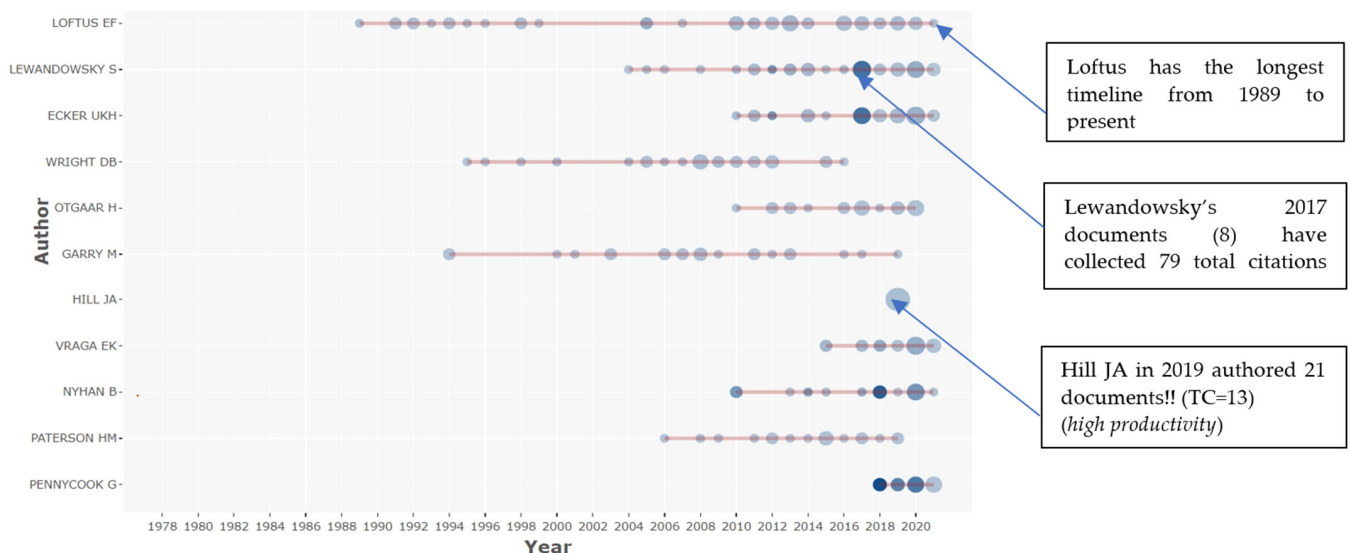

Figure 19. Top authors production over time. Legend: line = authors' timeline; bubble size = number of documents per year; color intensity = total citations per year. The first bubble on a line shows when an author began to publish in the field. A big bubble indicates a big number of articles published per year. The darker the color, the higher the number of citations [54].

The co-occurrence of author keywords demonstrates a substantial diversity and a significant variety of published ID literature. In Figure 5 we see a sustained increase in research on distorted narratives, misleading interpretations, the negative influence of false content on human behavior, the effects of exposure to fake news about COVID-19 on social media, how digital platforms combat misinformation, etc.

According to de Bellis [43], scientific production is an important indicator of the degree of a country's development and reflects its influence in the field of research. There is no doubt that the impact of research from the USA, England and Australia is the most significant, since it accounts for 56% of the total papers. As we can see in Figure 6, the study of ID has a greater impact on countries where elections were organized (USA, UK, Brazil), natural disasters occurred (Katrina in the USA, the fires in Australia, etc.) or those which are targets of Russian or Chinese disinformation attempts. On the other hand, it is not surprising that in this top 10 we find countries such as China, Brazil or India, knowing that they are countries where, in recent years, fake news and disinformation have spread rapidly, with the highest number of rumors and conspiracy theories [6,55]. For example, Guo [56], exploring the spread of online rumors in China where the media environment is tightly controlled by the government, demonstrated that the government institutions also advanced some rumors themselves and contributed to the perpetration of misinformation in a coordinated effort to control the narrative.

In India, the spread of fake news occurred in relation to political (e.g., Citizenship Amendment Act 2019, general elections) and religious matters (e.g., Delhi religious riots) and has been a particular problem during the coronavirus pandemic [57], contributing to the epidemiological explosion in the country. According to WHO, in July 2021, India is the country that reports the most cases of COVID-19 infection after the USA [58]. Misinformation and disinformation related to Pakistan and Kashmir is also widely prevalent [59,60].

Brazil, a country that has a culture of communication via WhatsApp, witnessed the distribution of false information through this messaging service that protects private conversations. In fact, according to Alves et al. [61], WhatsApp has become an ideal platform for disinformation particularly during the 2018 presidential election, when far-right candidate Jair Bolsonaro was accused of benefiting from an undemocratic "industry" of fake news in his attempt to become president of the country. During the pandemic the situation worsened and [62] reported that "digital media, especially social networks, become a breeding ground for fake news, political attacks and large-scale misinformation".

According to our data, the most active institution is Harvard University, with 134 papers published by affiliated authors. The top only includes North American institutions, with very few exceptions (The University of Sydney and Oxford University). It should be noted that Harvard University runs a special program to tackle disinformation through the Berkman Klein Center for Internet & Society and housed until 2019 the organization First Draft, "the world's foremost nonprofit focused on research and practice to address mis- and disinformation" [63].

From our dataset, 950 papers (10.6%) featured in the top 20 highly productive and visible specialized journals: *Applied Cognitive Psychology*, *PLoS ONE* or *Journal of Medical Internet Research*. The vast majority of top 10 publications have a high impact factor and offer open access publication, which is considered the best way to improve knowledge flow and to increase research impact (the probability of being cited).

On the other hand, as we can see in Figure 20, among the mainstream journals the most dynamic is the *Journal of Medical Internet Research* (JMIR), the pandemic creating a fertile ground for disinformation, especially in matters of public health. Thus, there was an increase to 45 papers published in JMIR in 2020 and 22 papers in 2021 (up to date).
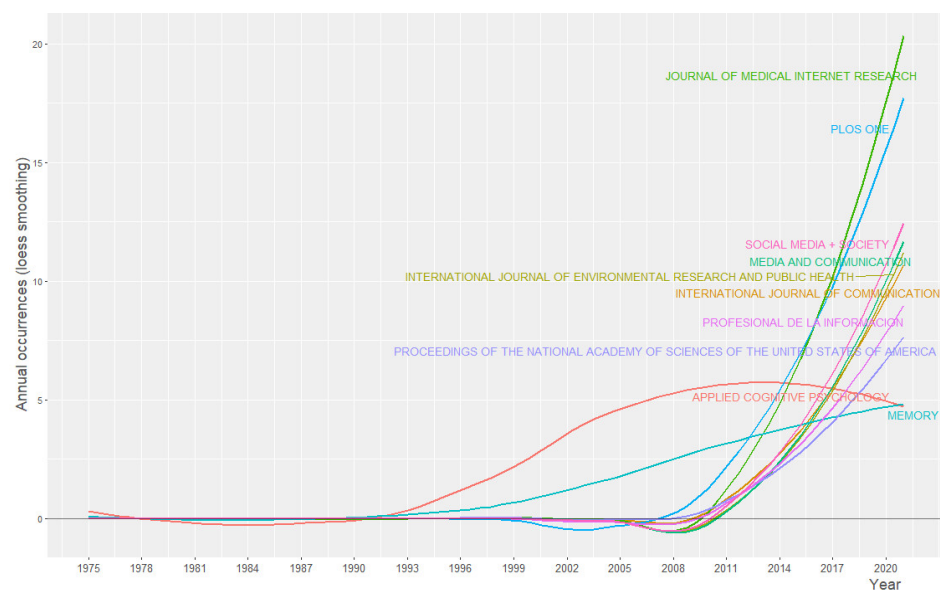
Figure 20. Top 10 source dynamics (in terms of number of publications per year).

5.2. Conceptual Structure of Knowledge Analysis

In order to properly assess the complexity of ID research, we must first understand the conceptual foundations of the construct. Besides the progress and issues of the field, from the co-occurrence analysis we can also identify emerging concepts within themes.

The strategic diagram (Figure 10) presents six clusters out of which two are motor themes (COVID-19 and emerging technologies), two are basic and transversal (fake news and communication), one is emerging or declining themes (false memory) and one is highly developed and isolated themes (freedom of expression).

The first cluster that contains *motor themes* is the one entitled COVID-19, with research on COVID-19 (276 items), Internet (145), coronavirus (89), infodemic (77), public health (74),

pandemic (68), China (34), stigma (33), mental health (27), SARS-COVID-2 926), prevention (23), risk communication (22), health information (19), infoveillance (19), health literacy (19), patient education (19), anxiety (18), surveillance (18), women (17), risk perception (16), etc.

Many of the topics in this cluster have China as a major player in this new global disinformation order from at least two perspectives: *surveillance capitalism* [64,65] (that is, the ways in which technology—especially the Internet—is used for social control) and infodemia—*information pandemic* triggered by the virus pandemic [66].

Until the protests in Hong Kong in 2019, Chinese disinformation operations were carried out on domestic online platforms such as Weibo or WeChat. However, China's growing interest then also spread to Facebook, Twitter or YouTube, which could or should be a wake-up call for targeted democracies [56].

In the context of the coronavirus pandemic, we are simultaneously facing an informational pathology with dramatic effects on the human psyche and, consequently, on its health [15]. Moreover, the infodemia and mistrust feed into each other, therefore disinformation can have devastating effects on society, causing division between groups, social tensions, weakening the rule of law and creating general confusion [67]. COVID-19 pandemic management, with all related syncopes, has generated a crisis of confidence (eroding public trust in a COVID-19 vaccine), a wave of skepticism fueled by COVID-19 misinformation narratives and conspiracy theories proliferating in social media [68]. In addition, as long as the crisis in health persists, the information war connected to it will also exist. In a joint statement, WHO, United Nations, UNICEF, UNESCO and other international organizations stressed the fact that only by reducing uncertainty can the effects of disinformation be limited [69]. Thus, the new study area is aimed at finding measures to strengthen resilience (personal and societal) in the context of the coronavirus pandemic [70].

The second cluster with *motor themes*, emerging media, must be understood in the context of online social networks and revolutionary technologies, which have fundamentally changed the way information is produced, consumed and transmitted: media (102 items), machine learning (86), fake news detection (66), deep learning (62), social network (52), natural language processing (49), artificial intelligence (35), sentiment analysis (32), classification (30), online social networks (28), data mining (27), reliability (20), transparency (18), privacy (18), advertising (17), text mining (17), rumor detection (17), crowdsourcing (16), text classification (15), blockchain (15).

Emerging media offer unlimited possibilities in terms of expression, participation, mobilization, but at the same time make way for disinformation, misinformation, confusion, division, polarization, etc. The new information disorder is organically linked to the media emergence and explosion, says the EU expert Alina Bârgăoanu [14]. They create the technological infrastructure that allows instant dissemination of fake news, fake visuals, opinions and interpretations that are disconnected from facts; and, above all, a lot of emotions are stirred [71].

In specialized literature we can already see a well-defined outline for studies that investigate the impact that artificial intelligence or virtual reality have in creating, detecting, spreading, stopping false content or misinformation, the use of narratives using machine learning, distorted deep fake interpretations, generation of computational propaganda campaigns, etc. [70,72,73]. Recently, because fighting this infodemic has become a significant challenge, researchers came with solutions for data analysis and fake news detection by applying emerging technologies such as Artificial Intelligence, Internet of Things, deep learning, blockchain, Neural Network, Fuzzy [74], machine learning algorithms [75] or chatbots [76].

Amid the global pandemic crisis, the importance of providing reliable information becomes increasingly crucial [77]. Emerging technologies (such as blockchain) could have an impact in filtering, combating or blocking fake news and deep fakes. Due to the traceability, transparency and decentralization nature [78,79], blockchain is going to

revolutionize the way information is produced and distributed and will increase confidence by providing communications and media organizations and online users with trusted data tracking systems, ensuring a reliable way of verifying digital content, including video, and its source and history [80–82].

Basic and transversal themes are included in the fake news cluster, covering topics such as fake news (878 items), misinformation (683), social media (662), disinformation (343), Twitter (178), social networks (110), post-truth (110), journalism (96), media literacy (79), Facebook (77), propaganda (75), fact-checking (60), trust (60), democracy (54), information literacy (49), credibility (49), climate change (41), etc.

In the post-truth era, communication takes forms and channels of manifestation that we are just beginning to identify and understand [8,79]. So, in this cluster we find dominant themes which try to pin down "the new informational disorder", the changes, and even malformations affecting the current informational ecosystem, from politics, economy, environment, health to society, culture, journalism, science, education and technology. However, we also find research on very narrow or new topics (either due to technology, or to the pandemic context), such as the blockchain approach for detecting and blocking fake news in social networks [81,82], data deficits on social media [68,83], cognition security [84], misinfodemics [85,86], etc.

Nevertheless, fake news should be annihilated by cultivating media literacy [87] and information literacy [88], by sharpening critical thinking and the ability to decode messages [89]. However, in the current context of "infobesity", "infoxication", "infosaturation" or "data smog" [90–92], more and more people are actually overwhelmed when it comes to assessing the credibility and importance of content they come in contact with for the first time in the online environment [91]. A solution to navigate more easily through the "information jungle" [93] would be to use critical thinking abilities, as well as abilities to *critically ignore information* [70,94].

Less studied topics that have potential for future research identified in this cluster are combating misinformation through nudging [95,96] or manipulation via TikTok [97]. Manipulation is possible on all platforms, but of all the social networks, TikTok, a platform with many children and young people among its users, is the most vulnerable to fake news and disinformation [98,99].

The second cluster with basic and transversal themes is health communication, and it includes topics about disinformation as a risk to public health (misleading health information, false claims, conspiracy theories, patient protection fraud, etc.): communication (88 items), vaccination (62), health communication (54), education (51), infodemiology (35), ethics (37), qualitative research (36), contraception (31), vaccines (28), pregnancy (28), abortion (27), vaccine hesitancy (27), attitudes (24), reproductive health (24), adolescents (24), immunization (23), HIV (23), nutrition (21), vaccine (21), regulation (19), gender (18), news media (18), information dissemination (18), misconceptions (18), etc.

Since March 2020 we have been fighting the COVID-19 pandemic. Huge efforts have been made to study and find the vulnerabilities of this new coronavirus, to develop an effective vaccine, but also to stop the spread of misinformation about the harmful consequences of vaccination [67,68,74]. It has never been clearer that *communication is an important public intervention in health* [70].

Whether true or false, excessive amounts of information can negatively affect people's health, increasing stress and possibly causing people to accept advice that could be dangerous [29]. However, this is not a new problem, even though online misinformation, with and without public health intent, has become a major political and societal problem in the current context of the coronavirus pandemic [31]. We have witnessed over the years the erroneous, unclear, misleading or false communication of health-related information on topics such as diet and fitness, contraception and pregnancy, especially among vulnerable groups such as children, adolescents and young people, who face a higher risk to be misled [100]; promoting false remedies and wrong beliefs for terminal or chronic illnesses such as cancer or smoking [30,101]; anti-vaccine propaganda [102]; spreading false narratives

about the pharmaceutical and beauty industry [103]; fueling misconceptions about HIV, AIDS, Ebola or Zika [104], etc.

So far, research [30,31,77] has shown that false or misleading discourse regarding health information comes in various forms that require different reactions. New topics of interest are those related to mental and psychosocial health during and after the pandemic [105] or the way in which online platforms and social networks will handle these threats [106]. A solution may come from *infodemiology* that aims to study how best to manage these threats [16,107]. In theory, this can also be achieved by providing clear information that can help the public better understand the current situation of media literacy. For example, in a recent study [55] that examines how COVID-19 vaccine rumors and conspiracy theories circulate on online platforms, the authors suggest that by tracking COVID-19 vaccine misinformation in real time and engaging with social media to disseminate correct information could help the public against misinformation. At the same time, as [108] show, a better understanding of the relationship between public emotions and rumors during the epidemic may help generate useful strategies for guiding public emotions and dispelling rumors. Moreover, the authorities should more clearly communicate the necessity of the measures taken to combat the current crisis, such as the use of web-based monitoring methods to guide public emotions and behavior [108]. The cluster comprising *emerging or declining themes* was named false memory because of the subjects it covers: memory (120 items), false memory (108), misinformation effect (70), eyewitness memory (66), suggestibility (64), children (45), eyewitness testimony (37), rumor (35), memory conformity (31), source monitoring (29).

Many themes in this cluster stem from the research of Elizabeth Loftus, a psychologist and expert in human memory, who has conducted numerous studies trying to explain the sensitivity of memory to distortion [109,110]. She demonstrated through a series of experiments that false memories can be induced through suggestion, and this can be achieved relatively easily. Loftus has been studying false memories since the 1970s, and her work has revealed the serious consequences that disinformation can have on memory. She also showed that these memories can become stronger and more vivid over time [49]. In some cases, the original memory may even be modified to incorporate new information or experiences [111]. Moreover, a false memory transmitted during a criminal testimony can lead to an innocent person being convicted of a crime [112].

In more recent studies, Murphy et al. [113] highlighted that exposure to propaganda may include false memories or push polls exposure increase false memories for fake news. Surprisingly, people with exceptional memory are still likely to do things without realizing it [114]—an aspect that still needs in-depth research—which explains why this cluster is in both the emerging and declining area.

A new research theme (multidisciplinary research field) has emerged, *cognition security*, which investigates the intrinsic propagation and cognition mechanisms of fake news [84]. In addition, recent studies on memory and cognitive processes [115] try to explain how this type of information works on individuals and what makes them so easily attracted and determined to believe what they are told.

Due to an increase in disinformation, misinformation and fake news during the coronavirus pandemic, Greenspan and Loftus [105] suggest that it is more important than ever to understand the factors that influence the development of false memories [70]. For example, the study by Greene and Murphy [116] measures the susceptibility to false memories that follows exposure to fabricated news stories about the pandemic or the work of Murphy and Flynn [117] which studies how deep fake videos may distort memory for public events.

The cluster *highly developed and isolated themes* is grouped around freedom of expression (15 items) and also includes authoritarianism (14), Indonesia (14), censorship (14), television (10), Middle East (8), immigration (8), public diplomacy (8), soft power (7), Iran (7), free speech (7), digital technologies (6), political economy (6), human rights (6), copyright (6), Malaysia (5).

We also encounter topics about "computational propaganda" used as a tool for controlling information, weaponization of information and social media, COVID-19 as a political weapon [62] and misinformation in the post-truth era as part of the hybrid arsenal of authoritarian states for which social media has become an associated working tool [32,33,79]. Other issues address authoritarian states such as Iran, some states in the Middle East, or less developed, more politically and economically fragile countries (e.g., Malaysia, Indonesia) where human rights are violated, and which have found an opportunity to carry out social media and social networks campaigns to promote their regimes and silence their dissidents [56].

Another interesting topic is connected to deep fakes and how they affect the democratic process, whereby constant contact with misinformation causes users to lose confidence in what they see and hear, leading to a phenomenon in which individuals will look at everything around them as false information [70]. In this way, the security of the individual, the attribution of words and personal identity are subject to an increasing number of threats.

Because in an information-dominated society, situations of information pollution are not excluded, the individual's ability to find some order in the information chaos (real or apparent), to control information through selection, ranking, processing, to identify and eliminate irrelevant, eroded or useless elements, becomes a necessary feature, without which the question of his freedom could not be posed [79]. Therefore, this cluster not only launches new topics for discussion but also invites us to reflect on the limits of freedom in an era dominated by digital technologies, whose development seems to have no other limit than that of time.

On the other hand, as we can see in Figure 11, the field of ID is maturing, with varied research themes in different periods, with the one connected to the coronavirus being in a development stage. The same holds true for deep learning and fact checking (online news) because of the rapid progress of technology. It is clear from the diagram that the term "fake news" started gaining in popularity in 2016, when presidential elections took place in the United States. Later it began to be used frequently by experts in political communication, international relations and security studies, with references to Russian disinformation campaigns (Russia's involvement in the internal affairs of some Central and Eastern European states, as well as in the presidential elections in the United States, on vaccines, etc.).

5.3. Intellectual Structure of Knowledge Analysis

De Bellis [43] stressed the fact that the citation and co-citation networks among scientific documents in a specialized area over a given period of time may be thought to reflect its socio-cognitive structure and evolution. Therefore, by taking citations into account as indicators of usage and visibility, we were able to assess the structure of the essential part of fundamental literature on ID regarding important documents, authors, and journals. At the same time, citation context analysis gave us useful perspectives on the performance of certain scholars and research groups concerning the impact citations have on researchers' work. From Figure 12 one can notice that, after 2016, there has been a very rapid increase in the number of citations, which confirms both the researchers' growing interest and the evolution of the field.

The most cited author is Professor Brendan Nyhan, Dartmouth College, whose research focuses on misperceptions and conspiracy theories about politics and health care, political communication and the media, political scandal and corruption (Table 2). At the time of writing this paper, 49 documents co-authored by professor Nyhan that have 4498 citations are included in WoS. However, it is important to note that in our collection, the author with the most published papers (Loftus) has the highest h index (21) and g index (44). However, in a recent large scale-study, Koltun and Hafner [118] suggest that the "h-index is no longer an effective correlate of scientific reputation" and should be reconsidered.

On the other hand, if we are looking at global citations, the first position in the top 10 most globally cited documents is occupied by Meyers' paper from 1997, with 1294 global

citations. The paper [119], published in *Organic Geochemistry* (journal that appears in the top 10 most cited journals only with this paper—see Table 6), talks about how the magnitude of the diagenesis can be a potential source of misinformation, and the author stresses the idea that it "must always be considered and evaluated". Although the paper addresses an information disorder, namely misinformation, it is a niche (a very specialized, narrow field). So, we can ask ourselves: "It is really an impactful paper (in our analysis)?" Basically, Meyers' presence demonstrates that, for many documents, a large part of global citations could come from other disciplines. Therefore, by looking at local citations we can measure the impact of a document in the analyzed collection.

Browsing the most cited papers (Table 3) provided a very quick understanding of ID mainstream related research and its major trends. The most cited papers belong to economists Hunt Allcott (New York University) and Matthew Gentzkow (Stanford University). In their study [120], they estimated an ordinary US adult consumed one to three fake news in the months leading up to the 2016 presidential election. They also identified other practices that could be likened to fake news, such as journalistic errors, the spread of clearly unreasonable rumors, the spread of conspiracy theory, political satire, unfounded or false statements made by politicians and electoral contestants or journalistic content that is not false, but is created in a way that confuses voters.

In terms of relative impact of countries, American research was outstanding with 52.72% of all citations referencing papers from the USA (52,015 citations) with an average article citation of 16.079. Interestingly, Iraq has only 10 papers but leads in the top of average citations per year (34.5).

The most cited institution is the University of Michigan, as a leader in research, learning and teaching for more than 200 years (Table 4). According to the Times Higher Education University ranking [121], University of Michigan is ranked 15th in the World Reputation Rankings 2020. This could be due to Meyers' affiliation with the University of Michigan and with the fact that some of the most cited authors, such as Brendan Nyhan or Professors Lewandowsky and Ecker, either worked for a time at the University of Michigan or they wrote in collaboration with authors affiliated to this university [53,122].

After analyzing the dispersion of journal citations, we found that the journal with the greatest influence on the field is *Applied Cognitive Psychology* (Table 5). The most cited journal entry in our dataset belongs to Hyman et al. [123]. It is about false memories of childhood experiences and has 271 citations. It is followed by Loftus et al. [124], with a paper about individual differences in memory and suggestibility.

The analysis of co-citation was first presented by Small in 1973 in [36] and since then it has been the dominant method for creating bibliometric maps. A special case of co-citation analysis is "author co-citation analysis", in which the analyzed units are authors. This method has also been applied for the analysis of journal co-citation (in which case the analyzed units are journals) and cited references (in which case the analyzed units are papers in bibliographic association). The power of co-citation and the power of bibliographic association express the resemblance between two journals, two authors or two documents, as reflected by the authors' reference system. All three forms of co-citation analysis were applied in this study. The resulting maps can be interpreted as follows: a long distance between points representing objects corresponds to a weak resemblance and vice versa.

The author with the biggest impact is Elizabeth Loftus. However, we can notice in Figure 13 that the ID phenomenon is examined by various specialists, bringing together experts from different fields or with similar specializations who have common research interests. To paraphrase Lazer et al. [125], addressing ID news requires a multidisciplinary effort, which is classified in five clusters:

- The red cluster, oriented towards political psychology, behavioral economics, behavioral science, includes Lewandowsky Stephen, Allcott Hunt, Nyhan Brendan, Gordon Pennycook and organizations such as WHO and the European Commission.

- The green cluster is dominated by cognitive psychology, false memory and has authors such as Elizabeth Loftus, Henry L. Roediger, Daniel B. Wright or Lindsay D. Stephen.
- The blue cluster is more oriented towards computer science, artificial intelligence, deep learning, machine learning, social computing, with researchers such as Soroushi Vosoughi, Kai Shu, Suhang Wang, etc.
- The yellow cluster is focused on developmental psychology, human cognition, consumer psychology, having Stephen J. Ceci, Charles J. Breinerd, Merrie Brucks as central scholars.
- The purple cluster groups together topics connected to cognitive science and memory and includes researchers such as Ullrich K. H. Ecker, Johnson H.M. and Marsj E.J.

It is no coincidence that we find WHO in the red cluster, since it is an organization responsible for managing global health issues, setting the health research agenda, setting norms and standards and developing evidence-based policies. In the current global COVID-19 crisis, researchers ground their studies on data and information provided by WHO and other institutions, such as the European Commission.

The most influential work (Table 6) is written by Vosoughi, Roy and Aral [72], who studied behaviors of spreading fake news on Twitter. Their research suggests that disinformation spreads further, faster and deeper than the truth in all categories of information because of perceived novelty and the ability to inspire fear, disgust and surprise.

A more visualized representation of relationships among prolific scholars, references they cite and keywords they use is shown in Figure 21, a three-fields plot. The left-most column represents the references the top authors cite, the middle column shows scholars' names contributing the most to the research in the field of ID and the right-most column represents the most used keywords used by the authors.
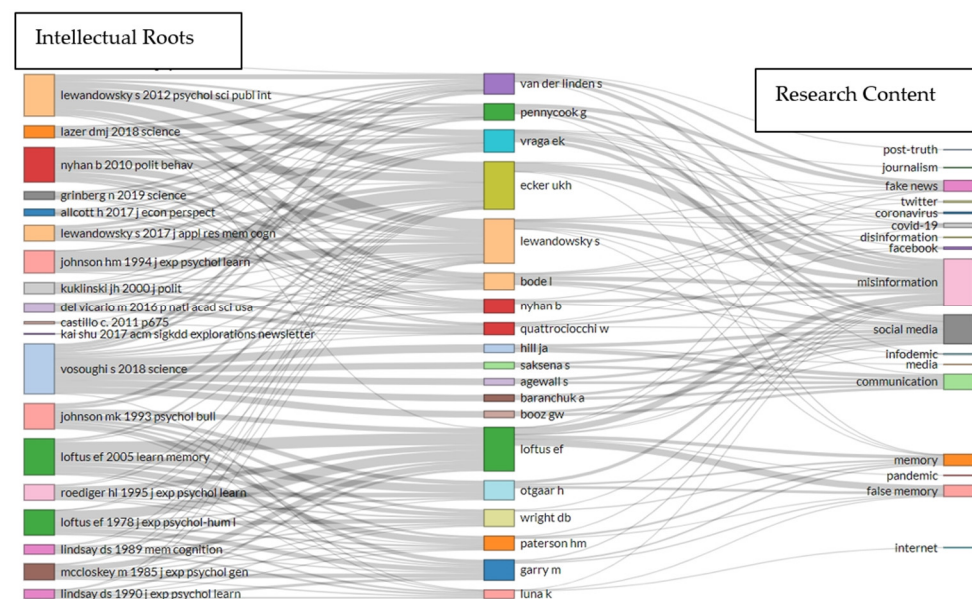
Figure 21. A three-field plot of references, authors and themes of ID.

Taking into consideration the height of the boxes and the thickness of the connecting lines (the taller the box, the more significant and the thicker the lines' correlation, the more information or volume of work was produced [54]), the above diagram emphasizes the central research content as misinformation, social media, communication and fake news with emerging topics as infodemic, pandemic, coronavirus and COVID-19.

In Figure 14 we can see that the essential part of the intellectual base really belongs to ID research in fields such as health, communication, politics, technology and psychology, with several journals placed in the center of the map and less cited and co-cited journals in

more peripheral positions. VoSViewer identified four major clusters. In each of them we can distinguish a core publication around which the others gravitate:

- The red cluster (287 items) includes journals from the medical/health area such as *LANCET* (1524), *Nature* (1112), *J. Med. INTERNET RES.* (1279), *Vaccine* (1509), *BMJ-BRIT. MED. J.* (803) or *JAMA-J. AM. MED. ASSOC.* (1395).
- The green cluster (267 items) focuses more on communication, political sciences and economics, and includes *NY Times* (1765), *Forbes*, *BBC*, *ABC News*, *Business Insider*, *Corriere della Sera*, *Economist*, *El Mundo*, *Financial Times*, *Foreign Policy*, *Gallup*, *Guardian* and journals such as *J. Commun.* (1507), *Digit. Journal* (971), *J. ECON. PERSPEC.* (722), *Harvard Law Review* (90), etc.
- The blue cluster (236 items) is oriented towards technology and sciences and comprises: *SCIENCE* (2711), *PLoS ONE* (2327), *Comput. Hum. Behav.* (1137), *P. Natl. Acad. Sci. USA* (1564).
- The yellow cluster (210 items) focuses on different aspects of psychology and includes *Appl. Cognitive Psych.* (2522), *Mem. Cognition* (2311), *J. Exp. Psychol. Learn.* (2022), *J. Pers. Soc. Psychol.* (1675) and *J. Exp. Psychol. Gen.* (1528).

Among the most co-cited sources, there are both high impact journals such as *Science*, *Appl Cognitive Psych* or *Lancet*, and journals dedicated to a particular field of research such as allergology (*Journal of Allergy and Clinical Immunology*—126; *Clinical & Experimental Allergy*—46; *Allergy*—34; *Pediatric Allergy and Immunology*—21).

5.4. Social Structure of Knowledge Analysis

The social structure shows how authors, institutions or countries relate to others in the field of scientific research of information disorders. As one can see from Figure 15, there are some cooperation patterns between the topmost productive and cited authors, but in general these research communities are islands of cooperation.

There is a need for a global cooperative effort among researchers and institutions to produce studies that help expose the harmful impact of fake news, mis- and disinformation and to propose potential remedies. In our set, co-authors per document is 3.05 and collaboration index 3.02. Authors that have co-authored also tend to be located close to each other on the map. Eleven collaborative groups were found.

From Figure 16 we can see that in each cluster there are some core countries. By looking at the clusters placed further from the core countries, such as the one which includes Austria, Czech Republic, Slovakia, Poland, Hungary, Romania or Ukraine, we notice that the geographical advantage (they are all countries from Central and Eastern Europe) is not a primary factor that influences collaborations and relationships and that disinformation, misinformation and fake news are fields of interest for researchers all over the world, with research themes waiting to be developed further (e.g., how geopolitics is shaping online communities' responses to the pandemic or what is the impact of religious misinformation in Latin America). These results are similar with those of Abu Arquob et al. [26] and Jancowski [51] who suggest that there are some regions, such as Africa and South America, where research on ID has not been conducted and further studies need to be carried out.

Regarding the collaborative research aspects, our study's results can be summed up as follows: There were some collaboration patterns between the highly cited, most productive authors, countries tended to work together for a core-country, and regional cooperation among institutions predominated. Most of all, we need to create collaboration mechanisms that involve not only higher education institutions and research units, but also monitoring organizations, experts in the field, social media platforms, government and decision makers [11] to make sure that data deficits can be identified early on and replaced with accessible, evidence-based information [83]. These results are in line with those of Skarzauskiene et al. [126], who argue that in this way the successful spread of harmful narratives can be prevented.

5.5. Limits and Suggestions for Further Research

The data we analyzed provided interesting insights on research about ID: the number of publications, authors, and journals has increased, research on ID has earned considerable attention in multiple academic fields, there are more and more works written in collaboration by people from different parts and cultures of the world, etc.

Nevertheless, there are some *limitations* that should be acknowledged: (a) Our study was based on a sample of documents from WoS (there are other databases that should be explored); (b) There are other terms related to the subject of this study which can be taken into consideration, such as "misinfodemics" or "viral misinformation" [85,106]; (c) Following the analysis of the complete data set covering the period 1975—present, we made an overview of the field, considering the impact of documents, authors and how publication in journals changes over time; (d) Regarding institutions, we did not separately analyze the affiliation of authors to private and public institutions, academic or non-academic ones; (e) We did not insist on the type of journals (open access or non-open access), nor on the publishers. For example, we did not focus on predatory publishing. Considered "the fake news of science", predatory practices represent not only a global threat to quality science, but they also particularly affect young students and researchers). Bibliometrics is not designed to evaluate research performance directly, so this type of analysis should be accompanied by qualitative analysis as well.

However, these limitations can be seen as pathways for *future research*. The co-occurrence analysis indicates there are important, highly specialized, niche topics or less prominent key aspects that are less researched and are awaiting contributions. Here are some examples identified by us, with some of them being mentioned in other studies as well [6,12,70,125,127]: the impact of religious misinformation in different countries; how to develop literacy programmes to combat mis-, mal- or disinformation; what are the psychological consequences of mal- or non-information; what are the implications of artificial intelligence that enables fake news creation and sharing (deep fake techniques); how new technologies such as blockchain can prevent digital disinformation; what are the effects of information overabundance or of the information vacuum; how data analytics and open-source tools can be used to identify misinformation and disinformation networks; individual security and cognitive security; combating misinformation through nudging; how to build resilience to misinformation.

Similarly, we need to understand the infodemic if we are going to address it. Questions to be asked before the next infodemic occurs [128]: how geopolitical and nationalist narratives are influencing online communities regarding medical cures; how to debunk false information especially on social media; how to measure, post-pandemic, the effects of misinformation on the mental health of the population; what ways are there to identify "data deficits" and "data voids" in order to prevent the spread of medical disinformation narratives [83,129]; how to build our mental (and therefore social) resilience [70], etc.

6. Conclusions

This paper conducted a comprehensive quantitative analysis and evaluation of the literature on the complexity of ID in the Web of Science Core Collection database from 1975 to June 2021. The goal of this study was to map an overall picture of the topic from a global perspective, clarify the knowledge framework of research in this field, examine the development dynamics, identify future research directions and enrich understanding of the research on ID. Three types of bibliometric indicators were used: quantity indicators (for measuring productivity), quality indicators (for measuring the impact) and structural indicators (for measuring the connections). A network analysis (i.e., co-keyword analysis, co-authorship analysis and co-citation analysis) was also performed and major clusters of the information disorders research were identified.

We witnessed a significant development in a range of disciplines (history, media and communication, education, psychology, philosophy, health, economics, environment, etc.) with contributions to research made by a big number of authors (26,242). The co-

occurrence of author keywords demonstrates a substantial diversity and a significant variety of published ID literature, with a remarkable increase in research on distorted narratives, misleading interpretations, the negative influence of false content on human behavior, the effects of exposure to fake news about COVID-19 on social media, how digital platforms combat misinformation, etc. On the other hand, addressing news reports that disseminate false information requires a multidisciplinary effort. After 2016, there has been a rapid increase in the number of citations, which confirms both the researchers' growing interest and the evolution of the field. We also identified emerging concepts within themes included in six clusters, out of which two are motor themes (COVID-19 and emerging technologies), two are basic and transversal (fake news and communication), one is emerging or declining themes (false memory) and one is highly developed and isolated themes (freedom of expression).

Undoubtedly, the digital revolution has brought with it a series of information disorders which affect each and every one of us. We are witnessing a true technocalypse, in which the truth is contested, denied, settled, judged, condemned with ferocity [130]. Hence, several questions remain: What is the truth? What does communication look like from the perspective of technological evolution? What is the influence of literature? What is new and what is true about mis-, mal- and disinformation? How much does fake news and disinformation affect our daily existence? What news has the biggest impact and in what way? How serious is the problem of ID, of informational pathologies? What makes people accept and distribute fake news and what can be done against misinformation? How do opinions influence public health messages? How do we build psychological "immunity" against online mis- and disinformation? etc. All these and others demand a reformulation of the research framework and a common effort of the whole society.

In conclusion, based on our findings, we believe that this paper makes important contributions to the literature, not only by providing researchers and practitioners with a coherent and perceptible intellectual basis to find answers, but also by bringing valuable insights for further investigation and future research directions.

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Article

The Interaction of Civil Engineering Students in Group Work through the Social Network Analysis

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Abstract: A sustainable approach in the construction industry requires civil engineering professionals with technical and soft skills. Those skills complement each other and facilitate the professional to work effectively in multidisciplinary groups during the development of construction projects. Universities apply collaborative learning methods such as group work (GW) in the classroom to achieve these skills. There is disagreement on the best way to select the members of the GW to achieve their best performance, but it is clear that it should favor the interaction of diverse actors to promote the development of soft skills. A random or criteria-based selection could bring groups of people very close together, leading to the academic homogeneity of GW members and impairing performance and learning. Even the most alert instructors lack information about the closeness of their students, so they rely on their intuition without having tools that allow them to confirm their assumptions or relate them to GW performance. The objective of this paper was to discover the social structures within the classrooms and to identify the groups of people close by trust, knowledge, and informal conversation to relate them to their GW performance. For this purpose, a social network analysis (SNA) was applied to Civil Engineering degree students. In addition, a correlation analysis between SNA metrics and GW grades was performed. The results show that beyond the way in which members are selected, there is a social structure that affects such selection and GW performance. This study presents information that can be used for instructors for a better GW selection that propitiates the development of soft skills in Civil Engineering students.

Keywords: social network analysis; group work; civil engineers; students' performance

1. Introduction

In the Architecture, Engineering, and Construction (AEC) industry, the increasing complexity of construction projects demands the work of complex organizations and multidisciplinary professional groups for their execution [1,2]. During project development, the civil engineer coordinates and collaborates with diverse stakeholders, for example, architects, builders, engineers, suppliers, workers, and the community [3]. Such activities require technical knowledge, and personal or behavioral skills as leadership, social skills, professional ethics, and effective communication [4–6]. These skills complement each other and make it easier for the professional to work effectively in multidisciplinary groups during the development of construction projects [7–9]. With the rapid growth of sustainable development, there has been a growing demand for social sustainability to be included into the AEC industry [10,11]. Social sustainability covers social considerations of the final user and health and safety issues of the project team [12,13]; therefore, social sustainability is associated to the management practices that includes employee skills training (BIM education program, information communication technologies, teamwork, among others) [10].

The demand of the AEC industry for professionals with technical skills and soft skills has moved universities to incorporate methodologies that promote the learning and development of those skills in their civil engineering training processes [5,14]. Consequently, the universities have gone from professor exposition as main teaching method to the use of collaborative methodologies which promote these types of social skills among the students by the use of group work (GW) or team-based learning methodologies [15].

GW is a learning method based on students working together in groups relying on and supporting one another through cooperation and collaboration to achieve a set goal. This is formally termed cooperative learning or collaborative learning [16,17]. Those groups in civil engineering depend on the instructor's selection of the students in the classroom and their attendance to the operational needs of the tasks and activities of the course [14]. They are also traditional classroom learning groups created to carry out a specific assignments [18]. The selection of the students to form GW is a central issue since several studies indicate that when group members' are too close to each other it distracts students from the main task, causes lower acquisition of social skills, and leads to the academic homogeneity of members, which further endangers the learning performance [14,19–21].

The most frequent methods for selecting students for GW are random association, by the affinity of the students, or selected by the instructor [19]. When selected by the instructor, team members can be chosen by the relevant skills needed for the tasks assigned to the group, looking for an optimal distribution of those skills across the teams [22,23] or the use of a criterion of rotation of the members of the groups to achieve diversity in each task. This diversity is understood as a reduced presence of close friends or acquaintances in the same group.

In any type of selection, the instructor is responsible for establishing the initial rules for the formation of the groups and, to reduce GW failures, should structure and control them in an intentional manner to obtain the planned outputs [22]. However, at the beginning of a course, the instructor can hardly identify students' particular skills or the closeness pre-existing between them. Such conditions are diverse depending on the semester of the course and whether students are at the beginning or end of their undergraduate program [14]. In addition, the evolution of personal relations within the group, influenced by mutual trust, searching for advice to solve problems, and social affinities, defines the closeness of people [24].

Even the most alert instructors lack information about the ways in which their students relate to each other in the courses, and thus so relies on their observation skills without having the tools that allow them to confirm their assumptions. Thus, the pre-existing social relations between the students and their individual social skills may be not considered for the formation of the groups. Therefore, it would be hard to apply adjustments or to know the impact of the selection of the member of the GW on the performance of the students.

Social Network Analysis (SNA) provides a tool for knowing the social relationships that occur within classrooms [25]. From the study proposed by Krackhardt and Hanson [24], it has been applied in various companies and organizations, including in the analysis of the relationships between students of higher education centers. SNA allows instructors, through network metrics, to identify the members of the groups that have outstanding communication, knowledge, and relational characteristics. There are not many studies that use SNAs to assess interactions in student contexts. A recent paper presented a four-year longitudinal study, where the authors evaluated the friendship and learning networks of civil engineering students using SNA [26]; however, it does not explore the relationship between interaction networks and students' academic performance, neither does it include suggestions for academics' management of work teams. Another study evaluated the relationship between student academic performance and team interactions using SNA [27]; nevertheless, this was a single capstone course effort where BIM methodology was taught, so it is unknown what happens in courses in previous years and in subjects where management and collaboration methodologies are not necessarily taught. There is

also insufficient background information to provide instructor with tools on strategies to form work groups.

It is important for instructors to know the social dynamics, as well as students' preexistent conditions that affect GW and its outcomes [22]. This leads us to ask the following research questions: (1) What are the characteristics of the social networks of general communication, trust, and consultation within civil engineering classrooms? (2) Are these characteristics related to the performance of the students in the course and in the GW? (3) Is there a social diversity among the members of the GW? The main objective of this research was to characterize social networks inside the classrooms of civil engineering, aiming to unveil student's closeness relations and identify individuals with high levels of trust, knowledge, or skills highlighted by their classmates. It was also sought to establish if there is any relationship between a student's closeness with the performance of the GW measured by their grades.

The information provided by the network diagrams generated by SNA may enable instructors to leverage these relations with the aim to improve the formation of workgroups, considering not only pedagogy but students' social interactions [28], making the method of selecting the members of the work groups more efficient and providing a control tool that the traditional forms of selection do not have. The paper is formed by five sections. The first is the present section, the second is the theoretical framework, the third describes the methodology used for SNA and correlation analysis, the fourth contains the results and discussion, and finally, the fifth section contains the conclusions.

2. Literature Review

2.1. Collaborative Learning for Civil Engineers

Professional competence is understood as a complex phenomenon that is related to the potential of the person to guide their performance in the exercise of their profession. In this role, the integration of knowledge, skills, motives, and values that are built in the process of social interaction and that influence efficient, ethical, and social professional performance plays an important role [9].

A competence is the result of a learning process that enables students to integrate the knowledge, skills, attitudes, and responsibilities that the professional profile demands [5]. The professional profile of a Civil Engineer includes technical and social competences, such as communication and social interaction skills, participatory skills related to group membership, decision making, and the assumption of responsibilities. In consequence, the academy is strengthening the aforementioned competencies through the construction and reconstruction of learning by collaborative methodologies [15].

Collaborative learning through GW generate spaces for social interaction, allows for direct relationships between peers, and creates environments that enable participatory knowledge building, favor communication between students, and increase shared responsibilities [19]. According to Davis and Michalaka [29], collaborative learning allows students in an environment of interaction to integrate the knowledge and social aspects necessary for the exercise of their profession. Despite the benefits described, collaborative learning presents some difficulties during its application by GW. As highlighted by Riveiro et al. [30], the lack of responsibility and individual commitment makes the collaborative work less effective, producing little coordination and inadequate organization when designing actions for the development of a task, an absence of consensus for decision making, disagreements in the organization and planning of the proposed work, and a lack of coordination during the work. According to Guirao and Escobar [14], under such conditions, difficulties appear in evaluating the learning process and the results obtained by each student; indeed, it is hard to assign grades in a fair and equitable way.

A drawback is that not all teams collaborate effectively since students focus especially on the result and not on collaborating. The structuring of the groups may be an aspect that influences the students' collaboration and performance. In addition, achieving heterogeneity is a critical factor to improve individual performance in cooperative learning

groups [17]. Actually, instructors should directly take control of group formation process to avoid pre-existing closeness between members that endangers group cohesiveness [19]. One way to evaluate the interactions between groups of people is social network analysis.

2.2. Social Network Analysis

The use of social network analysis (SNA) has spread in all areas of human activity [31]. This tool derived from graph theory is often used to characterize relationships between people in diverse organizations. Based on the study proposed by Krackhardt and Hanson [24], it has been applied in various companies and organizations, so it has also been used in the analysis of relationships between students from higher education centers [32]. SNA allows, through network metrics, to identify the members of the groups that are formed in the classroom that have outstanding communication and relationship characteristics [31]. This helps to predict human group behaviors and intervene to enhance the capabilities of informal organizations [33].

An important aspect of the SNA is that it allows for viewing the lines through which information flows inside a social network. Furthermore, by means of graphs and indicators, the roles played by its members can be estimated, which may be structurally different depending on the network being analyzed and its evolution over time [34].

Social networks are formed from sets of social or interpersonal relationships that link individuals or organizations in groups. As a result of the direct and indirect connections between actors (interaction, communication, exchange, among others), relational structures can be identified [35]. These social structures can help to better understand, predict, and manage the results of human action [33].

When effective communication is achieved within social networks, the members develop trust. The trust generated in their interactions drives commitment with the accomplishment of assigned tasks [19,36]. The fulfillment of commitments in engineering groups has been associated with better performances [37,38]. Thus, trusted social networks are enhancers of the commitment of group members and the fulfillment of collaborative tasks.

The number of links that a person has within the social network has been interpreted in different ways. A greater number is associated with high levels of influence and power because their opinions can be quickly spread among members of the network affecting even rational decisions made by individuals. However, even when high degrees of individuals are regularly associated with leadership and success, this is not always true [39]. The identification of knowledge leaders in classrooms may require different approaches in addition to the SNA since in social networks it is not better who has better ideas than who best reaps the ideas of others [33,40].

The links imply communication and may be strong (friendly) or weak (acquaintances) [34]. Having many strong links is not always associated with the success of individuals in a social network. Rather, weak links are associated with innovation and the flow of ideas [33]. Communication takes place within small organizational units and needs to cut across the social network. Strong ties to close and frequent social contacts tend to be integrated into closely linked regions of the network, while weak ties to more casual and distinct social contacts tend to cross between these small units [34]. If strong ties are necessary for trust, weak ties are the input of new information to social networks. Isolated social groups within a network can become inefficient if they do not feed on information from other groups through weak ties between their acquaintances.

The graphics of social networks have been assimilated as spatial definitions of the behavior of its members. The components that form the networks delimit topological regions that mark the barriers of information and interaction within the group and subjectively delimit the path to be followed by the students [41]. In this way, the topology of the networks and their components allow for examining the interaction patterns between the individual and the whole network or their immediate social environment [42].

3. Materials and Methods

To achieve the objective of this study, all the courses of the civil engineering under-graduate program of a university in Ecuador were invited to participate. The first step was to explain to the students and teachers that the objective of the research was to improve GW implementation in Civil Engineering classrooms. In addition, they were informed that the participation would be voluntary under conditions of confidentiality of the information and anonymity. In total, 4 of 10 courses (40% participation) freely agreed to participate in the study, without any condition on the composition of the group of students, only verifying that GW had been developed within them [43]. Of the total number of students in the 4 courses, 93 of 102 answered the survey, that is, a 91% participation rate was obtained.

Four courses accepted the conditions and participated in the research: the National Reality Chair in second semester, Topography II in fourth semester, Project Management in ninth semester, and Graduation projects in tenth semester. The civil engineering undergrad-uate program has a duration of ten semesters. There are many courses where collaborative GW is carried out. The semesters, the chairs, and the description of the GW developed in them are described in Table 1.

Table 1. GW description by semester and subject.

Semester	Subject	GW Description
2	National reality	Workgroup for documental analysis.
4	Topography II	Field practices to carry out topographic surveys
9	Project management	Workshops in the classroom and tasks applied in a construction project
10	Graduation projects	Work on the state of the art and research methodology

To obtain information of the social networks that are formed in the courses, online surveys were applied through the virtual classrooms that teachers use to support a b-learning mode of teaching. These were applied four weeks after the courses started to allow all students to have the opportunity to interact in the classroom. The survey asked three questions that allowed the definition of three interaction networks. Table 2 shows the type of network and its respective question. Each student became a coded node, and a link was assumed as the student's statement regarding the interaction with another student. The direction of the interaction was abstracted and a weight equal to 1 was assigned in all cases. Under such a decision, social networks are considered undirected. In other words, it does not matter from whom the interaction was declared in the survey originated.

Table 2. Social network studied.

Network	Question
General interaction	Who do you communicate with frequently (more than twice a week) on general topics?
Trust	Who do you trust to tell you about personal and study issues?
Problem consulting	Who do you go to when you need help solving problems on course assignments?

The survey and method used in this study is an adaptation of that was developed by Krackhardt and Hanson [24] and have been tested in previous studies [44]. In addition, social relations inside a social network are better defined by the participants [41], even though there is always the risk of respondent bias when answering the questionnaire. Aiming to avoid this bias, the research team procured those participants who answered freely and voluntarily, so students would not have an incentive to be dishonest about their social connections and would provide reliable data.

The collected information was processed on an electronic sheet (MS Excel) and then imported into social network analysis software (Gephi 0.9.2). With this information, interaction diagrams (sociograms) were developed, and network and individual indices (metrics) were calculated. For each course, social networks of general interaction, trust, and problem-solving were developed based on the study by Krackhardt and Hanson [24].

Social network analysis (SNA) is a methodology whose application in the study of human relations has been widely disseminated in various areas [41,45]. The SNA is based on a set of indicators that measure the interactions between the members of a group of people, which are represented in graphs by means of links and nodes [46]. Social network indicators, also called metrics, characterize individuals in a group by their number of connections or relationships with other group members. In addition, social networks are characterized by the connectivity of all group members. These characteristics of the network, its nodes, and their relationships are the necessary input for the SNA [45].

The same group of individuals can generate different social networks depending on the type of relationship that exists between them, motivated by labor, family, corporate, and cooperation interests, among others. In each of them, there are differences in the level of communication and social influence of its members [33] depending on the number of strong links between close friends and weak links between acquaintances [47]. The relationships between people have different motives, and the networks that can be modeled and analyzed vary according to the reasons that motivate their study.

Various SNA metrics are particularly useful when analyzing friendship or work relationships within social networks. Among them are, at the level of individuals, the degree, the modularity, and the clustering coefficient; at the network level (global metrics), the average degree, diameter, density, number of components, and the average clustering coefficient measure the degree of cohesion [31]. The global metrics were discussed in this study, as the researchers seek to explain the interactions of the whole group. The referred global metrics are described in Table 3.

Table 3. SNA global metrics.

Metric	Description
Density	How many actual links exist between nodes divided by the number of the total possible links in the network.
Average degree	How many other nodes a node is connected to, on average.
Clustering coefficient	How clustered groups of nodes are compared with the rest of the network; the existence of closed triads and communities.
Modularity classes	How dense the connections between nodes within groups are compared to nodes of another group. The classes represent sub-communities within a network.

The sociograms generated using the SNA help to visualize the global metrics presented in Table 3. As an example, Figure 1 presents four sociograms in a network of six people (nodes). Each sociogram shows different interactions (links) among its members, which are represented graphically and mathematically, through the global metrics.

Figure 1a shows a network centralized in node A, which is the only person who connects with the other network members. This behavior is supported by an average degree of connection of 1.6 people, i.e., that on average each node connects with other 1.6 nodes of a total of 5 potential connections. Complementarily, the density of this sociogram is 0.33 (5/15), which is lower than the density of the sociogram in Figure 1b, where the actual connections are equivalent to the possible connections (15/15). Another difference between the sociogram in Figure 1a,b is the clustering coefficient; in the first one, there are no triads generated between the nodes, while in the second one, there are all the possible triads between the nodes. Therefore, the clustering coefficient in Figure 1a is 0 and that in

Figure 1b is 1. Nevertheless, in both sociograms, there is only one modularity class, that is, in these two sociograms there are no sub-communities within the whole network.
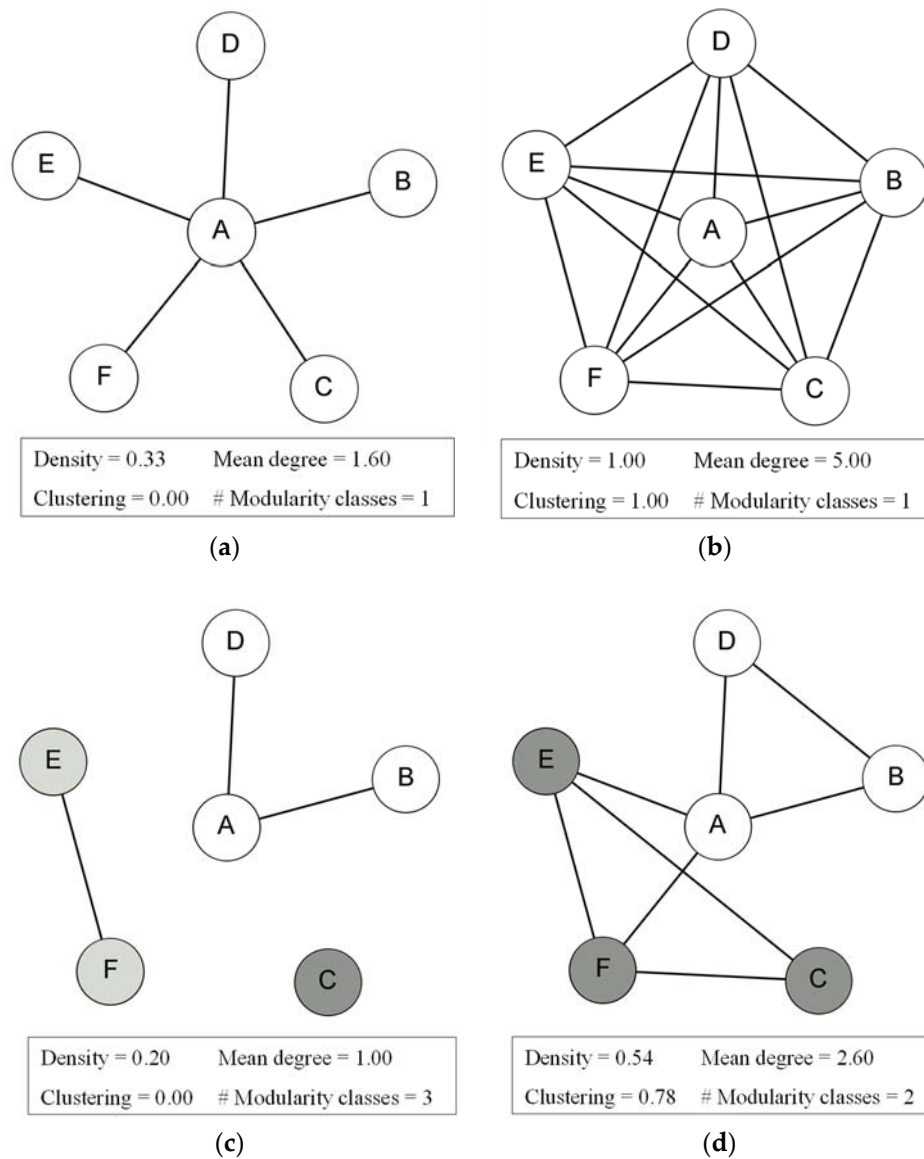

| Density = 0.33 | Mean degree = 1.60 |
| Clustering = 0.00 | # Modularity classes = 1 |

(a)

| Density = 1.00 | Mean degree = 5.00 |
| Clustering = 1.00 | # Modularity classes = 1 |

(b)

| Density = 0.20 | Mean degree = 1.00 |
| Clustering = 0.00 | # Modularity classes = 3 |

(c)

| Density = 0.54 | Mean degree = 2.60 |
| Clustering = 0.78 | # Modularity classes = 2 |

(d)

Figure 1. Example of sociograms and their metric: (**a**) low density network; (**b**) high density network; (**c**) three groups disconnected network; (**d**) two groups connected in a network.

Figure 1c contains only 3 connections of the potential 15; it is the network with the lowest density and the lowest average degree of all the shown sociograms. Additionally, Figure 1c) presents three clearly disconnected sub-communities (number of modularity classes equal to three); this is remarked through the node colors. Furthermore, the clustering coefficient is zero since there is no triad in this network. It is not necessary that the sub-communities are completely disconnected to have more than one modularity class. For example, in the sociogram of Figure 1d, it is possible to visualize two modularity classes, that is, two sub-communities (gray and white nodes) are generated because there is a relatively superior connection between one group of nodes and the other. Additionally, in Figure 1d, triads can be appreciated between the nodes ABD, AEF, and EFC, thus, there is a clustering coefficient higher than the sociograms in Figure 1a,c, but lower than Figure 1b.

The degree of a node is its number of connections, and it constitutes a basic metric to characterize the members of a social network according to their importance or centrality.

High-degree nodes are assumed to have a high probability of receiving and transmitting information within the network [41].

The grouping coefficient of a node defines the probability that two randomly selected friends of that node are friends of each other. The grouping coefficient of a node varies from 0, when none of the friends of the node are friends with each other, to 1, when all of the friends of the node are friends with each other [34]. The coefficient is calculated by dividing the number of triads existing in the network by the number of possible triads in it. A triad is made up of three nodes that maintain mutual connections with each other in the form of a closed triangle.

Members who have many connections with other members of a network tend to have low grouping coefficients, while nodes with a low degree tend to form triads more easily, and this also happens in small networks with highly cohesive groups [46]. Modularity allows for knowing the distribution of the network in communities. Communities are formed with members interacting with each other by some common characteristic, making their connections more systematic and less random [33]. The densities of interaction within communities are often different from the density of interactions between them. Identifying communities is used to design SNA-based intervention strategies [45].

The analysis of the characteristics of the networks, which are related to the connectivity, flow of information, and communication, usually focuses on cohesion indicators such as the average degree of their members, the density of the network, the number of components, and the average length on the way [41].

The average degree is calculated from the degree of each one of the nodes of the divided network for the number of nodes. It is assumed that a high average degree implies high connectivity of its members and a low dispersion in isolated groups.

- The density of the network calculated as the number of existing connections divided by the possible number of achievable connections of its members defines how closely its members are related. Low densities are associated with hemophilia and the appearance of many groups within the social network [46].
- The average path length is the average of all the shortest possible routes among all nodes in the network. Low values, close to 1, suggest a greater efficiency of the network to transmit information among its members.
- The number of components indicates how many isolated groups a social network is divided into. When there is more than one component, not all members of the network can contact another. Then, the number and size of components in a network define topological regions that can be associated with the ease of sharing information and resources [46,48].

Finally, the centrality metrics of each member of the network were calculated: degree and intermediation. The characteristic metrics of each network: average degree, diameter, and average path length. For the analysis of the networks, the SNA criteria were applied to identify the central members of the networks and the network characteristics that facilitate the communication of their members. On the other hand, teachers were asked for the qualifications of each student in the courses, both for the general activities and for the activities carried out as GW. Using the social network metrics, a comparative analysis was carried out at each level of the career, using the average degree. In addition, students' grades, and network metrics were used in a correlation analysis with the Spearman method to establish whether the connectivity characteristics of social networks are related to the grades obtained by students in the semester and in the GW.

4. Results

4.1. Comparative Analysis of Social Networks

The results of the SNA are shown in Table 4, in groups containing six social network metrics, for each of the courses participating in the study and for general communication networks (Figure 2), personal trust (Figure 3), and consultation (Figure 4).

Table 4. Social network metrics in civil engineering courses.

| Metric	General Interaction	Trust	Problem Consultation
Second semester			
Average degree	3.926	2.640	2.923
Diameter	6	9	7
Density	0.151	0.110	0.117
Components	1	2	1
Average clustering coefficient	0.195	0.255	0.060
Fourth semester			
Average degree	4.500	3.250	4.500
Diameter	4	4	4
Density	0.300	0.217	0.300
Components	1	2	1
Average clustering coefficient	0.661	0.471	0.508
Ninth semester			
Average degree	4.414	2.148	3.760
Diameter	7	7	5
Density	0.158	0.083	0.157
Components	1	4	2
Average clustering coefficient	0.542	0.246	0.526
Tenth semester			
Average degree	3.556	1.000	3.222
Diameter	6	4	5
Density	0.209	0.059	0.190
Components	1	10	2
Average clustering coefficient	0.477	0.417	0.523
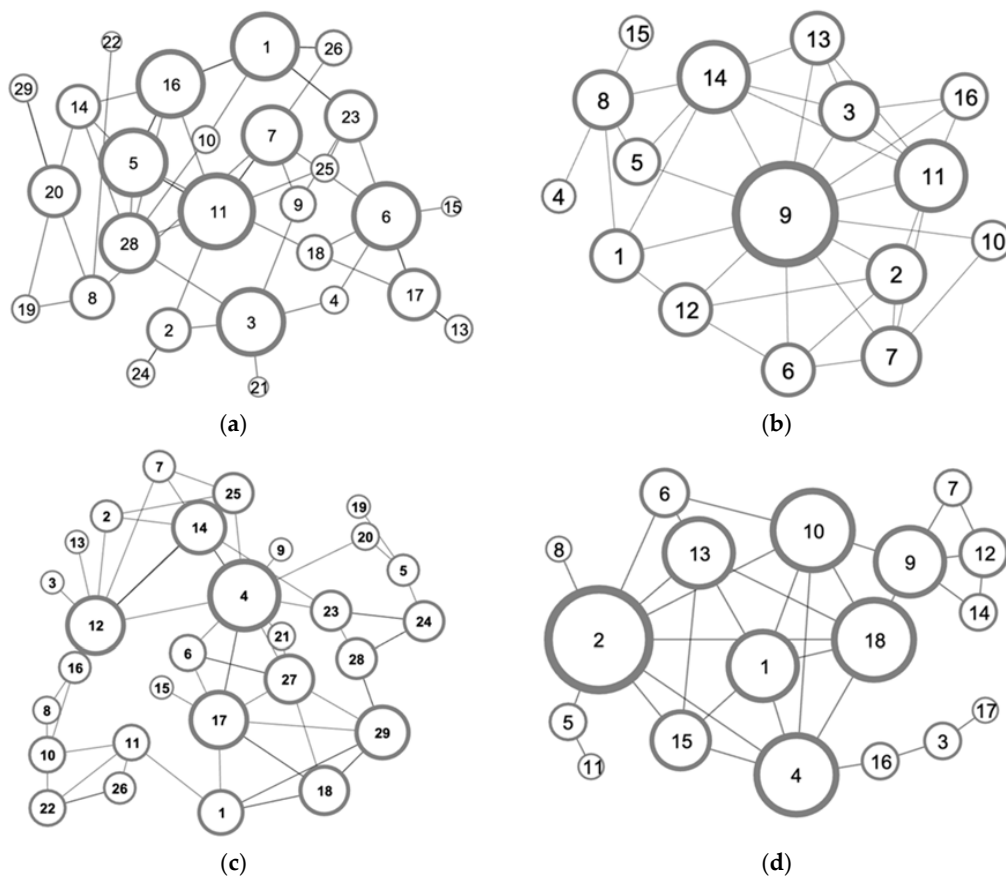
Figure 2. General interaction social networks. (**a**) Second semester; (**b**) Fourth semester; (**c**) Ninth semester; (**d**) Tenth semester.
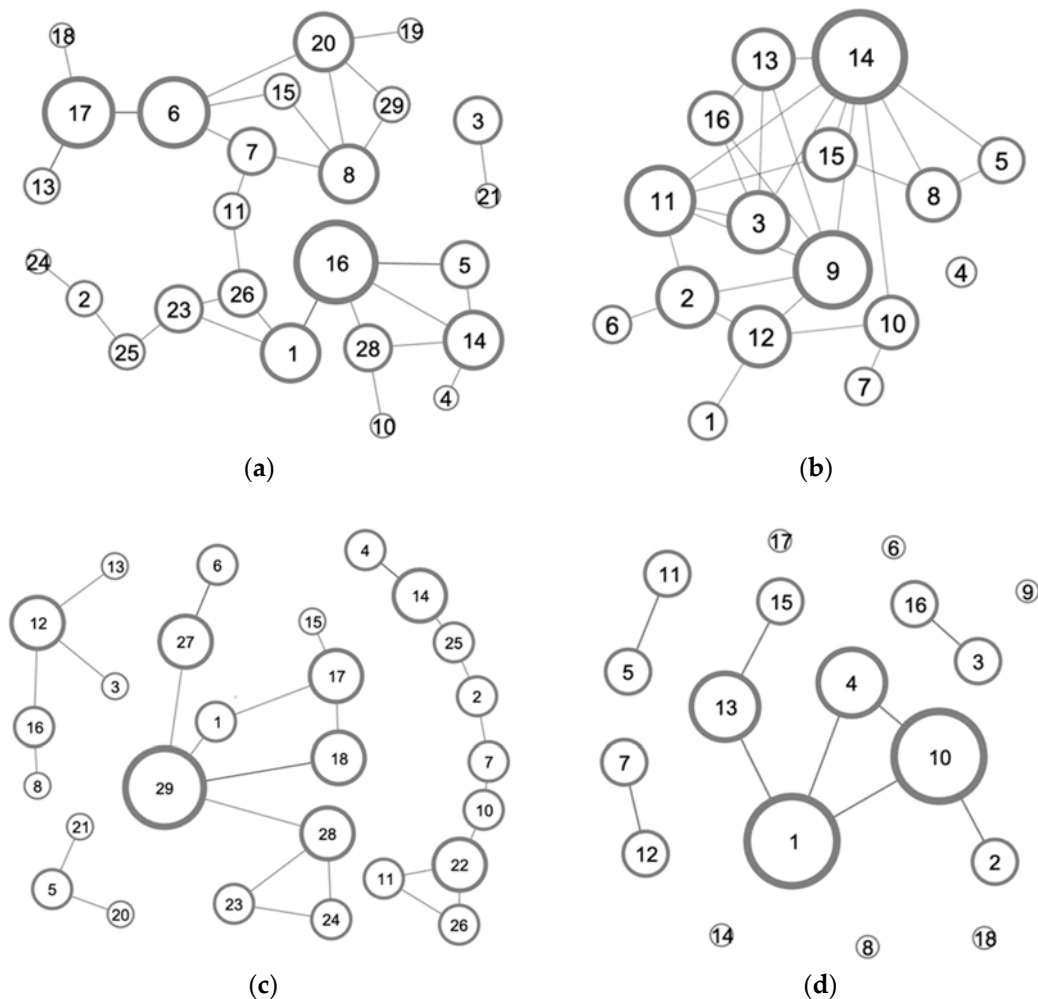
Figure 3. Trust social networks. (**a**) Second semester; (**b**) Fourth semester; (**c**) Ninth semester; (**d**) Tenth semester.

The density of the three networks in all semesters is low, with a maximum of 30% in the fourth semester and a minimum of 6% in the tenth-semester trust network. This is uncharacteristic of small networks with less than 30 people in which it is easy to make contacts, which reveals poor communication between students in the courses. In addition, low densities in social networks are a sign of the existence of several small groups of friends in the courses [46]. Results shown in Table 4 are depicted ahead in network graphs, showing the members with a higher degree in a bigger node size.

The links between students include several intermediate members, which is reflected in long diameters, as happens in the second semester. Although the diameters of the trust networks seem shorter, it must be considered that they are the diameters of the small groups that make up these networks and that, in some cases, they do not incorporate several individuals isolated from the course Figure 3.

The average clustering coefficient shows that in the second semester, there are members with many connections but with few closed triads, especially in the consultation network. The clustering coefficient increases as the career progress, and from the fourth to the tenth semester, the percentage of triads increases because personal relationships become more selective both in general relation and in consultations.

When making a comparison of the average network degree, in general, the metric of the trust networks is lower than the other two networks. Trust relationships are limited to small groups of frequent interaction or friends (strong ties), while general interaction and consultation networks include relationships between acquaintances (weak ties), often contacted through other members of the course (Figures 2 and 4). Weak ties are related to

the incorporation of new information and opportunities for individuals [34], so the union of many weak ties in the consultation network would help to spread the knowledge perceived by its members, and in this point, it is critical that the information have good quality [24].
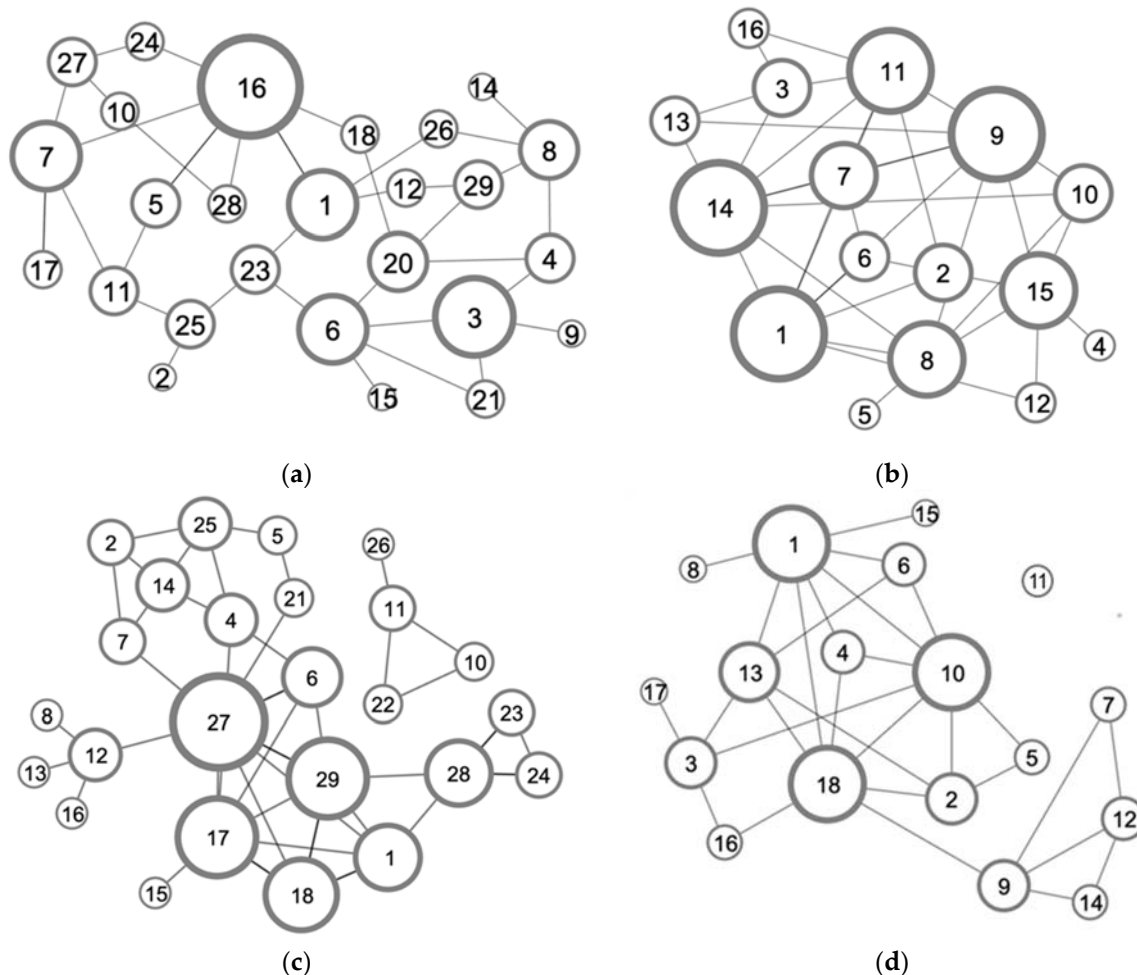

Figure 4. Problem consulting social networks. (**a**) Second semester; (**b**) Fourth semester; (**c**) Ninth semester; (**d**) Tenth semester.

Another interesting issue in the courses studied is that trust networks have few components in the initial semesters, whereas in the last semesters, there is a tendency towards individuality. This occurs in the ninth semester, with four clearly identified groups, and the tenth semester (end of career), in which a small central group appears, several couples, and isolated individuals (Figure 3). In the first semesters of social integration, trust networks with few compact components would make the information that enters the groups weakly innovative. On the other hand, in the last semesters, when developing GW, people who do not have confidence would be interacting. This is of paramount importance, since trust is necessary to achieve effective communication and fulfillment of commitments [36]. The number of components within the trust networks grows from the second semester to the tenth, and the disintegration grows as the career progresses, a social deterioration that is not being managed by teachers, as they do not have tools that allow them to notice it.

Another remarkable aspect in the studied group is the structural similarity of the social networks of general interaction and that of consultations in all the semesters of the degree. Those networks present a more abundant interaction than in the trust network, indicating that the greatest number of contacts among students occurs for reasons of informal chatting or academic work. From this point of view, it is easier to achieve a contagion of behaviors or learning by working with the networks of highest contact [34].

The results of the comparative analysis could be indicating that the GW have focused only on the tasks. Trust is what drives the fulfillment of commitments, so that a group in which people interact with each other without trust could hardly be fulfilling the objectives set in collaborative learning [30]. This raises questions that should be answered by the actors in the learning process after an analysis of the context and the GW results.

4.2. Social Networks and Group Work

The SNA allows us to look at another important aspect, which is the diversity of the members of the group. In this study, the social networks of two courses that made up the working groups were analyzed, the fourth semester of the professor and the ninth semester by affinity and kept them fixed during the semester. The resulting graphs allow us to appreciate the trust and consultation networks of the fourth semester and ninth semester, as shown in Figures 5 and 6, highlighting the groups formed by letters on the social network diagram (Group A, Group B, Group C, Group D, Group E, and Group F).
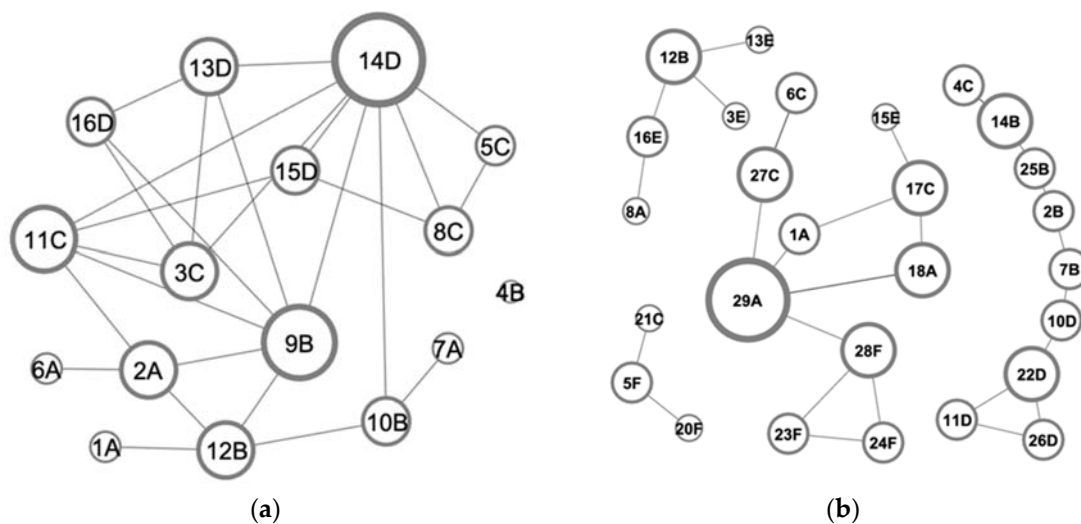

(a)   (b)

Figure 5. GW inside the trust social network. (**a**) Fourth semester; (**b**) Ninth semester.
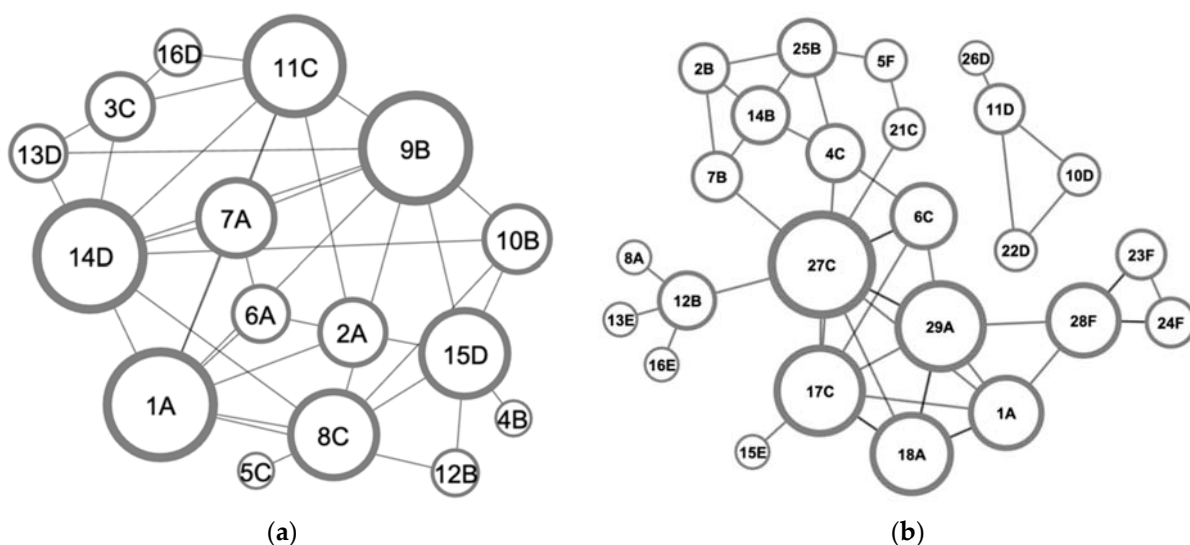

(a)   (b)

Figure 6. GW inside the problem consulting social network. (**a**) Fourth semester; (**b**) Ninth semester.

The fourth semester diagrams show a certain diversity, from the point of view of the social network, among the members that make up the workgroups that were chosen by the

teacher. However, many of the members of the groups belong to trust or consulting cliques that existed before the professor's intervention.

It is evident in the ninth semester diagrams that the members of the groups were trust associated and hooked up central consulting people with a high average degree. There are closed cliques based on triads that attach to a member of another subgroup; this is especially noticeable in consulting networks. It is also visible that few groups formed by affinity come from trust networks. This means that when affinity selection is allowed, it is not always out of friendship or trust, but it may be for the convenience of integrating members with a useful quality for the performance of the group.

In either case, the recommended diversity for the GW has not been achieved due to group conformation mistakes. Affinity association is the most popular among students, but it produces exclusive groups that selectively incorporate some students from other social groups and generate isolated individuals who associate out of necessity rather than affinity. In semester nine, where groups 2, 7, 14, and 25 incorporate student 12 that belongs to another trust clique, students 13 and 16 are forced to form another group, not out of affinity but out of necessity, with node 15.

Additionally, in the fourth and ninth semesters, a statistical analysis was applied to determine if there is any significant difference between the medians of the GW scores of these two courses, aiming to find a difference in performance due to group selection. Each course has a different number of students: 16 in the fourth semester and 29 in the ninth semester, so the Kruskal Wallis test was applied, which does not require equal sample sizes. The result [χ^2 (1, N = 29) = 28.94, p = 0.0001] supports the idea that there is a significant difference between the scores of the two groups studied, given that the mean of the fourth semester is greater and variability is lower [Mean (M) = 7.55, Standard Deviation (SD) = 0.58] than the media of the ninth semester whose variability is higher [M = 5.47, SD = 1.10].

4.3. Social Networks and Performance

The results of the correlation analysis between the individual metrics of the course members and their GW and semester grades are presented ahead. No significant correlations were found between the metrics of the three social networks and the scores obtained by the second-semester students. However, a moderate but significant correlation was found between the semester grades and those of the GW, [ρ (30) = 0.57, p = 0.0025].

Spearman's test for the fourth semester showed a significant correlation between their semester grades and those of the GW, [ρ (14) = 0.94, p <0.0001]. The test also yielded other meaningful correlations between the grades, the clustering coefficient, and the modularity coefficient of its members, as shown in Table 5.

Table 5. Correlation between grades and social network in the fourth semester.

Social Network	Metrics	ρ (*p*-Value)
General interation	GW grade and Clustering coefficient	−0.500 (0.049)
	Semester grade and Clustering coefficient	−0.514 (0.042)
Trust	GW grade and Modularity	−0.748 (0.001)
	Semester grade and Modularity	−0.725 (0.002)
Problem consulting	GW grade and Modularity	−0.615 (0.011)
	Semester grade and Modularity	−0.722 (0.002)

The members of the fourth semester consulting and trust networks with high modularity present low grades. Membership in modules with dense connections, but with sparse connections between modules, seems to be negative for student performance.

The clustering coefficient is also associated to the poor performance of such individuals. Network members who are closest to forming closed triads with their general communication network neighbors have lower grades. The presence of closed and exclu-

sive groups within the course hinders communication and dissemination of knowledge among course members, despite the implementation of the GW. In addition, in the ninth semester, an important correlation was found between their semester grades and those of their GW, [ρ (25) = 0.81, *p* = 0.0001]. The other meaningful correlations are detailed in Table 6.

Table 6. Correlation between grades and social network in the ninth semester.

Social Network	Metrics	ρ (*p*-Value)
General interaction	GW grade and Degree	0.393 (0.043)
	Semester grade and Degree	0.411 (0.033)
Trust	GW grade and Degree	0.425 (0.027)
	Semester grade and Degree	0.539 (0.004)
Problem consulting	GW grade and Modularity	−0.420 (0.037)

In the ninth semester, the fact that a student belongs to a module that is not well connected to other modules in the consultation network is negative for their GW grades. However, the fact that an individual has a high number of connections in the general interaction and trust networks is directly related to a better performance in both semesters and GW. This highlights the importance of relationships between group members as a determinant of better performance [33]. Finally, in the tenth semester, a relevant correlation was also found between their semester grades and those of their GW, [ρ (16) = 0.77, *p* = 0.0002]. No correlations were found between the trust network metrics with the students' grades. That was expected since students with the greatest dispersion in the trust network would not generate enough commitment for the GW [36]. The other meaningful correlations found are detailed in Table 7.

Table 7. Correlation between grades and social network in the tenth semester.

Social Network	Metrics	ρ (*p*-Value)
General interaction	Semester grade and Clustering coefficient	0.5742 (0.013)
Problem consulting	Semester grade and Clustering coefficient	0.6485 (0.004)

Moderate correlations with high significance indicate that there is a direct relationship between network members who are forming closed triads in the general interaction and problem consulting network with achieving better grades. A better relationship between the students of the course impacts their individual performance and not the GW performance [49].

5. Discussion

The selection of the teacher-created groups with some diversity in terms of social relations may be appropriate when the variety of points of view are necessary for learning. For example, in semester four, the teacher's decision to form the work group B made the trust group of nodes 9, 10, and 12 incorporate isolated node 4, who is closer to consult node 15 when it comes to working. This happens even when there is no significant diversity in the conformation of the groups from the point of view of the social relations of the two courses described by the social network diagrams. In this case, the SNA graphs allowed us to detect the characteristics resulting from the group formations that have been noticed by Guirao and Escobar [14]. The instructor could use this information to create better balanced groups in terms of closeness diversity of its members [22]. In addition, it can be thought that the formation of the groups by teacher selection produced a better performance of the groups than the association by affinity. In this case, the method of selecting the students

that make up the groups would have a relationship with their performance, unlike what was found in Gunderson and More [17] for engineering students. Instructors must consider that, beyond the way in which the GW members are selected, there is a social structure that affects such selection and GW performance. However, these results should be analyzed considering the differences inherent in each subject and the type of GW that is developed.

The results associated with clustering coefficient and grades shows a dissociation between the modules that the students form in the social network and the groups that are selected for the GW. Perhaps the groups or modules that are formed for the GW are not the most appropriate. An analysis of the triads and modules of the networks could provide a guide for the formation of working groups. There is a clear opportunity for improvement that the instructor can implement. The use of collaborative techniques, such as JigSaw for example, could help to widen communication and cooperation among all the students, breaking the triads and cliques. Another option is the creation of web communities or the use of virtual learning management systems, where students can strengthen their interaction, communication, collaboration, and coordination skills. In this study, interactions were evaluated through student perception surveys, as opposed to other experiences in which the effectiveness of massive processes in the universities' web communities was evaluated [50].

The results presented above make clear two facts that occur in the courses studied. The correlations between the semester grades and the GW emphasize the importance of good grades in the GW as they determine the semester performance. On the other hand, the fact that no relevant correlations appear between individual centrality in the consulting networks and the student's qualifications means that those students who are frequently consulted by their classmates are not necessarily the best-rated. This implies that such students could be consulting the wrong people. It should be noted that low grades are not necessarily associated with a single factor, and they may have different causes, such as motivation, communication, learning facilities, proper guidance, and family stress, among other aspects [51].

From a long-term perspective, engineering students and future professionals in the AEC industry will have to design, build, and operate sustainable projects now and in the future. The life cycle approach has been explored in depth from the economic and environmental perspective; however, the social perspective in construction has been less addressed [10]. Within the social perspective, AEC professionals are expected to be able to interact effectively with different stakeholders of their projects (clients, users, work team, community, suppliers, subcontractors, among others); therefore, the development and practice of interaction skills that are promoted in group work are fundamental. This paper provides tools for teachers to identify students who are not developing their teamwork, communication, collaboration, and coordination skills; consequently, teachers could propose improvement actions for students who have dropped out and actions to enhance the skills of the advantaged students.

6. Conclusions

The use of SNA in the classrooms of a civil engineering degree allowed for identifying the characteristics of its social network structure in the aspects of trust, general interaction, and problem consulting. The last two present an important connectivity reflected in the average degree of their members and in the density of connections, which indicates that informal chat and the search for knowledge on course topics motivates communication among students of all the semesters of the degree. Conversely, trust networks appear to be made up of various components and disconnected cliques. This characteristic of the social relationship shows that people who do not trust each other are in GW.

It was also possible to see a pattern of the behavior of the networks according to the semesters of the degree. In the first semesters, there is a tendency for networks formed by various interconnected groups. Aspects that should be considered by teachers when working with collaborative techniques that seek the development of integration skills and

social skills. However, this cannot be confirmed because of the cross-sectional nature of this study. To study the evolution of student behavior, it is recommended to perform a longitudinal study with a course from the first semester to the tenth semester.

A relationship was established between the social characteristics of individuals in the networks with their educational performance expressed as grades. The existence of closely connected groups and triads within the networks is related to low grades in the first semesters of the degree. While the clustering and the degree in the networks of trust, general communication, and consultations in the last semesters are related to a better performance of the students, perhaps driven by the selection of their contacts that is evident in the number of components of the networks.

The SNA was also useful to identify the diversity of the members in the formation of the collaborative methodologies GW. It was established that in the studied courses, neither the selection made by the teacher nor the selection by affinity achieves an important social diversity in the formation of the groups. The results of this application of SNA in a civil engineering career show its usefulness in diagnosing the composition of three main social networks: general interaction, trust, and consultation. These should serve as an input for a better configuration of the GW when considering the pre-existing relationships between the students. In this way, segregation can be reduced by preventing certain students from always being in the same workgroups, which reduces the possibility of spreading knowledge and new ideas.

The correlation analysis between the students' grades and their social network metrics allowed us to know if the GW methodology is effectively producing any effect on student performance. A lack of relationship would be an indicator of deficiencies in the application of the GW that should be corrected in a timely manner. There are limitations of this research, the main one being the small sample size and the fact that it only constitutes a snapshot of the social networks studied, as they are in constant evolution. In addition, the free will to participate is assumed as a source of reliable information from social networks and there is always the risk of bias due to personal perceptions.

The results of the diagnosis established in this paper remain to be applied in the conformation of GW as well as the measurement of its impact on the students' qualifications and on the development of other non-technical skills such as leadership and communication. The structure patterns of the social networks of trust in the different semesters that tend to a greater segregation as the students progresses in the career, is an issue that remains to be investigated. Additionally, another line of future research is to apply different strategies to create work groups and evaluate their performances. It would be interesting to include in the evaluation other variables of interest, such as attitudinal variables, students' previous performances, context variables, among others. Finally, how the skills acquired by civil engineers in GW are related to the development of sustainable projects needs future research.

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