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PAPER

5G Technology for Innovation Education (Sustainable Development Goals 4): A Systematic Review

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ABSTRACT

Access to quality education remains a significant global challenge today. In line with the goals outlined by the World Health Organization (WHO) in its 2030 agenda, ensuring access to education is a fundamental objective. Consequently, it is imperative to undertake an investigation into the influence of technological innovation on educational practices. This study examines the impact of incorporating the 5G network into educational settings to improve learning experiences. The analysis covered 134 articles, 62 of which were deemed relevant, classifying the research as ongoing projects or pilot studies for future exploration. The main digital tools identified were artificial intelligence, the Internet of Things, virtual reality, and machine learning. The use of the 5G network appears to have a more significant impact on higher education and universities. Research in this field is mainly concentrated in Europe, America, and Asia. In addition, it is clear that the adoption of 5G technology is influencing pedagogical methods, emphasising immersive learning, e-learning platforms, and flipped classrooms. This study argues for further research into the integration of technology in education, advocating a careful examination of the implementation of 5G infrastructure and its potential to improve access to high-quality education.

KEYWORDS

educational innovation, 5G technology, mobile learning, technology education

1 INTRODUCTION

Today, the world faces a major challenge regarding both the accessibility and quality of education. As outlined in the Sustainable Development Goals (SDGs) defined by the World Health Organization (WHO), SDG 4 strives to “ensure inclusive and equitable quality education and promote lifelong learning opportunities for all” [1]. The United Nations has always worked to promote and encourage quality and equitable education. When people have access to quality education, they can break the cycle of poverty. It helps reduce inequalities and fosters tolerance between people, enabling them to build more peaceful societies [2].

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In September 2015, as part of the Sustainable Development Action Plan and its 17 goals, world leaders adopted the following measures [3], which include "quality education" in their SDG4. While September 8 is International Literacy Day, the United Nations stipulates in Goal 4 of the Agenda 2030 SDGs the importance of ensuring lifelong learning. However, this task remains unresolved. This task is still pending. Literacy is the liberating path to autonomy, dignity, and the full enjoyment of human rights [4]. A firm commitment to public funding of education is urgent and cannot be postponed so that the human right to education becomes a concrete reality for all populations.

Educational quality is one of the most commonly used terms in the field of education, serving as a benchmark for justifying progress and enhancing social transformation. In this sense, there are numerous quality proposals or standards that are approached from various perspectives. They all share the common foundation of holistic personal development, considering the current circumstances, including the specific location and time. This approach allows for the realisation of the central concept of quality education [5]. Education must, therefore, be seen as a process of lifelong learning based on an integral vision of the human being, their dignity, rights, and duties.

In the field of education, sustainability has become increasingly important over time. It can be described as the implementation of educational methods that can be developed without excessively depleting resources or marginalising certain demographic groups [6]. Education for sustainable development involves integrating educational approaches that promote the continuous development of knowledge in various disciplines. Recognition of the importance of education is evident in UNESCO's establishment of the Decade of Education for Sustainable Development from 2005 to 2014.

The global educational landscape was dramatically affected by the COVID-19 pandemic, resulting in an abrupt shift towards widespread adoption of on-demand e-learning during periods of global lockdown [7], [8]. The management of the pandemic has already involved inter-calendar mobility blockages and restrictions, along with recovery plans for a return to normalcy. These measures have created numerous vulnerabilities, particularly in terms of reduced access to distance learning [9], [10]. According to UNESCO, many countries have opted to close their educational centres and implement distance learning where feasible in order to curb the spread of COVID-19 [11]. In the context of the COVID-19 pandemic, access to inclusive education in virtual learning environments remains a major challenge [5], [12], [13].

Educators are now embracing new trends [14], and traditional lecture-based models of teaching and learning are merging, or even being replaced, by learning models based on information and communication technologies [15], [16]. Today, mobile technologies and applications (apps) are an indispensable part of education, including language learning [17], due to the utilisation of mobile apps [18], blockchain technology [19], and augmented reality in education [20], as Additionally, the integration of 5G technology and artificial intelligence (AI) in higher education has become increasingly prevalent [21]. In this era of innovation, there is bound to be something life-changing. Portable remote communication, the latest era known as 5G, according to the report, today's organizational innovation has been significantly boosted by high bandwidth and low-latency transmission, along with a substantial increase in transmission speeds and improved reliability [22]. Unlike existing wireless networks, 5G technology offers superior performance, faster data transmission speeds, lower latency, increased connectivity between devices with greater energy efficiency, improved reliability, and support for mobile capabilities.

According to a report published in February 2023 by the Global Mobile Suppliers Association (GSA), 5G deployment around the world is progressing rapidly, with 156 countries having already invested in the fifth generation of mobile technology [23]. It includes testing, planning, deployment, and launches, with the Americas, Europe,

and Asia having the largest deployments in their respective countries. There are over 200 commercial 5G networks launched worldwide [24], with EMEA (Europe, the Middle East, and Africa) having the largest research share, followed by the Americas.

Therefore, the research aims to analyze various articles that help us emphasize the areas of application associated with the adoption of 5G technology and its impact on education, as well as how technology influences the learning process [25]. The aim of obtaining different perspectives is to facilitate progress towards achieving quality, inclusive education.

The rest of the article is organized as follows: Section 2 describes the methodology used to conduct the systematic literature review. Section 3 presents an overview of the results obtained, which are discussed in Section 4. Finally, Section 5 provides a concise summary of the main conclusions drawn from the literature review.

2 METHODOLOGY

2.1 Type of study

To conduct the present study, we employed a systematic literature review [26] as our primary method to identify relevant studies and organize information. Such reviews are recognized as invaluable tools for researchers, providing access to synthesized scientific literature [27]. Meta-analysis, as described in reference [28], is a secondary research method used to combine findings from studies within specific fields. The principal implication of meta-analysis pertains to the rigor and systematicity of the study, aiding in the presentation of empirical evidence across independent research domains [29].

We adopted the PRISMA methodology, which is widely regarded as one of the most effective frameworks for conducting systematic reviews [30] across diverse scientific disciplines. This methodology assists researchers in clarifying and defining the scope of their review, as exemplified by our own efforts [31].

2.2 Research questions

The following four research questions (RQs) were developed to address the objective and highlight the relevant attributes necessary to answer it:

- RQ1. Which countries have the most research implemented and in progress regarding the use of 5G technologies in education?
- RQ2. Which digital technologies are most commonly used to enhance access to quality education?
- RQ3. What are the educational levels at which the utilisation of technology based on the 5G network has the most significant impact?
- RQ4. What are the types of 5G network-based teaching that are most relevant to educational innovation?
- RQ5. What is the impact on performance levels (latency) when a 5G backbone is implemented in education?

2.3 Data collection

A conventional systematic literature search approach was followed, using predefined queries and explicit inclusion/exclusion criteria across a predetermined selection of bibliographic databases.

Databases used. Display the search terms and literature sources utilised in this study, which will be considered throughout the search procedure [32]. To address the research questions, articles were gathered from prominent databases such as Scopus, IEEE Xplore, ScienceDirect, EBSCO Host, and IOP Science. In total, 134 articles were gathered. After applying the inclusion and exclusion criteria, 62 pertinent articles were identified and are depicted in Figure 1.

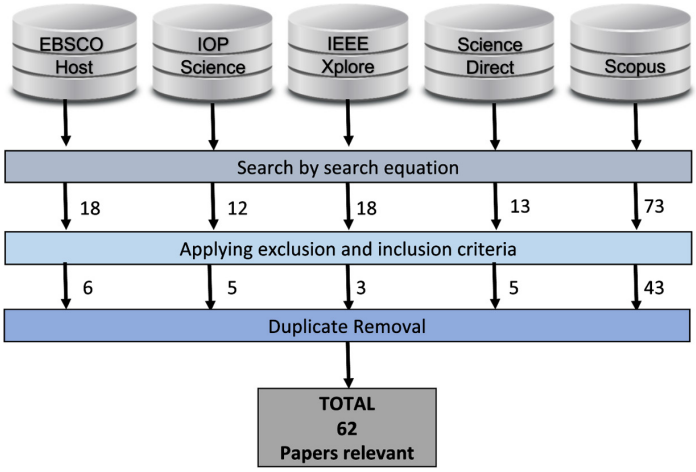

Fig. 1. Element collection chart

Search terms. The search terms were primarily in the English language. Searches included terms related to 5G technology and education (5G, e-learning, and alternative terms like educational innovation) combined with gender issues. Taking into account that when databases allow it, the search is limited to titles, abstracts, and keywords.

The following keywords were considered during the search for information related to the research topic: "5G AND (educational AND innovation) OR (educational AND application)," "educational innovation, 5G digital platforms," "5G education innovation."

Selection of studies. Specific criteria for inclusion and exclusion were employed in the systematic review study (refer to Table 1).

Table 1. Inclusion and exclusion criteria

Criteria		
Inclusion	I01	Articles related to the impact of 5g networks in education.
	I02	Articles focusing on the utilization of digital technologies based on 5G for educational purposes were considered.
	I03	Articles that incorporate a methodology, model, and/or approach in their research process were eligible for inclusion.
	I04	Technology articles related to education.
Exclusion	E01	Articles unrelated to the impact of 5g networks on education.
	E02	Articles unrelated to 5G-based digital technologies utilized for educational purposes.
	E03	Non-education-related technology articles.
	E04	Articles that fail to address the research questions to some extent.

3 MAIN RESULTS

Based on these criteria, 62 studies ultimately participated in the final analysis. Figure 2 illustrates the selection procedure.

Figure 3 illustrates the articles examined within the database.

Figure 4 depicts the annual distribution of published articles across different databases.

The bibliometric methodology or analysis allows for the extraction of literature by analysing and grouping concurrent words, enabling the identification of patterns corresponding to the production of different authors [33]. Bibliometrics is a technique that enables the retrieval, evaluation, and statistical analysis of quantifiable data from the literature of a specific publication. This technique helps fill research gaps and promotes collaboration for future scientific research [34].

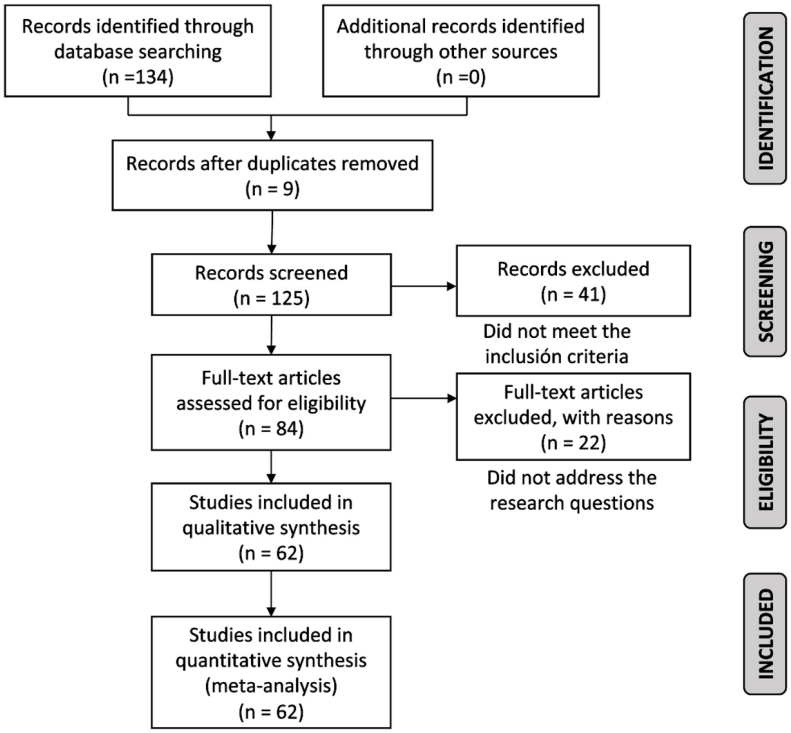

Fig. 2. PRISMA diagram methodology

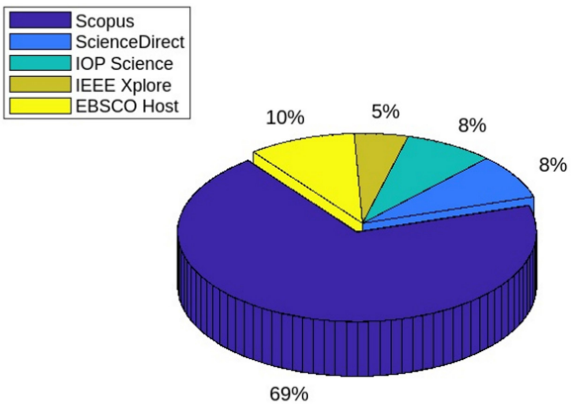

Fig. 3. Articles classified by database

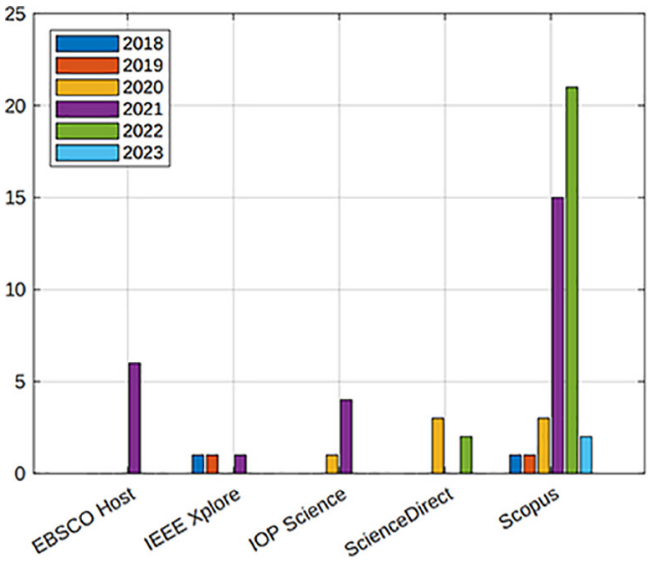

Fig. 4. Distribution of publications by year and database

The VOS viewer software application utilises co-authorship connections, co-citations, and the co-occurrence of significant terms to facilitate the creation and visualisation of bibliometric networks [35]. Using this tool, visualisation maps were generated, as depicted in Figure 5.

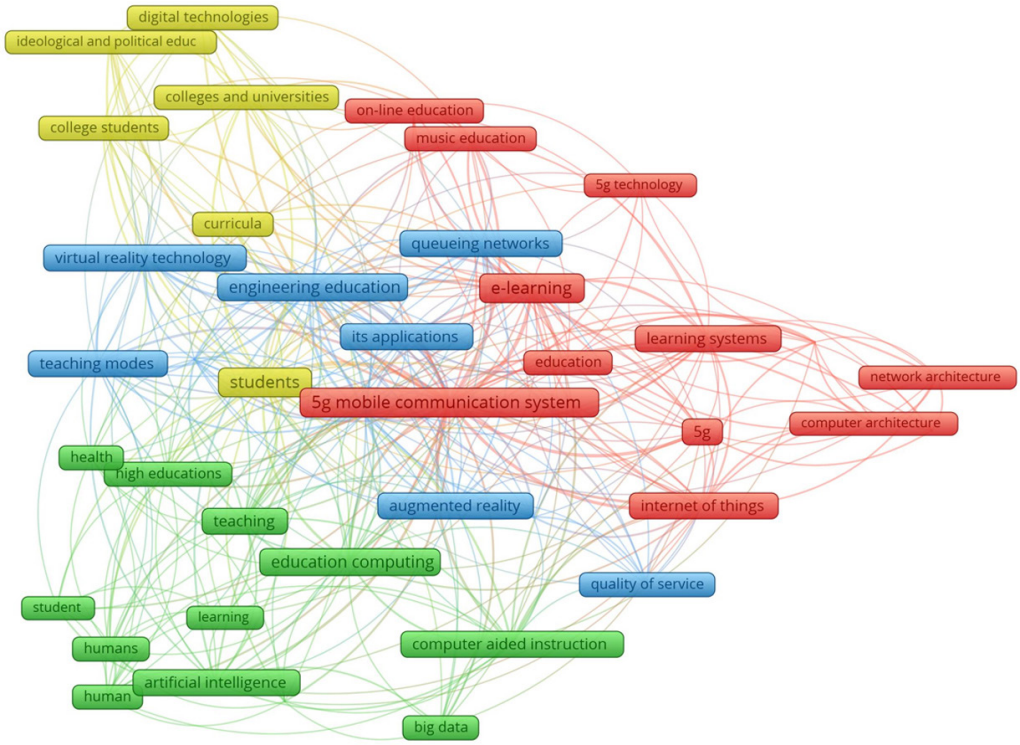

Fig. 5. Network visualization to analyze the bibliometric data of OSNFIM documents accessible in the Scopus database

Figure 6 provides a visual representation of the word cloud derived from the compiled articles, emphasising key terms such as 5G technology, education, e-learning, and smart education.

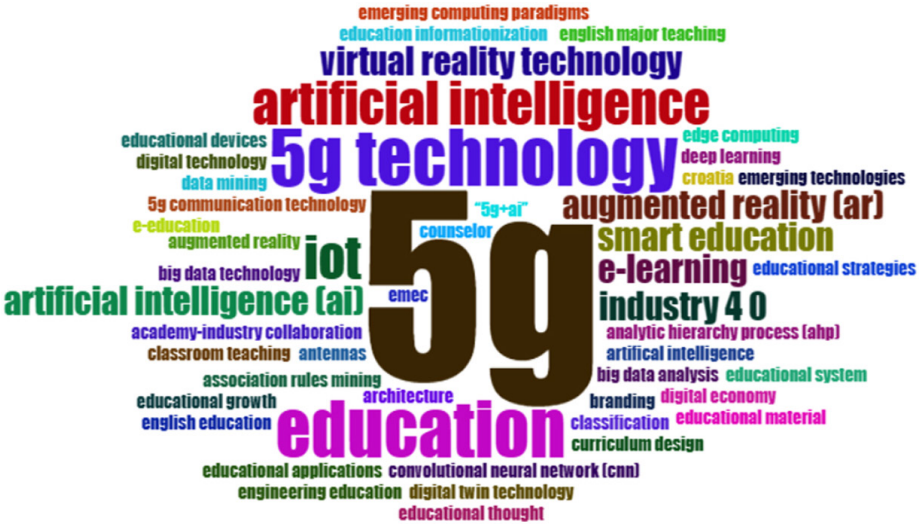

Fig. 6. Word cloud to visually represent the compilation of OSNFIM documents available in the Scopus database

Figure 7 displays a tree map representing the bibliometric analysis, illustrating the proportions of the most frequently occurring keywords.

The classification of the 62 articles based on the research conducted by the continent and the technological tools applied in education is depicted in Figure 8.

The digital instruments used to analyse the 62 selected articles are illustrated in Figure 9, classified by country.

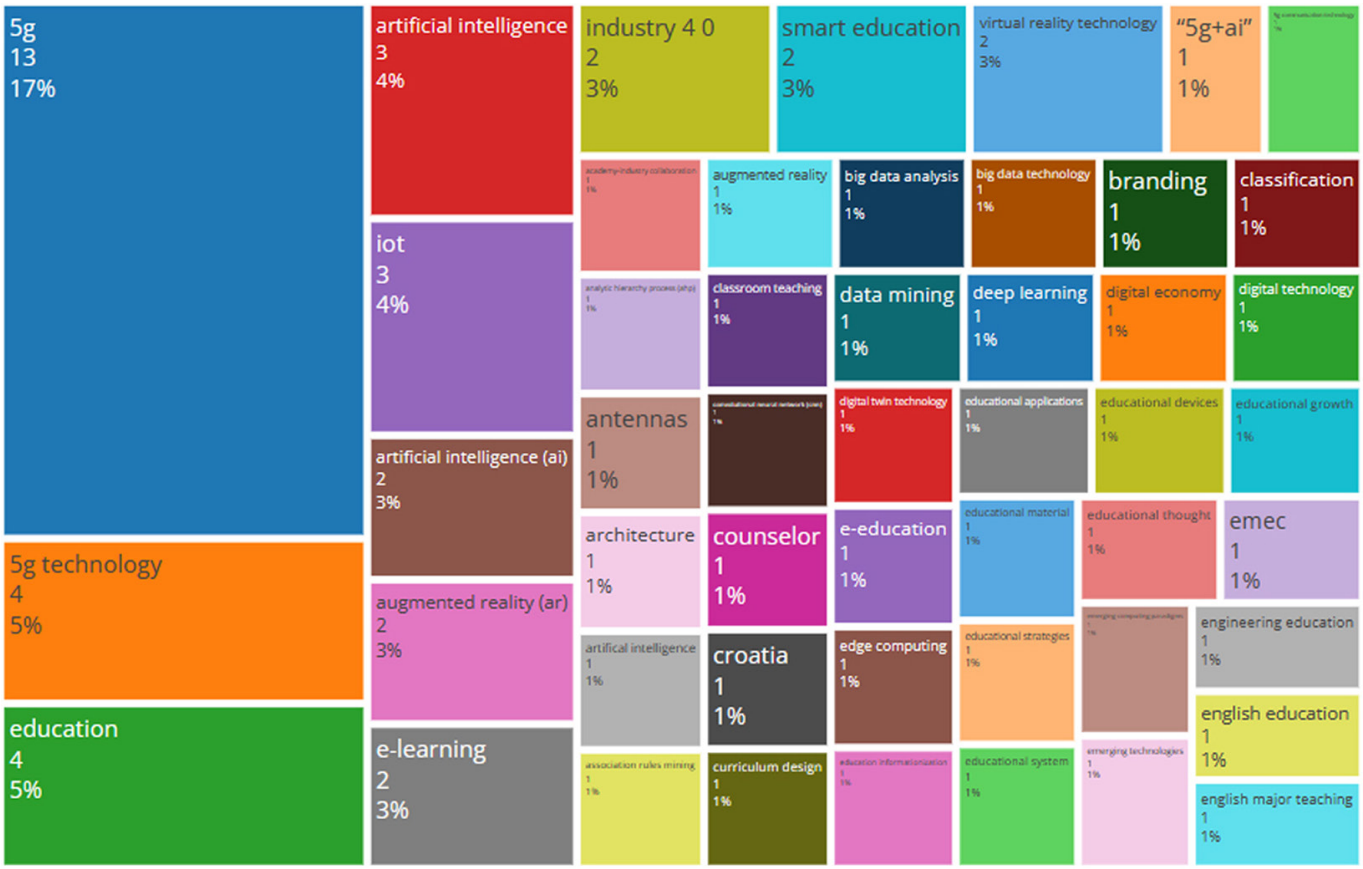

Fig. 7. Visualisation of the tree map to evaluate documents using bibliometric analysis

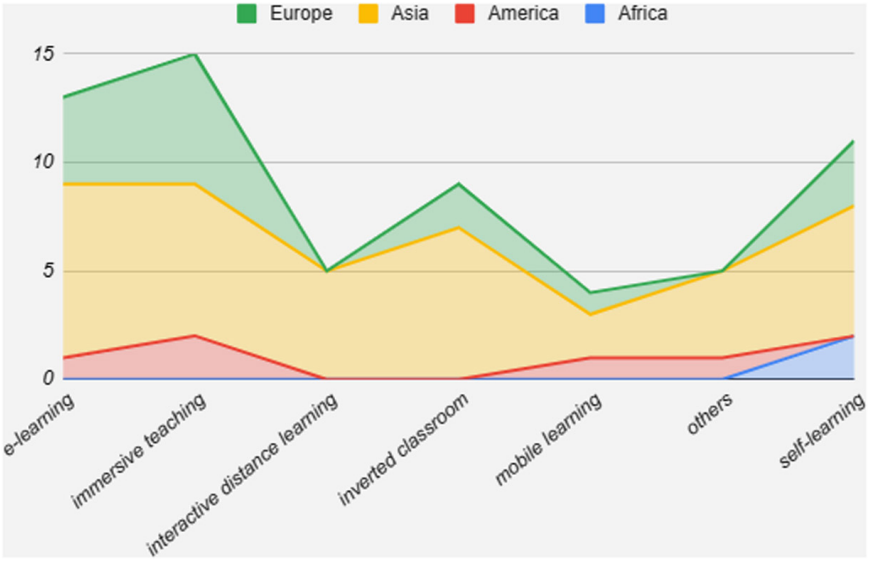

Fig. 8. Articles by technological tools 5G-education and continent

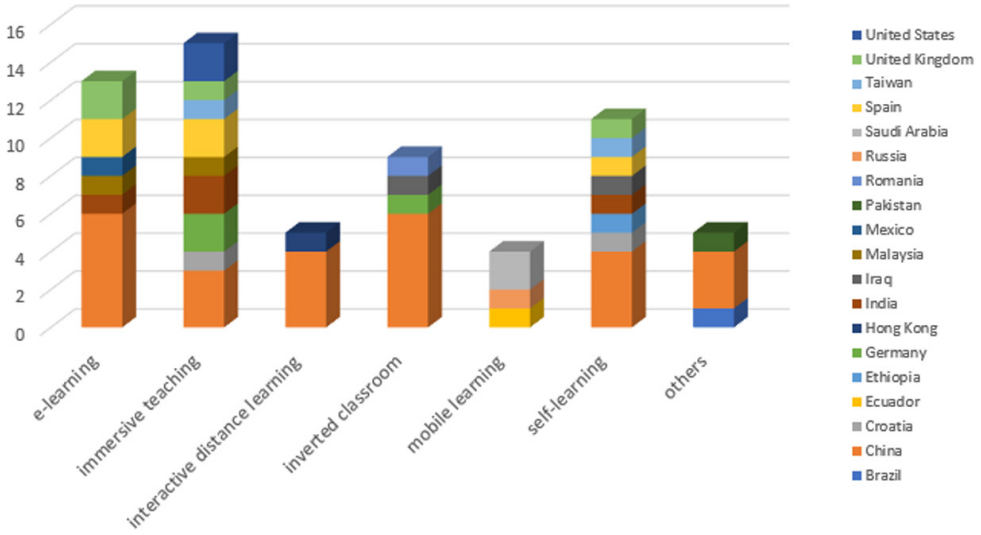

Fig. 9. Digital tools and countries associated with the articles analysed

4 DISCUSSION

The aim of this systematic review is to address the questions raised and propose relevant answers.

4.1 Answering the research questions

RQ1. Which countries have the highest research implementation and ongoing projects related to the use of 5G technologies applied to education? From the article analysis, it is apparent that a significant portion of research primarily focuses on pilot projects or prospective endeavours rather than research already implemented within the 5G infrastructure. Figure 10 illustrates the distribution of articles based on their implementation status, categorised by continent.

Research conducted in Europe demonstrates the highest percentage of implementation, followed by America and Asia.

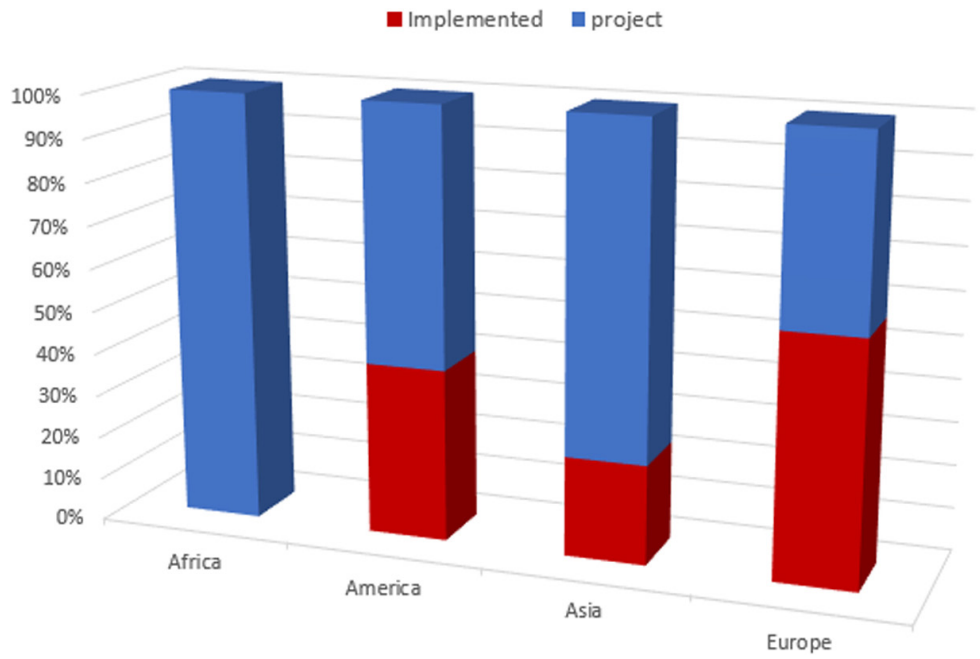

Fig. 10. Distribution of articles by application and continent

Data from the United Nations provides valuable insights into global population statistics [36], [37], allowing us to calculate population density in relation to research conducted using the 5G infrastructure. As depicted in Table 2, Europe exhibits a higher population density, with America following closely behind.

Table 2. Density determined by implemented projects

Continent	Population Million	Implemented	In Project	Total	Density (Implemented/ Population) x 1000
Europe	750	9	7	16	12.0
Asia	4600	9	30	39	1.96
America	1000	2	3	5c	2.00
Africa	1300	0	2	2	0.00
Oceania	43	0	0	0	0.00
Total		11	51	62	

Figure 11 shows the distribution of published articles by country. China leads with 26 selected articles, followed by Spain with five publications. The United Kingdom and India each have four articles, while Germany has three. Croatia, Taiwan, Iraq, and the United States each have two publications. Russia, Romania, Saudi Arabia, Brazil, and Mexico have a smaller number of publications.

Figure 12 provides a comprehensive overview of the articles published by country during the project phase, with a particular focus on those related to the 5G infrastructure. Notable countries highlighted include China, Croatia, Spain, the United Kingdom, Romania, and others.

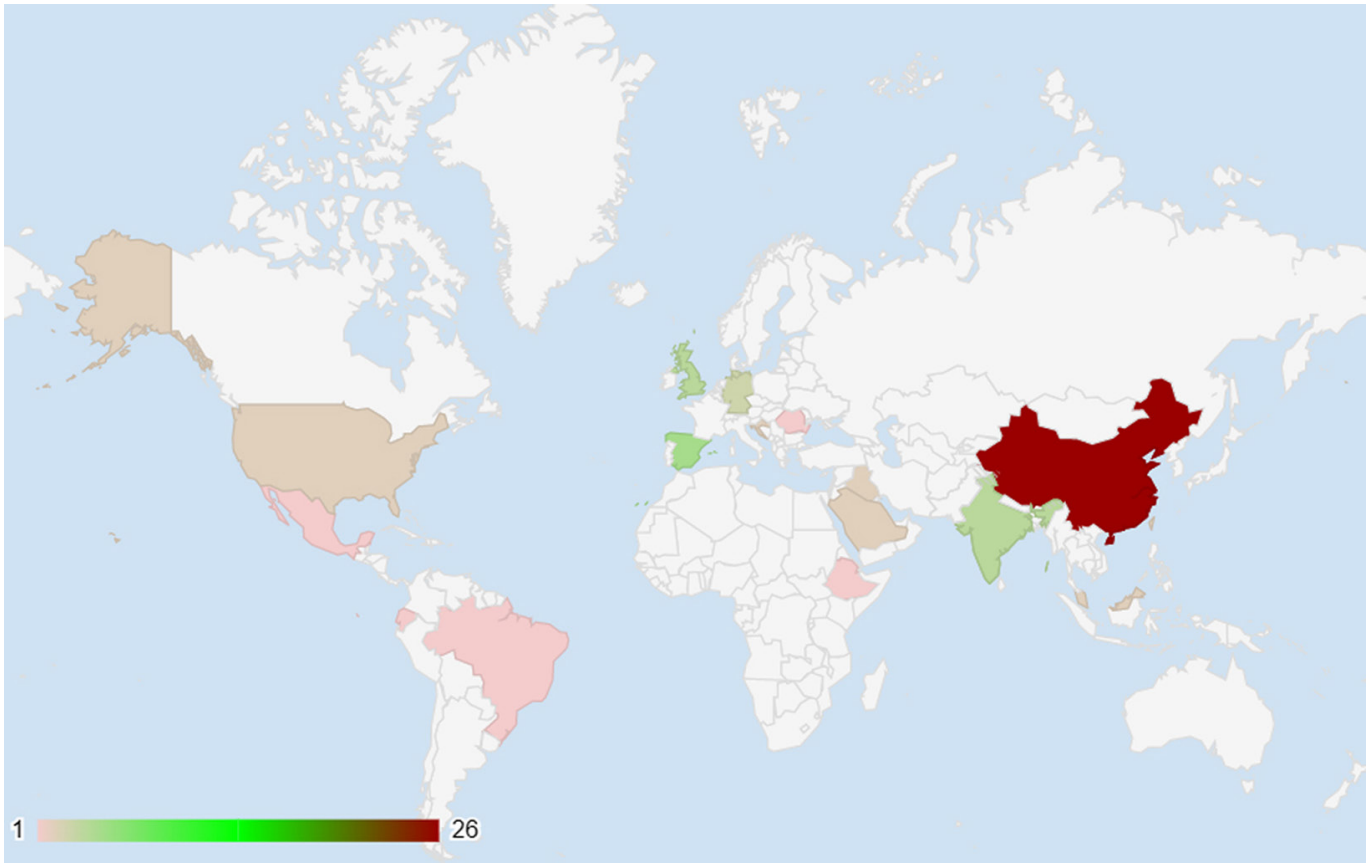

Fig. 11. Distribution of articles published by country

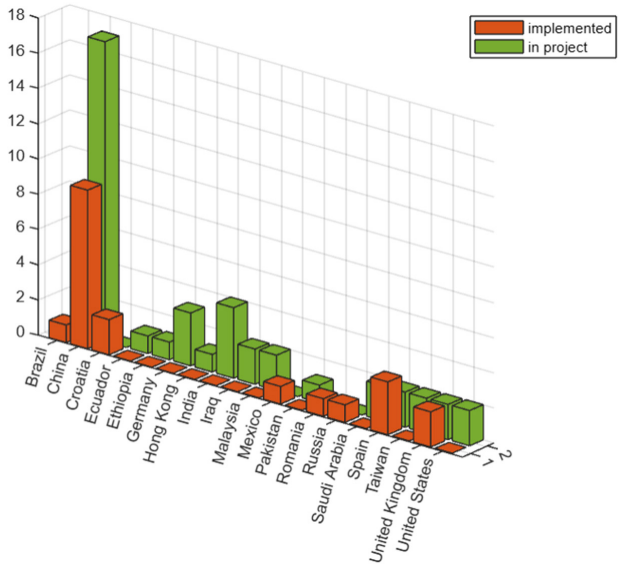

Fig. 12. Comprehensive overview of the articles published by country

RQ2. Which digital technologies are commonly employed to enhance access to high-quality education? Figure 13 illustrates the most significant items analysed based on digital tools: artificial intelligence (24%), the internet of things (17.7%), virtual reality (14.5%), machine learning (14.5%), deep learning (9.7%),

augmented reality (6.5%), big data (4.8%), extended reality (3.2%), cloud computing (1.6%), machine-to-machine (1.6%), and clustering algorithms (1.6%).

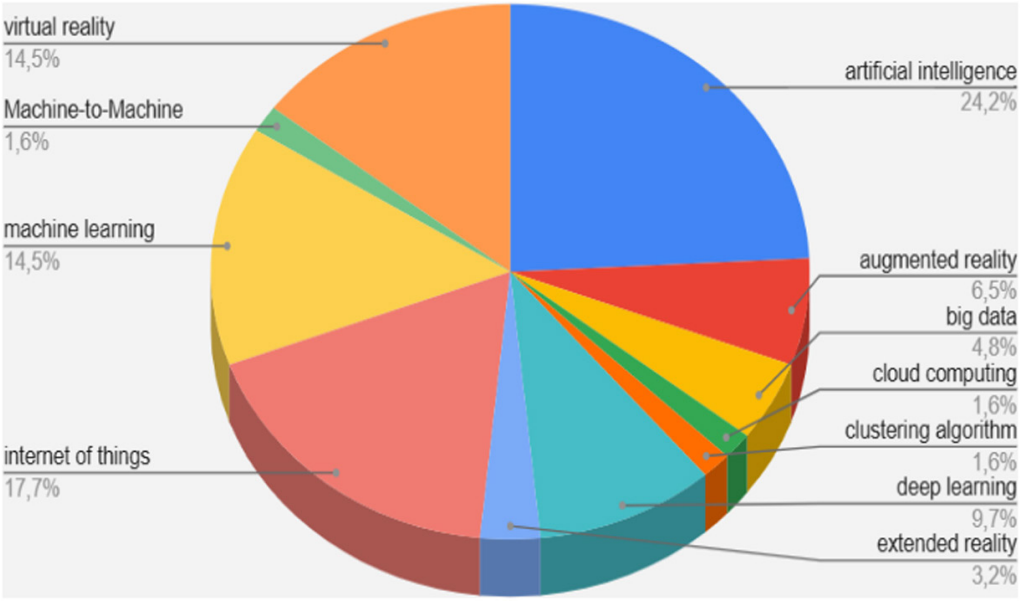

Fig. 13. Distribution of research topics based on digital tools

Table 3 shows that the most commonly used technology is artificial intelligence, enabling greater availability and access to quality education.

Table 3. The articles are classified based on the research conducted on digital tools

Categories	Quantity	Articles
Artificial intelligence	15	[37], [38], [39], [40], [21], [41], [42], [43], [44], [45], [46], [47], [48], [49], [50]
Internet of things	11	[51], [52], [53], [54], [55], [56], [57], [58], [59], [60]
Virtual reality	9	[61], [62], [63], [64], [65], [66], [67], [68], [69]
Machine learning	9	[70], [71], [72], [73], [74], [75], [76], [77], [78]
Deep learning	6	[58], [79], [80], [81], [82]
Augmented reality	4	[83], [84], [85], [86]
Big data	3	[87], [88], [89]
Extended reality	2	[90], [91]
Cloud computing	1	[92]
Machine-to-Machine	1	[93]
Clustering algorithm	1	[94]

RQ3. What are the levels of education at which the use of technology based on the 5G network has the greatest impact? Figure 14 displays the most pertinent articles concerning the influence of 5G technology on educational levels, highlighting higher education and university education as the most significant.

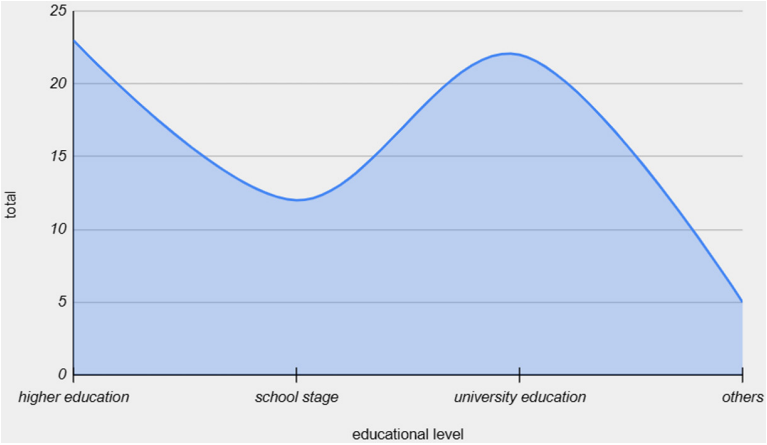

Fig. 14. Distribution of total number of articles published by level of education

Table 4 reveals that the application of 5G network-based technology in education has greater relevance and impact at the higher education and university levels, which allows for improving the quality of educational teaching.

Table 4. Articles classification according to educational level

Categories	Quantity	Articles
Higher education	23	[82], [81], [77], [49], [47], [46], [69], [56], [80], [54], [66], [85], [21], [83], [40], [93], [39], [65], [64], [63], [62], [61], [52]
School stage	12	[91], [50], [57], [76], [75], [42], [90], [41], [55], [74], [89], [71]
University education	22	[37], [87], [38], [51], [58], [60], [59], [79], [45], [78], [43], [68], [86], [67], [73], [94], [84], [72], [53], [92], [88], [70]

RQ4. What are the types of 5G network-based teaching that were most relevant to educational innovation? Figure 15 shows the articles analysed by type of teaching: immersive teaching (15), e-learning (13), self-learning (11), inverted classroom (9), interactive distance learning (5), and mobile learning (4).

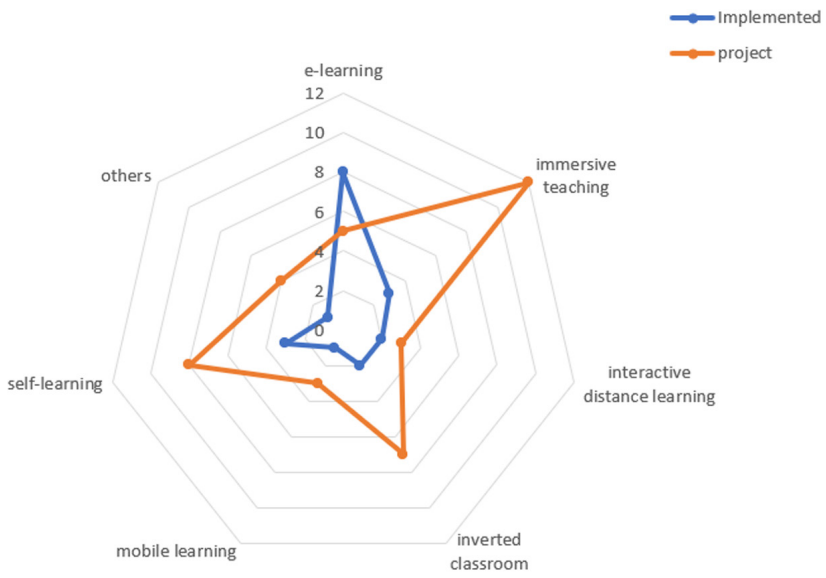

Fig. 15. Distribution of total number of articles published by type of teaching

Table 5 presents articles that demonstrate the use of 5G technology in various educational settings, focusing specifically on the popularity of immersive teaching.

Table 5. Types of 5G-based teaching used in education

Categories	Quantity	Articles
E-learning	13	[78] [82], [38], [81], [56], [55], [67], [73], [54], [40], [72], [61], [52]
Immersive teaching	15	[60], [87], [59], [45], [58], [90], [86], [79], [66], [94], [84], [83], [64], [63], [62]
Interactive distance learning	5	[91], [76], [43], [42], [80]
Inverted classroom	9	[50], [77], [47], [78], [68], [89], [85], [65], [71]
Mobile learning	4	[49], [46], [93], [53]
Self-learning	11	[69], [57], [75], [51], [41], [74], [21], [39], [92], [88], [70]

RQ5. What is the impact on performance levels (latency) with the use of 5G backbone applied to education? Figure 16 details the published articles based on performance levels and latency levels using 5G backbones, illustrating their impact on enhancing the quality of educational instruction.

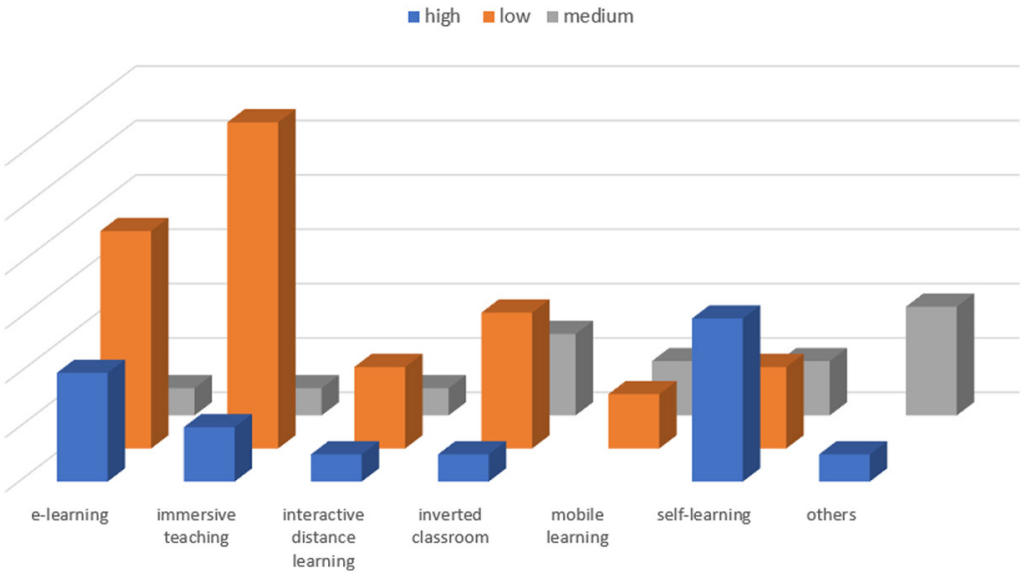

Fig. 16. Distribution of articles by type of education and performance (latency) in using the 5G network

4.2 Looking ahead to future technologies

Looking ahead to the future of education, 5G technology emerges as a revolutionary tool to drive educational innovation [38]. As we delve into an increasingly digitised future, it is essential to explore how the ongoing implementation of the 5G network could further transform the educational landscape by providing a robust platform for the development and adoption of new educational technologies [21], [78]. Its ability to deliver ultra-fast connection speeds with lower latency and increased device connectivity opens up a plethora of possibilities for creating more interactive and dynamic learning environments.

Looking ahead, the integration of artificial intelligence, the Internet of Things, virtual reality, and machine learning, which includes pattern recognition, has the potential to revolutionise the methods of teaching and learning [95], [96], [97], and [98]. These emerging technologies have the capability to facilitate more personalised and adaptive learning experiences, enabling educators to tailor their approach to meet the individual needs of each student.

Moreover, augmented reality and virtual reality could offer unique opportunities for exploration and immersion in educational settings, taking learning beyond traditional classrooms and into new realms of experiential learning [97].

5 CONCLUSIONS

Digital tools for enhancing access to education primarily rely on artificial intelligence, the Internet of Things, and machine learning. The regions with the most research on 5G backbone implementation and education are Europe, followed by Asia and America. Similarly, greater relevance was achieved in 5G-based universities and higher education. Similarly, the authors highlight their research on the availability of access to educational resources and its impact on various teaching methods, such as immersive teaching, e-learning, and flipped classrooms. 5G-based technologies were most commonly used in education.

Projecting into future technologies with the implementation of 5G technology in education opens up an exciting path to educational innovation. It is essential that we continue to research and explore these opportunities to ensure that we are ready to take full advantage of the transformative potential of technology in tomorrow's education.

The results of the systematic review lay the groundwork for future research on e-learning and 5G backbone implementation in various countries. This study also serves as a benchmark for integrating technology in the classroom to enhance teaching and learning, particularly by advancing access to high-quality, inclusive education.

The rapid pace of technological progress can be a limitation, as it can render current educational practices obsolete or necessitate constant adaptation, presenting challenges to both educators and students. In addition to the limitations mentioned above, this study is constrained by the keywords used to select the analysed bibliography. Specifically, the inclusion criteria for "education-related technology articles" encompass a broad area of research where 5G technology may be "hidden" under related terms such as "Wi-Fi," "Internet connection," or "technical difficulties." Consequently, there may be relevant literature on 5G technology in education that has not been captured by the search criteria, limiting the completeness of the analysis.

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