A SYSTEMATIC MAPPING STUDY OF THE EVOLUTION OF EDUCATIONAL PRACTICES USING DISRUPTIVE DIGITAL TECHNOLOGY

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ABSTRACT

This study examines the evolution of educational practices in the digital era and the integration of information technologies in teaching. Through an automated search in six digital libraries, we identified 99 relevant studies spanning the period from 1990 to 2021. We draw on a systematic mapping approach to classify these studies for better analysis. The results indicate that Education 4.0 is characterized by contextualized and student-centered learning. Researchers primarily focus on technical contributions, exploring technologies such as Artificial Intelligence (AI), Internet of Thing (IoT), Virtual Reality (VR), and Augmented Reality (AR). However, few studies have addressed technologies like biofeedback, blockchain, and chatbots. Solution proposals and case studies are the most used approaches. This study highlights the importance of information technologies in education and has significant implications for teachers, educators, researchers, and curriculum designers.

Keywords: *information technology, educational practices, Education 1.0 to Education 4.0, learning method, systematic mapping study*

INTRODUCTION

The evolution of educational practices is crucial to address the changing needs of learners and improve learning outcomes. According to Huk (2021) and Gerstein (2014), traditional teaching methods, often referred to as Education 1.0, are teacher-centered and lecture-based, and cater to all learners in a uniform manner. However, various research studies such as Hmelo-Silver (2004), Sriphong (2019), and de Oliveira et al. (2022) indicate that this approach may not suit all learners and may not promote their engagement and motivation. In this context, it is essential to examine how disruptive technologies have influenced these changes in educational practices, as they can provide valuable insights for practitioners, educators, researchers, and curriculum designers. Education is a constantly evolving field that is influenced by technological advancements that have transformed the traditional methods of teaching and learning. Over the past decades, advancements in information and communication technologies, artificial intelligence (Ciolacu et al., 2018), virtual reality (Al- Khiami et al., 2023), augmented reality (Martin et al., 2018), the internet of things (Ciolacu et al., 2019; Ciolacu et al., 2020; Ramlowat & Pattanayak, 2019) and other related areas have opened new, exciting prospects for education. The World Economic Forum recognizes these technologies, often referred to as

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"disruptive,, as having the potential to transform educational practices by offering features such as personalized learning, enhanced collaboration among learners (Grinshkun & Osipovskaya, 2020), innovation and creativity, immersive learning experiences through the integration of augmented reality (AR) and virtual reality (VR) in the teaching process (Pierdicca et al., 2020), and gamification (Ibda et al., 2022; Khaldi et al., 2023), along with extended access to a variety of educational resources. This redefinition aims to enrich the learning experience by offering more interactive, personalized, and stimulating learning opportunities (Bhattacharjee et al., 2018). This approach can be applied at all levels of education, from primary school to university, as well as in professional training contexts (Huk, 2021).

However, despite the growing interest in integrating these technologies in educational environments, there are still gaps in our understanding of their true impact on educational practices (Kaminskienė et al., 2022). This justifies the need for this study. By conducting a systematic mapping study on the evolution of educational practices traced through the use of disruptive technologies from Education 1.0 to Education 4.0, we aim to identify trends, themes, and gaps in the existing literature. This exploration will provide an in-depth understanding of the impact of these technologies on learning and identify best practices for their effective use. We also seek to understand the current state of knowledge, identify disruptive technologies, analyze their effects on educational practices, and examine the associated advantages and challenges.

By studying different phases of education, a comprehensive understanding of the evolution of teaching methods, pedagogical approaches, and the technologies used can be obtained. This will help us better grasp the current context of education and put ongoing changes into perspective. Ultimately, this research will contribute to guiding educators, policymakers, and researchers in their efforts to improve educational practices and optimize the use of disruptive technologies for the benefit of learners and educators. For this purpose, we selected 99 relevant studies in the field of teaching and learning from the initially collected 773 papers.

The rest of this study is organized as follows: Section two presents the research methodology adopted for this systematic mapping study. Section three presents the results of the classification of the studies under review. Section four discusses the results. Section five addresses the implications for teachers, educators, researchers, and curriculum designers. Section six concludes by highlighting some limitations of the conducted studies and providing prospects for future work.

RESEARCH METHODOLOGY

This study has been organized as a systematic mapping study based on the process proposed by Petersen et al. (2008). As shown in Figure 1, the key steps in the process of our systematic mapping study are (1) defining research questions, (2) developing a research strategy, (3) selecting studies, (4) keywording using abstracts, and (5) implementing data extraction and the mapping process. These steps are explained in the following subsections.

Figure 1.
The Systematic Mapping Process

Mapping Questions

This systematic mapping study aims to provide a comprehensive overview of studies published from 1990 to 2021 on the application of digital technology in education. Table 1 serves as a guide, clearly presenting the five research questions that we explore in our study set out to explore along with the core motivation for each question. Over the span of the years we examined, the growing impact of technology on teaching and learning methods becomes increasingly apparent, and our study seeks to make a crucial contribution to the overall understanding of this pedagogical transformation.

Table 1.
Research questions

ID	Review Question	Main Motivation
RQ1	What are the trends of digital technologies in Education research in terms of: publication year, source, and geographic region?	To recognize the distribution of articles in the various publishing channels and identify the way towards future articles.
RQ2	What are the existing disruptive digital technologies in Education?	To discover the frequency of publications according to the types of technologies.
RQ3	How has the use of information technology in Education changed over time?	To be aware of IT types circulating in the field of Education in the last three decades.
RQ4	Which learning channel do researchers process the most?	To have insight into the learning trends of students.
RQ5	What are the most popular learning methods?	To pick out the suitable learning method to be used in future surveys.

SEARCH STRATEGY

This subsection aims to find relevant studies that would help answer the research questions in Table 1. The first phase of the search strategy was to build the search string, and the second phase consisted of applying this search string to a set of selected digital libraries to find all the relevant studies. In the third phase, we followed a search procedure to ensure that no relevant documents had been missed. The three phases are explained in the following subsections.

Search string

The development of terms and their equivalents constituted a crucial step that occurred after a preliminary search yielded a significant number of irrelevant results. This meticulous selection grew from our efforts to refine the relevance of the research, which required exploring various combinations of search elements. Our team diligently worked to identify the most suitable key terms, thus undertaking multiple rounds of search iterations until arriving at a carefully adjusted set of keywords, as shown in Table 2. This process of methodical refinement reflects our commitment to ensuring that the chosen terms effectively captured the essence of our inquiry and accurately guided our exploration in the study's domain.

Table 2.
Initial search string

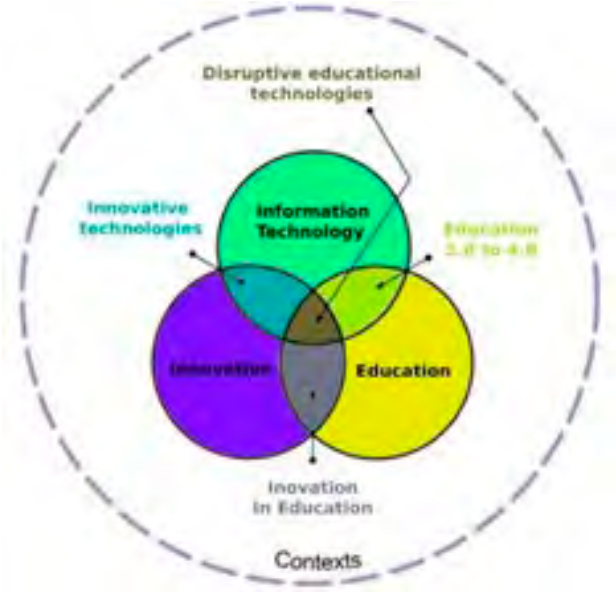
Topic	Search Terms
Disruptive Digital Technology	"digital technology" OR "information technology" OR "social network" OR "artificial intelligence" OR "internet of things" OR "machine learning" OR "deep learning" OR "big data" OR "blockchain" OR "virtual reality" OR "augmented reality" OR "cloud computing" OR "printer 3D" OR "chatbot" OR "intelligent tutoring system" Or "multi-agent system" OR "intelligent agent"
	AND
Education	"education" OR "learning" OR "teaching" OR "literacy" OR "learn*" OR "student*"
	AND
Not Digital Literacy	"Not digital literacy" OR "digital natives" Or "digital immigrants"

We then combined the different terms using the operators AND, OR, and NEAR (*) to improve the results' completeness (Figure 2). Here is the initial search string after its formulation: ("digital technology" OR "information technology" OR "social network" OR "artificial intelligence" OR "internet of things" OR "machine learning" OR "deep learning" OR "big data" OR "blockchain" OR "virtual reality" OR "augmented reality" OR "cloud computing" OR "printer 3D" OR "chatbot" OR "intelligent tutoring system" OR "multi-agent system" OR "intelligent agent") AND ("education" OR "learning" OR "teaching") AND ("disruptive" OR "innovative")

Literature resources

We searched with the established search string six major scientific databases: SCOPUS, Web of Science, ACM Digital Library, IEEE Xplore, ScienceDirect, and Springer Link (books). Since the ScienceDirect scientific database does not accept using more than eight connectors in a topic and does not accept the use of the operator (*)

Figure 2.
Disruptive Educational Technologies



asterisk, we subdivided the initial research string into eight strings. A list of them is given in Table 3. After searching the six databases, we obtained the following search results: Scopus (160 papers), Web of Science (71 papers), ScienceDirect (246 papers), Springer Link (222 papers), ACM Digital Library (29 papers), and IEEE Xplore (45 papers).

SEARCH PROCESS

To ensure a comprehensive approach to examining the applications of information technology in the field of education, our research process was divided into three distinct stages. Each of these stages was carefully designed to delve deeply into the research questions and enable a meticulous analysis of the various aspects of integrating information technology into education. This tripartite structure ensured a methodical progression, thereby facilitating a comprehensive and thorough understanding of the subject under study.

Stage 1: Initial Search

We initiated the automated research process by implementing specific search strings within each of the six databases. This approach enabled us to target and extract relevant articles that aligned with our research objectives. Through this methodology, we were able to gather a precise selection of

Table 3.
List of Research Strings

	Research Strings
Q1	("Digital Technology" Or Information Technology) AND ("Education" OR "Learning" OR "Teaching") AND ("Education 1.0" OR "Education 2.0" OR "Education 3.0" OR "Education 4.0")
Q2	("Social Network" OR "Social Media") AND ("Education" OR "Learning" OR "Teaching") AND ("Education 1.0" OR "Education 2.0" OR "Education 3.0" OR "Education 4.0")
Q3	("Intelligent Tutoring System" OR "Multi-agent System") AND ("Education" OR "Learning" OR "Teaching") AND ("Education 1.0" OR "Education 2.0" OR "Education 3.0" OR "Education 4.0")
Q4	("Artificial Intelligence" or "Deep Learning" Or "Machine Learning" OR "Neural Networks") AND ("Education" OR "Learning" OR "Teaching") AND ("Education 1.0" OR "Education 2.0" OR "Education 3.0" OR "Education 4.0")
Q5	("Blockchain" OR "Chatbot") AND ("Education" OR "Learning" OR "Teaching") AND ("Education 1.0" OR "Education 2.0" OR "Education 3.0" OR "Education 4.0")
Q6	("Internet of Things" OR "Big Data") AND ("Education" OR "Learning" OR "Teaching") AND ("Education 1.0" OR "Education 2.0" OR "Education 3.0" OR "Education 4.0")
Q7	("Cloud Computing" OR "Printer 3D") AND ("Education" OR "Learning" OR "Teaching") AND ("Education 1.0" OR "Education 2.0" OR "Education 3.0" OR "Education 4.0")
Q8	("Virtual Reality" OR "Augmented Reality") AND ("Education" OR "Learning" OR "Teaching") AND ("Education 1.0" OR "Education 2.0" OR "Education 3.0" OR "Education 4.0")

articles that met the defined criteria, thus making a significant contribution to enriching our study.

Stage 2: Scan References

In this stage, we retrieved the relevant studies by analyzing the references of the shortlisted studies (from the first step) to avoid any missed articles not listed in the primary search. The investigation was based on the title, abstract, keywords, and full text of the article, if necessary. This step ensured that the research covered the maximum number of studies relating to the applications of IT in education.

Stage 3: Study Selection

In this pivotal step, our objective was to meticulously choose relevant studies that shed light on the research questions. To ensure a rigorous selection, we meticulously applied the inclusion and exclusion criteria outlined in Table 4, thus methodically determining the inclusion or exclusion of each article. This process of selective screening was undertaken with a keen focus on precision, thereby ensuring the coherence and relevance of our research corpus.

Table 4.
Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Published 1990– October 2021 English Empirical, primary research Indexed Indexed in Web of Science or Scopus Journal article or Conference Proceedings Use case of IT in learning	Published before 1990 Not in English Not primary research (e.g., review) Not Indexed Web of Science or Scopus Not a journal article No IT in Education Duplicate papers Papers that were available just in the form of abstracts and/ or PowerPoint presentations

Data Extraction and Synthesis Method

The purpose of this subsection was to extract relevant information from the selected articles to answer the research questions in Table 1. Table 5 presents an extraction form. The data extraction process was done in two steps. First, one researcher read the full text of each selected study and collected the relevant data for the research questions. Next, another researcher verified the extracted data. Any disagreement between the verifier and the extractor was resolved through mutual discussion.

Table 5.
Data Extraction Form

Data extractor
Data checker
Study identifier
Paper title
Author's name(s)
Publication year
Source
URL
RQ1: What are the trends of digital technologies in educational research in terms of publication year, source, and geographic region?
Requires identification of the source, channel, and year of publication for each selected article.
RQ2: What are the existing disruptive digital technologies in education?
Selected papers can be classified by IT and research type.
RQ3: How has the use of information technology in education changed over time?
Selected papers can be classified into the following types:

- By IT and publication year
- By generation of Education: Education 1.0; Education 2.0; Education 3.0; Education 4.0

RQ4: Which learning channel do researchers process the most?
By learning channel.
RQ5: What are the most popular learning methods?
By learning methods and year of publication.

RESULTS

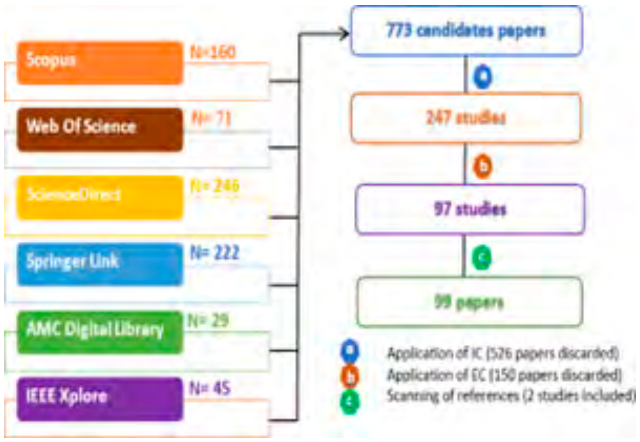
Within this third section, our exploration focuses on the results stemming from the classification and categorization of the data extracted from the selected studies (see Figure 3) in conjunction with responses to the research questions. This pivotal step allows us to delve deeper into our understanding of the emerging trends and findings in the studied field. In this segment, we undertake an in-depth examination of the outcomes arising from the selection process that sheds light on the criteria that guided our choices and the implications of this rigorous selection on our subsequent analysis. This detailed analysis serves as a robust foundation for systematically exploring the various dimensions of the collected data and contributes to illuminating our discussion on the impact of information technologies in education.

Overview of the Selection Process Results

Based on abstracts and keywords, we first filtered out all publications not related to education or not published in peer-reviewed conferences or journals (e.g., technical reports and master theses). Next, through a second round of filtering based on the full text of some articles, we removed the publications that were concerned with applying IT for tasks that are not directly related to learning, such as university orientation for freshmen, library orientation, academic advising, etc. As a preliminary

result, 773 papers were recorded in the six scientific databases (Scopus, Web of Science, ScienceDirect, Springer Link, ACM Digital Library, and IEEE Xplore). Applying the inclusion and exclusion criteria (see Table 4) excluded 676 items from the selection, and after scanning the references, we added two additional articles. In the end, 99 relevant papers (Figure 3) were retained and analyzed to answer the research questions.

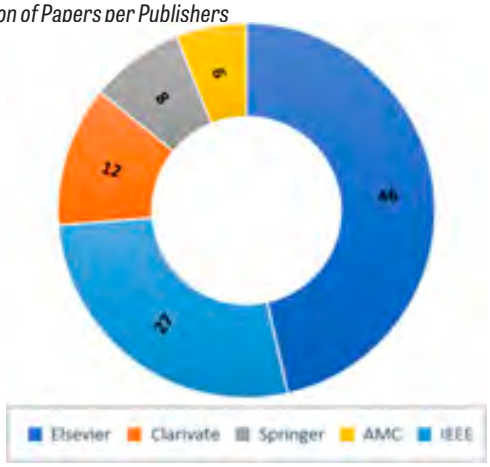
Figure 3.
Results of the Study Selection Process



RQ1: What are the trends of digital technologies in educational research in terms of publication year, source, and geographic region?

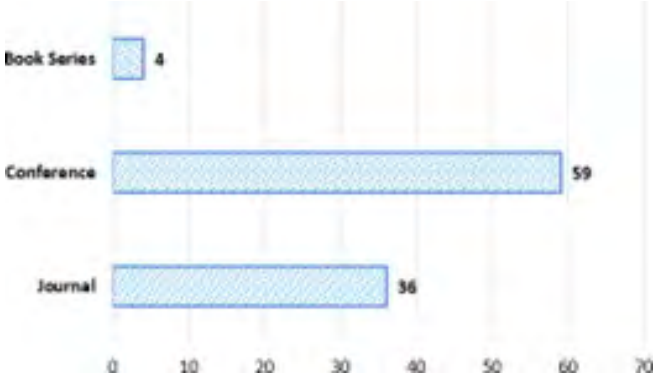
The 99 selected papers were gathered from five publishers, as illustrated in Figure 4. Elsevier contributed 46 papers, while IEEE accounted for 27 papers. Additionally, 12 papers were obtained from Clarivate, eight studies from Springer, and six papers from ACM.

Figure 4.
Distribution of Papers per Publishers



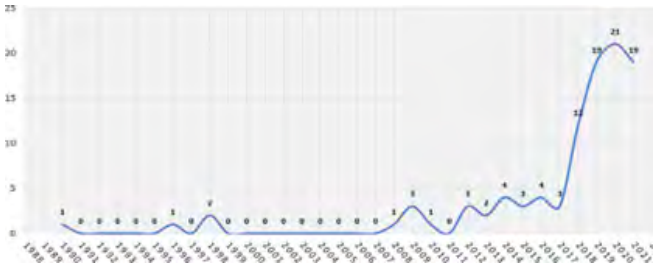
As depicted in Figure 5, most articles were published in conference proceedings (59 papers). In addition, there were 36 papers from indexed journals and four papers that originated from the Book Series.

Figure 5.
Publication Sources



As shown in Figure 6, we noticed that the production of papers in the educational field started to rise in 2018, especially during the COVID-19 pandemic. We noted that there is a considerable increase in innovative digital technologies in student learning, which occurred as the global education system was inevitably turning to distance or hybrid learning.

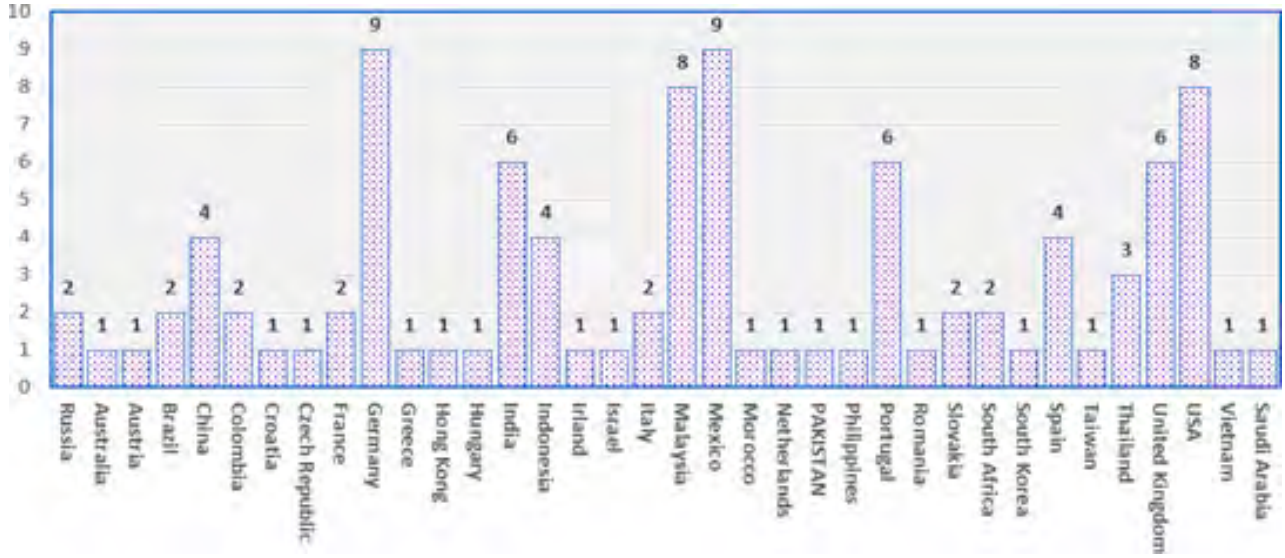
Figure 6.
Distribution of Papers per Year



As illustrated in Figure 7, Germany and Mexico had nine papers each, the United States and Malaysia eight papers each, and India, Portugal, and the UK had six papers each. These are the countries that contributed the most among the 36 countries in the study. In contrast, the rest of the countries had four or fewer studies each.

In terms of graphical representation per year and country of production (Figure 8), the countries that

Figure 7.
Distribution of Papers per Country

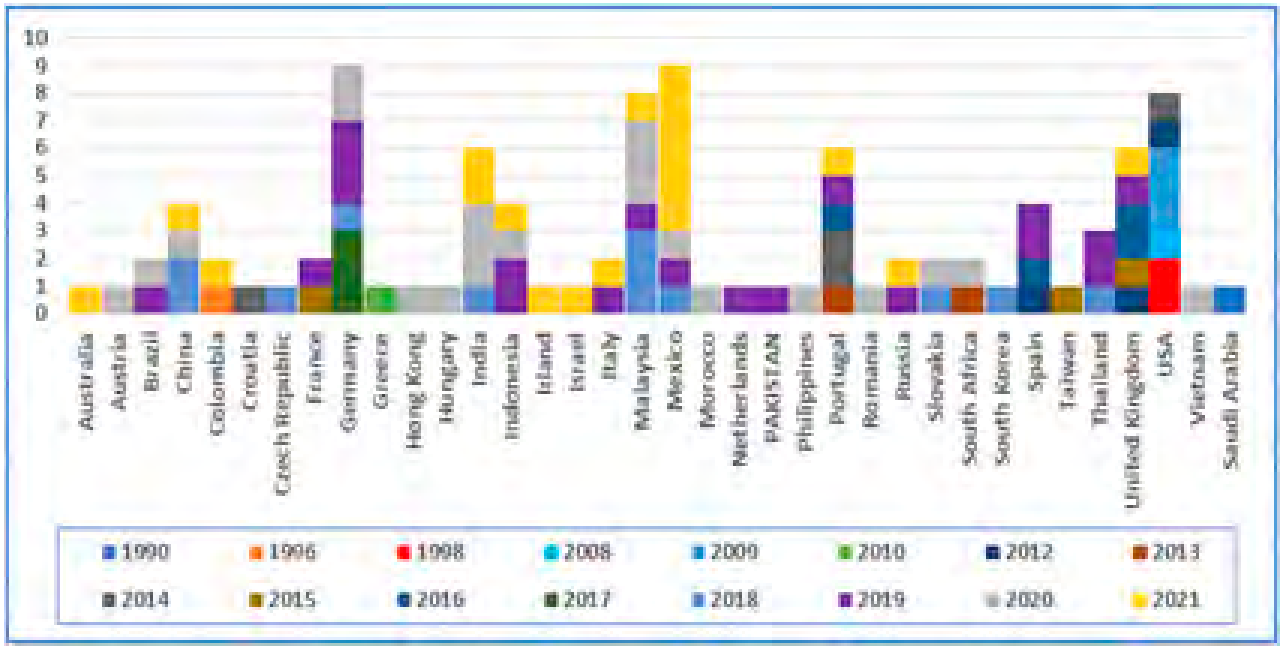


contributed the most during the period 2018–2021, when there was a significant increase in the use of information technologies, are Mexico (one paper in 2018, one in 2019, one in 2020, and six in 2021), Malaysia (three papers in 2018, three in 2020, and one in 2021), Germany (one paper in 2018, three in 2019, and two in 2020), India (one paper in 2018, three in 2020, and two in 2021), China (two papers in 2018, one in 2020, and one in 2021), Indonesia (two papers in 2019, one in 2020, and one in 2021), and the United States (three papers in 2018), while the remaining countries are represented by zero, one, or two papers for each.

RQ2: What are the existing disruptive digital technologies in education?

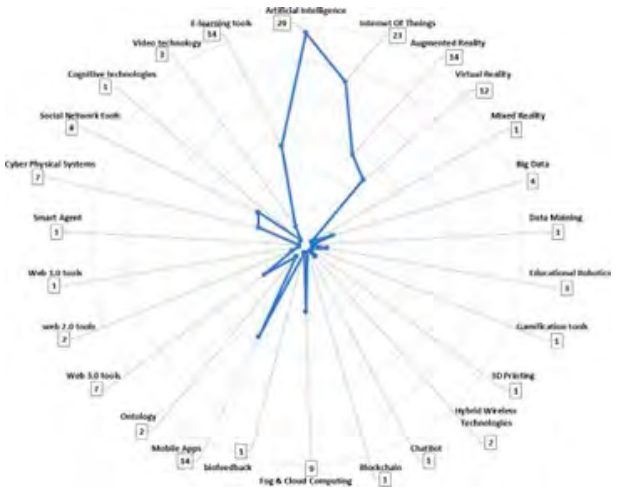
Innovative technologies are concerned with developing new techniques and technologies for human advancement, and they have become

Figure 8.
Distribution of Papers per Year by Country



indispensable in all areas, particularly in education. Figure 9 depicts the distribution of relevant studies using information technology in the educational field, particularly for human learning, from 1990 to 2021. During data extraction, we discovered that some studies dealt with more than one technology, such as Verma et al. (2021), which focused on the use of the internet of things (IoT), fog and cloud computing, and the study (Daniyan et al., 2020) that combines artificial intelligence (AI) and IoT.

Figure 9.
Distribution of Papers According to the Use of IT in Education



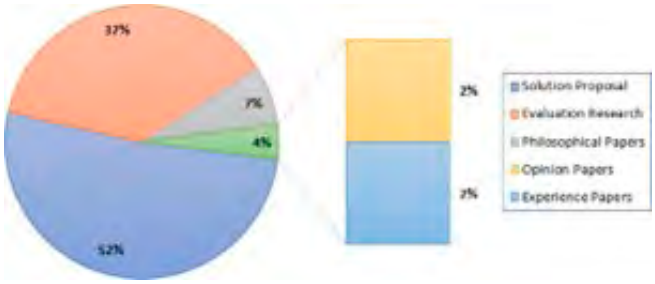
As shown in the graphical representation in Figure 9, we discovered that AI, with its technologies, algorithms, and methods, has the most papers with 29. This means that incorporating artificial intelligence into education has provided educators with educational opportunities that they have successfully used to guide their students through the learning process (Zawacki-Richter et al., 2019). The internet of things has 23 papers because the researchers incorporated objects in the learning process. Wearable devices, smartwatches, sensors, biosignals, and biofeedback Ciolacu et al., 2019), Google and Levi's intelligent Jacquard clothing, Google glasses, and multisensory objects (Zhamanov et al., 2017) are examples of innovative technologies used to improve student's learning. Next, augmented reality, mobile apps, and elearning tools have 14 papers each, followed by virtual reality with 12 papers, cloud computing with nine papers, and social networking tools with eight papers.

The widespread presence of augmented reality is due to its characteristics that can be used in various educational settings, particularly in experiential learning (Jose et al., 2020), where it can be combined with virtual reality to improve learning capacity. Some of its applications in the field of student learning are learning the micro- and macroworlds in chemistry (Cai et al., 2014), teaching the presentation of objects in space in geometry (Rizov & Rizova, 2015), capturing works of art in museums (Sáez-López et al., 2020), and learning the function of human body organs in biology (Petrov & Atanasova, 2020), among others.

Classification Based on the Type of Research

This classification aimed to get an idea of the frequency of IT solutions offered in the field of Education. As seen in Figure 10, 52% of the selected studies (51 papers) were technological solutions, with evaluation research accounting for 37% of the studies (37 papers). This shows that researchers continue to develop technological solutions that can improve students' learning.

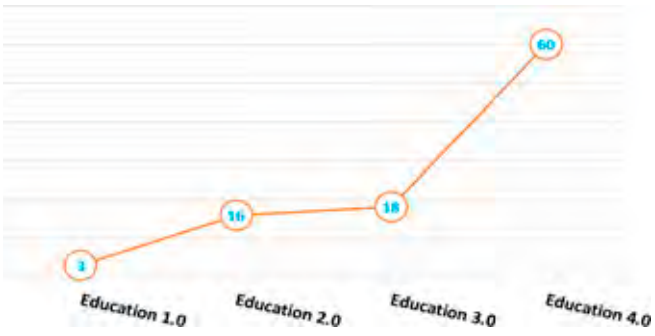
Figure 10.
Distribution of Papers by Research Type



RQ3: How has the use of information technology in education changed over time?

The graph in Figure 11 illustrates the distribution of papers across different educational paradigms. Specifically, three papers centered on Education 1.0, while Education 2.0 was represented by 16

Figure 11.
Distribution of Papers by Education Generation



papers. Additionally, Education 3.0 was the subject of 18 papers, and there was a notable emphasis on Education 4.0, which was addressed by a significant majority of 60 papers.

Educational Practices Evolution: From Education 1.0 to Education 4.0

The evolution of technology arises from the economic and social needs of human beings. These changes have also had an impact on the educational field. Gerstein (2014) identified the process of these changes in which the education development stages 1.0, 2.0, and 3.0 were linked to the development of Web 1.0, 2.0, and 3.0.

Education 1.0: Informational Learning

Much like Web 1.0, which was characterized by one-way communication and information sharing through HTML code, Education 1.0 revolved around the instructor's role in imparting knowledge. This traditional educational approach involved the transmission of information from teacher to students. Furthermore, students had the option to access course materials through textbooks and digital platforms (Sulaiman et al., 2018).

Education 2.0: Collaborative Learning

The concept of Web 2.0 emerged from the second stage of web development (Vagelatos et al., 2010), in which users could communicate with one another (e.g., through social networks; Brown & Adler, 2008) and edit the content of websites (e.g., weblogs and wikis; Rosen & Nelson, 2008). With the help of Web 2.0 tools, Education 2.0 replaced Education 1.0, which was centered on the teacher, with a collaborative and participatory model that allowed for knowledge sharing between student and student, student and teacher, student and pedagogical content, and student and experts (DePietro, 2013).

Education 3.0: Personalized Learning

In Web 3.0, collaboration was assigned to artificial intelligence and the semantic web, allowing computers to understand information. As a result, Education 3.0 is a personally oriented education based on web technologies. This approach transformed the teacher into a guide, orchestrator, collaborator, coordinator/facilitator, advisor, and learner (Gerstein, 2014; Twyman, 2014), while the learner became more creative, conducted research, and transitioned from a passive student to an actively engaged learner in developing their skills. According to Kloos et al. (2019), various technologies such as internet-based Computer Supported Collaborative Learning, augmented reality, adaptive learning, intelligent tutoring systems, gamification, and many others have been implemented to support students in their learning processes within the framework of Education 3.0. These tools and approaches promote interactive pedagogy and enable students to collaborate, experiment, and actively engage in their learning.

Education 4.0: Ubiquitous Learning

Ubiquitous learning, also known as ubiquitous education, refers to an educational concept where learning takes place continuously and seamlessly in various environments through the use of communication and information technologies. Learners can access resources and participate in learning activities anytime and anywhere using mobile devices, applications, and online platforms (Vallejo-Correa et al., 2021).

Based on El Guabassi et al. (2018), this type of learning emphasizes flexibility, adaptability, and personalization and allows learners to choose their own pace and learning style. It also promotes collaboration and social interaction among learners, teachers, and educational resources.

Key technologies used in ubiquitous learning include mobile devices, wireless networks, virtual environments, AI, IoT, and location-based systems. The goal of ubiquitous learning is to provide more accessible, personalized, and engaging learning opportunities by leveraging the benefits offered by digital technologies in various educational contexts, including formal, informal, and lifelong learning (El-Sofany & El-Seoud, 2022).

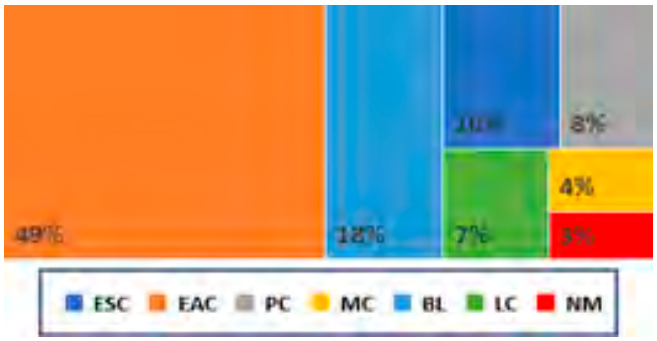
RQ4: Which learning channel do researchers process the most?

Previous research, such as Chan and Fung (2020), classified learning channels into four categories: Electronic Asynchronous Channel (EAC), Electronic Synchronous Channel (ESC), Physical Channel (PC), and Mobile Channel (MC). We have included three other channels: (a) Blended Learning (BL) for studies that use EAC, ESC, and PC to provide learning; (b) Laboratory Channel (LC) for studies that deliver learning through hands-on experience, whether in person or remotely; and (c)

Not Mentioned (NM) for studies that do not specify the type of learning channel used.

Based on these types of channels, the classification shown in Figure 12 shows that 49% of the studies (EAC) used asynchronous channels to learn, such as forums, MOOCs, and learning management systems, 18% (BL) involved hybrid learning, 10% (ESC) dealt with online learning (e.g., online lecture, virtual conference), 8% (PC) were related to courses supported by information technology in the physical classroom, 7% (LC) linked to learning by doing in physical or virtual laboratories, 4% (MC) involved learning through mobile applications, and 3% (NM) do not specify any channel at all.

Figure 12.
Distribution of Papers per Learning Channel



RQ5: What are the most popular learning methods?

To answer this question, we categorized the studies based on learning method and year of publication (Figure 13). The classification reveals that 15 papers did not mention the method used, 14 employed collaborative learning, 13 used self-learning, nine relied on personalized learning, nine utilize interactive learning, six employed competency-based education, five used learning by doing, and five relied social network-based education. While active learning, student-centered learning, and project-based learning are all innovative methods, they are utilized in only a few articles.

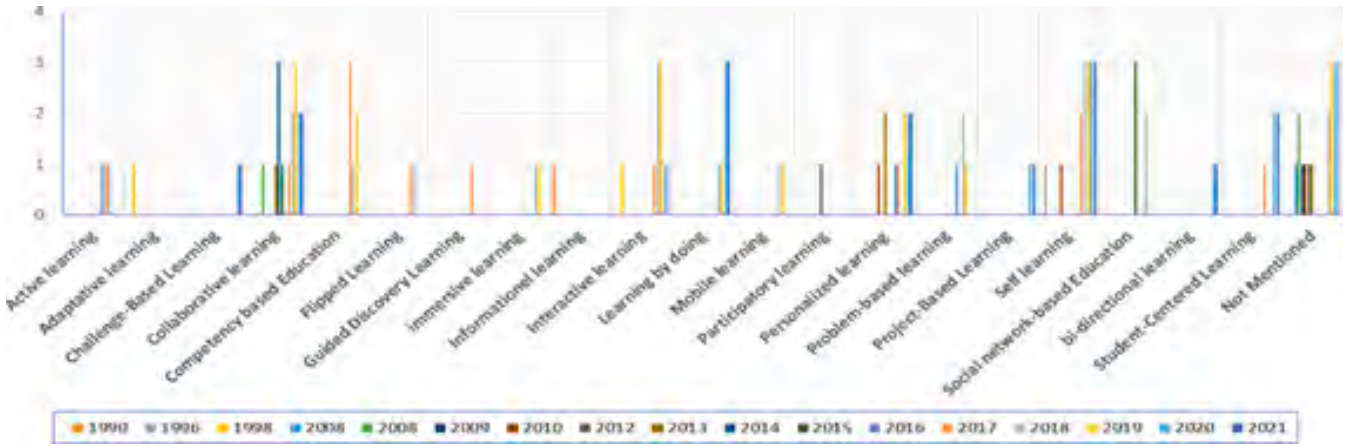
DISCUSSION

This section, we will meticulously analyze the outcomes of our study to effectively tackle the research questions. By dissecting the results, we aim to provide comprehensive insights into the matters raised by our research inquiries. Through this analysis, we endeavor to shed light on the intricate dimensions of our study's subject matter.

RQ1: What are the trends of digital technologies in educational research in terms of publication year, source, and geographical region?

The results of our study highlight several important trends regarding the use of digital technologies in educational research. We observed a significant increase in the number of published articles since 2018, indicating the growing in importance of integrating information technologies in the educational field. This is supported by the study conducted by Khajuria et al. (2023). Conferences have proven to be the primary means of research dissemination, with Elsevier and IEEE being the major publishers. Geographically, we observed a significant contribution from countries such as Germany, Mexico,

Figure 13.
Distribution of Papers per Learning Method and Year of Publication



the United States, Malaysia, India, Portugal, and the United Kingdom. However, it is important to note that these trends may vary depending on technological developments and educational contexts specific to each country. These results emphasize the ongoing importance of research in the field of education and information technologies, as well as the need to closely monitor the evolution of these trends to inform educational practices and foster innovation in this ever-changing domain.

RQ2: What are the existing disruptive digital technologies in education?

Our study identified various disruptive digital technologies in the field of education. The results highlight the prevalence of technologies such as artificial intelligence (AI), the internet of things (IoT), virtual reality (VR), augmented reality (AR), online learning tools, and mobile applications.

Exploring information technologies related to Education 4.0 through the analysis of Verma et al. (2021), key elements emerge, including the IoT, fog computing, and cloud computing. IoT, with its deployed sensors, enables real-time collection of student interactions and resource usage data. Fog-cloud nodes perform advanced preprocessing, facilitating the flow of information to the cloud. This synergy creates a model for predicting irregularities, such as the Multi-Layered Bi-Directional Long Short-Term Memory, instantly alerting to potential malfunctions. Thus, this integration concretely demonstrates how these technologies can innovate in educational monitoring and emphasizes their crucial role in creating responsive and effective educational environments in the era of Education 4.0.

To expand our understanding of the relevant technologies in Education 4.0, particularly augmented reality, we examined Brilian et al. (2020). AR, in the educational context, involves the use of interactive learning media, such as the ARTorque application, to improve the learning outcomes of vocational school students. ARTorque is a specific application developed by Brilian et al. (2020) that provides learners with an immersive and interactive experience, enabling them to visualize educational concepts in an innovative way. This technology allows students to interactively visualize educational content and transcend conventional learning methods. For example, in this study, the experimental class benefited from immersion in AR learning experiences, while the control class followed traditional learning. These experimental results, including tests of normality and homogeneity, are crucial to demonstrating how AR can be meaningfully integrated to optimize professional learning in Education 4.0.

Further expanding our understanding of relevant technologies in Education 4.0, particularly AI, we examined two crucial articles: Chen et al. (2020) and Ciolacu et al. (2018). AI in the context of Education 4.0 plays a pivotal role in predicting student performance and implementing personalized learning. The first article proposes the use of a Hybrid Deep Neural Network to predict student performance by identifying dynamics that influence academic outcomes. The results demonstrate that this method outperforms other popular approaches in terms of prediction accuracy.

The second article highlights an innovative approach for integrating AI into Education 4.0. It presents a higher education process assisted by AI with smart sensors and wearable devices that enables autonomous learning. The use of learning analytics and machine learning algorithms predict students' final grades before the final exam. This early recognition methodology relies on real data and provides an adaptive learning environment. It emphasizes the importance of focusing on student success and personalizing their learning experiences in Education 4.0. These technologies offer innovative opportunities that promote personalization, collaboration, virtual immersion, and expanded access to educational resources. However, less frequently cited technologies, such as biofeedback, blockchain, chatbots, 3D printing, and data analysis, deserve particular attention due to their innovative potential.

RQ3: How has the use of information technology in education changed over time?

The evolution of the use of information technology in education is clearly illustrated by our results. We observed a progression from Education 1.0 to Education 4.0, which corresponds to different generations of education. Initially, learning was primarily informative and focused on knowledge transmission by teachers (Education 1.0). Then, education transitioned to collaborative and participatory learning with the emergence of Web 2.0 (Education 2.0). Later, personalized learning based on Web 3.0 technologies gained importance

and transformed the roles of teachers and learners (Education 3.0). Today is the era of ubiquitous learning, where learning occurs anytime and anywhere through communication and information technologies (Education 4.0). This evolution demonstrates how digital technologies have reshaped educational practices over time by offering new opportunities for adaptive learning, collaboration, and access to resources.

RQ4: Which learning channel do researchers process the most?

Our study reveals that researchers primarily utilize asynchronous learning channels such as forums, MOOCs, and Learning Management Systems. This indicates a preference for online learning, which offers increased temporal flexibility and accessibility. This trend is supported by studies conducted by Morales-Romero et al. (2022), Omar et al. (2021), and others. However, we also observed a significant usage of hybrid learning, which combines both asynchronous and synchronous channels, as well as technology-supported courses in physical classrooms. It is worth noting that laboratory-based learning and mobile learning were also mentioned, albeit to a lesser extent. These findings underscore the growing importance of online learning and the use of information technologies in educational environments.

RQ5: What are the most popular learning methods?

To address this question, our findings indicate that the most popular learning methods in the examined studies are collaborative learning, autonomous learning, personalized learning, interactive learning, skill-based education, experiential learning, and social media–based education. These methods emphasize active learner engagement, active participation, and learner responsibility in constructing their knowledge. However, innovative approaches such as active learning, student-centered learning, and project-based learning are less frequently used in the reviewed articles. These innovative methods emphasize student engagement, active learning, problem solving, and the practical application of knowledge. Although these methods are less common, they have demonstrated their effectiveness in promoting meaningful learning and the acquisition of transferable skills. It is important to support the adoption of these methods in educational practice to provide enriching and transformative learning experiences for learners.

Our study highlights significant trends in the use of digital technologies in education, the evolution of technology use over time, and the most used learning methods. The results underscore the growing importance of integrating digital technologies to enhance educational practices, personalize learning, foster collaboration, and provide more interactive learning opportunities.

IMPLICATIONS

All classrooms, whether in primary, secondary, higher education, or vocational training, bring together students with different knowledge, abilities, and attitudes. Furthermore, according to Howard Gardner, the students all possess multiple intelligences (Gardner, 1983). In order to ensure quality and equitable learning for all, we recommend the following to teachers, educational researchers, curriculum designers, and programmers developing digital learning platforms and content:

a. **Pedagogical Differentiation:** Adopt a differentiated approach that recognizes and takes into account the diverse needs and learning styles of students. This can be achieved by providing various pedagogical strategies, materials, and assessments tailored to each student.
b. **Personalized Learning:** Utilize innovative information technologies and adaptive learning platforms to create personalized learning experiences for students. This involves adapting the pedagogical content and pace of learning to meet the unique needs and interests of each student, thereby fostering greater engagement and motivation.
c. **Collaborative Learning:** Focus on interaction and collaboration among learners through group work and the active exchange of ideas and knowledge. This also enhances collaborative learning and knowledge building and helps learners develop skills in communication, collaboration, and solving problems collectively.
d. **Integration of Information Technologies:** Integrate tools and resources of information technology into teaching and learning

processes by applying the principles of TPACK (Technological Pedagogical Content Knowledge) (Amhag et al., 2019; Wohlfart & Wagner, 2023). This involves using educational applications, online resources, virtual simulations, and collaborative platforms to enhance student engagement, critical thinking, and problem-solving skills, while effectively merging technological, pedagogical, and disciplinary knowledge.

e. **Curriculum:** Integrate digital literacy and information technology skills as essential components of the curriculum. Design learning experiences that incorporate technology and promote critical thinking, creativity, collaboration, and problem solving.
f. **Educational Policy:** Develop policies that support the integration of information technologies in education. Foster collaboration among educational institutions, technology companies, and government agencies to ensure access to quality digital learning resources and infrastructure suitable for all students.
g. **Technology and Publishing:** Create user-friendly and accessible digital learning platforms. Ensure that technological solutions align with educational goals, promote inclusion, and adhere to privacy and data protection standards.

By considering these aspects, teachers and education stakeholders can create an inclusive and technology-enhanced learning environment that caters to the diverse needs and abilities of students and fosters their academic success, and prepares them for the demands of the digital age.

CONCLUSION

This systematic mapping study has characterized and summarized 99 studies on the application of information technologies in the field of education. This research provides valuable insights for teachers, educators, and researchers to enhance educational practices and optimize the use of digital technologies for the benefit of learners.

Based on these results, we have several recommendations for practitioners, educators, researchers, and curriculum designers. We recommend they continue exploring less commonly used technologies and innovative learning methods to fully leverage the opportunities offered by technological advancements. it is also crucial to stay updated on emerging research trends, diversify the types of publications used, explore less commonly used technologies, and rigorously evaluate the effectiveness of proposed solutions.

However, it is important to note that our study has a limitation. The search query we used to collect relevant studies may exclude certain relevant studies. Therefore, further research is needed to comprehensively identify and integrate all relevant studies, assess the effectiveness of these technologies and learning methods, and explore new research avenues in the field of education and information technologies. Additionally, future research should focus on integrating different generations of education to create more comprehensive and personalized teaching and learning models. In this regard, our next work will involve conducting a systematic literature review to further explore these recommendations and gain a better understanding of the emerging trends in the use of information technologies in education.

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