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Science Teaching and Learning Through Digital Education: A Systematic Literature Review

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Abstract

Digital education has received strong attention in the context of education today. Digital education refers to the use of digital technologies and tools for the purpose of teaching, learning, and skill development. Science is a systematic and evidence-based exploration of the natural world, aiming to understand its phenomena, uncover underlying principles, and make predictions through observation, experimentation, and logical reasoning. By reviewing existing literature, the objective of the study is to review the existing literature on digital education in science teaching and learning. The study criteria were empirical articles that addressed the research issues. A total of 342 articles went through four stages in the PRISMA model: identification, screening, eligibility, and inclusion. Only 30 studies on the implementation of digital education in teaching and learning between the publication years of 2015-2022 were taken from Scopus, Web of Science (WoS), ERIC, and Google Scholar as a reference for this study. To find themes in the data, a thematic analysis was performed. The findings show that digital education has challenges in terms of technical difficulties, lack of learning motivation and engagement, and lack of teacher training and support. A strong strategy is needed for teaching methods and the use of appropriate digital tools and resources in the teaching and learning process. Recommendations for best practices include encouraging interactive learning experiences through digital applications that can be used with mobile phones. The lack of assessment of the use of digital education in science teaching and learning is one recommendation for further research.

Keywords: Digital Education, Teaching And Learning, Digital Tool, Digital Technology, Science Education

Introduction

The ability of students to compete worldwide is significantly influenced by their education. Education, especially STEM education, is highly valued in contemporary society. According to Holmlund et al. (2018), STEM education is an interdisciplinary method of teaching and learning that incorporates these subjects. An area of STEM that includes science. According to Taştan et al. (2018), science education mandates thorough science instruction at all educational levels, encompassing biology, chemistry, environmental science, physics, and sustainability. While Tytler (2020a) claims that science education refers to the teaching and learning of science courses in schools, which are significant at a worldwide level because of changes in the workplace.

The advancement of digital technology across all industries, including education, has caused a paradigm shift in the world. Combining communication means like the Internet with electronic tools like computers, teaching tools can be used to obtain and disseminate information in teaching and learning. Technology integration in the teaching and learning process can enhance students' understanding of subjects covered in the classroom (Callaghan et al., 2018). The TPACK Model has shown how technology and the teaching and learning process are related. TPACK is a framework that introduces a complex interaction between three types of knowledge: technology, pedagogy, and content (Mishra and Koehler 2006). TPACK comprises three essential components and an intuitive grasp of subject-appropriate pedagogical and technological methods.

Most countries in the world have started the transformation process in the education system through the integration of digital education including Malaysia. The Malaysian Education Blueprint (2013-2025) launched in 2012 is a comprehensive strategy developed by the Malaysian government to transform the education system. The plan, which covers the period from 2013 to 2025, aims to improve the quality and accessibility of education for all Malaysians. The plan outlines six key strategic thrusts to achieve its goals, including improving teaching and learning quality by implementing new teaching methods, technology, and assessment tools. Tiernan and O'Kelly (2019) conducted a study that indicates that despite Irish government initiatives like the Digital Strategy for Schools (2015-2020), aimed at integrating digital technology into the education system, students in Ireland have a substantial amount of technological exposure outside of the classroom. This finding suggests that students are more inclined to utilize technology in their personal lives rather than within the formal educational environment. In addition, India has also started the process of digitizing education. Thakur & Uikey (2018) stated that the Indian government is working to digitize education and provide content across the country for free and must reach every learning enthusiast. This indicates that, in conjunction with the rapid advancement of the industrial revolution, emerging countries have also begun to make efforts to develop the process of adopting digital education.

Digital education in science teaching and learning

According to the Trends in International Mathematics and Science Study (TIMSS) 2019 study by Martn-Páez et al. (2019) a significant number of teachers are aware of the importance of incorporating technology into teaching and learning. Over 70% of teachers believe that using technology in the educational process will play a crucial role in advancing their careers in education. This indicates their recognition of the significance of technology in the field. Tytler (2020b) further argues that digital literacy is becoming as important as traditional literacy and numeracy. In science education, there is a need to advocate for the inclusion of digital technology either as a separate subject or integrated into other subjects. This highlights the importance of incorporating digital tools and technology in science education. The TPACK Model offers a framework for comprehending how technology might be used as a pedagogical instrument in teaching and learning, as addressed by Ammade et al. (2020). This model places a focus on the fusion of technological expertise, instructional techniques, and subject-matter expertise. It draws attention to how closely science education and the demand for the use of technology and digital tools in the teaching and learning process are related.

School closures due to the COVID-19 pandemic have occurred in practically every nation on earth. As a result, online instruction quickly replaced face-to-face training in the educational system. Academic instructors have been given a limited period of time to transition from face-to-face teaching and learning techniques to online learning. Educators must incorporate digital tools into the teaching and learning process. Additionally, educators have not yet received the technical and pedagogical training required to incorporate technology into digital instruction (Schleicher 2020). Therefore, this is an opportunity that needs to be taken advantage off to update and restructure the educational system and switch from the traditional educational approach to the usage of digital applications. Since science disciplines are intimately tied to the use of technology, this is also the finest chance for all science teachers to investigate digital education and digital applications that are appropriate for use in the teaching and learning process.

Research Questions

The goal of this study is to perform a review of the literature on digital education in science teaching and learning. The following questions for research were employed:
1. How is digital education defined in science teaching and learning?
2. What are the challenges of digital education in science teaching and learning?
3. What are the strategies for incorporating digital education in science teaching and learning?

Methodology

Only journal publications published between 2015 and 2022 were used for this research. Researchers have identified numerous research articles about digital education in science teaching and learning, with a focus on articles published between 2019 and 2022. This may also be due to the influence of digital technology in education due to the pandemic outbreak of COVID-19. The PRISMA approach was used to evaluate the collected journal articles. Collected papers will be identified and screened to determine their eligibility and inclusion. It is possible to synthesize related journal articles using this synthesis method. The PRISMA flowchart Figure 1 is an adaptation and modification of the design by Page et al. (2021).

a) Identification

The systematic literature review's first step includes the PRISMA guidelines' identification procedure. The terms definition, challenges, and strategies of education in teaching learning emerge as four key terms from the research topic. The author tries to use this term in synonyms. To look up words used as study keywords and seek out pertinent terminology and variations, use an online thesaurus like thesaurus.com. This approach led to the study of several ideas, including digital tools, digital learning, secondary school, K12, and high school, to implement digital tools in science teaching and learning. This set of terms was processed using function searches like field code functions, phrase searches, wildcards, truncations, and Boolean operators (Table 1).

The trustworthy databases Scopus and Web of Science publications are used in this study. These two databases are the most extensive impact indicators and serve as sources for publication metadata. The selected database produced a total of 342 possible papers, including 142 from the Scopus database and 180 from the Web of Science. Furthermore, the search process is based on manual search techniques. Here, 'handpicking' is used in ERIC and

Google Scholar databases. The selected databases yielded a total of 20 possible papers, including 8 from the ERIC database and 12 from Google Scholar.

Table 1
Search string used in the selected database

Database	String
Scopus	TITLE-ABS-KEY (("Digital Learning" OR "Digital Education" OR "Digital Technology" OR "Digital Tool") AND ("teaching and learning" OR "science classroom") AND ("Secondary School" OR k12* OR "High School"))
Web of Science	TS = TITLE-ABS-KEY (("Digital Learning" OR "Digital Education" OR "Digital Technology" OR "Digital Tool") AND ("teaching and learning" OR "science classroom") AND ("Secondary School" OR k12* OR "High School"))

b) Screening
The screening process takes place after the article has been identified. The first step in selecting this article is to conduct a review to make sure it is not a collection of books or book chapters, a systematic review of papers, or conference proceedings. The study's chosen article is one of those that were published between 2015 and 2022. Research papers in English are used by the author. Due to the 163 articles being excluded because they failed to meet the requirements for inclusion, this process in the wake of the screening, duplicates from 12 articles were eliminated, leaving 342 items that were appropriate for further investigation. There are 228 articles still up for consideration in the resulting stage based on the inclusion and exclusion criteria (Table 2).

Table 2
Inclusion and exclusion criteria

Criteria	Eligibility	Exception
Resource Type	Journal (article)	Books, book series, book chapters, systematic reviews of articles, conference proceedings
Language	English Language	Other than English
Publication Period	2015-2022	2014 and previous years

c) Eligibility
To ensure that it complies with the standards required for this study, a total of 228 articles were screened. When compiling, it is important to read the title, abstract, findings, and discussion of the research again. 102 articles in total were ignored because they failed to continue and were less relevant to the topic of digital tools in science teaching and learning.

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d) Inclusion

After sorting, only 30 articles were selected because they met the standard and study needs. To avoid bias, the second author examined and confirmed the included and excluded articles against the criteria to ensure that all retained articles satisfied the requirements.

e) Quality appraisal

The quality assessment phase for the selected studies involved utilizing the Mixed Methods Assessment Tool (MMAT) developed by Hong et al. (2018). This tool was employed to assess the quality of the studies included in the research and specifically designed to assess the quality of mixed-methods systematic reviews. Before the assessment, two screening techniques were applied to select the relevant papers for inclusion in the review. Once the papers were selected, their quality was evaluated using the primary criteria outlined in the research design. The MMAT tool provided guidance on assessing the effectiveness of different research designs in addressing research questions, the integration of qualitative and quantitative methods, and the ability to account for variations among research designs.

After utilizing the MMAT tool, all authors agreed that the selected papers matched the methodology and analytical requirements. There were 23 papers in total that satisfied all the evaluation criteria. Furthermore, five of these papers met at least four standards, while two publications met at least three, indicating high levels of quality. Overall, it was ensured that the methodology and analysis of the selected studies met the standards set forth by the MMAT tool throughout the quality evaluation process. This exhaustive evaluation procedure supports the validity and reliability of the results reported in the mixed-methods systematic review.

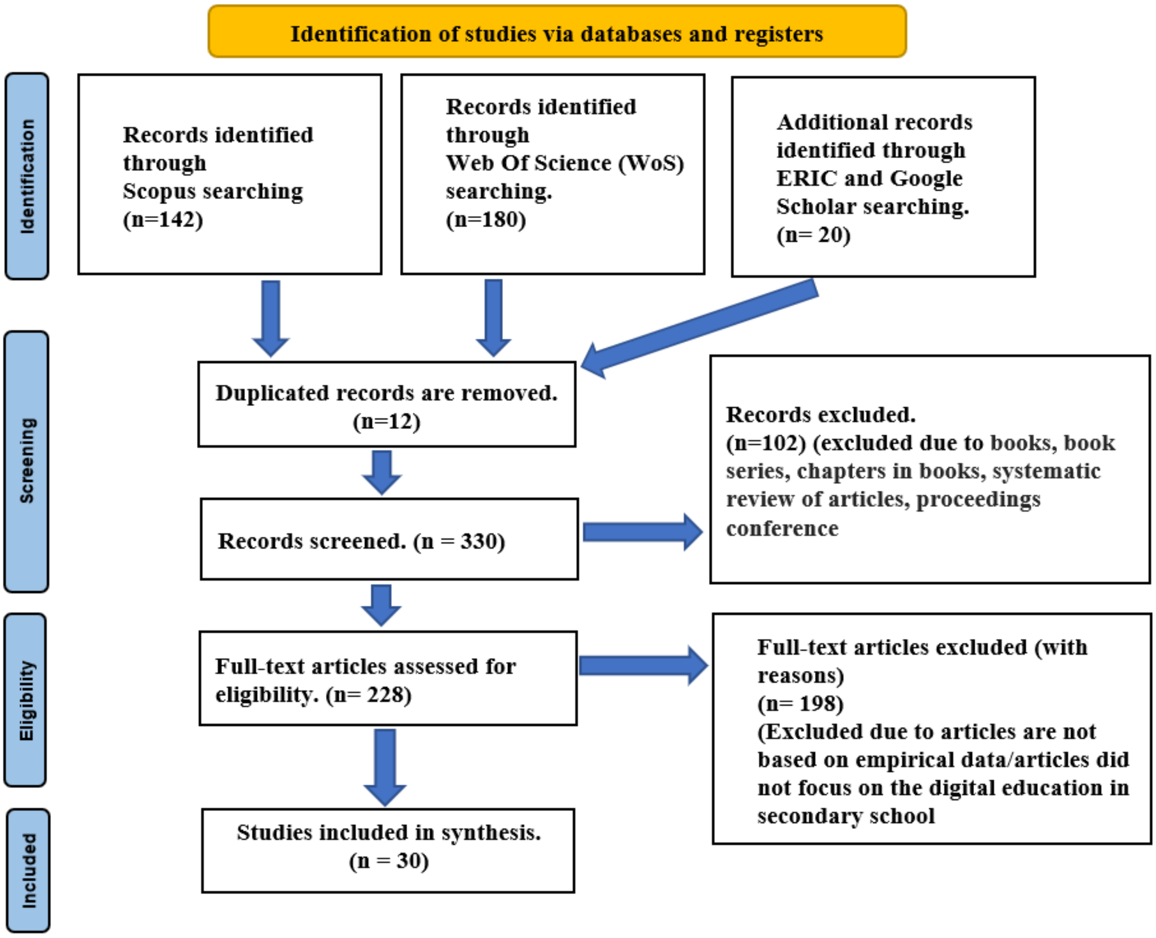

Figure 1. PRISMA Systematic Literature Highlights adapted from Page et al. (2021)

Table 3
Results of the quality assessment

No	Writer (Year)	Research Design	Country	QA 1	QA 2	QA 3	QA 4	QA 5	Number of criteria fulfilled	Inclusion in the review
1.	Guzzo et al. (2022)	QN	Italy	√	√	√	X	√	4/5	√
2.	Woltran et al. (2022)	QL	Austria	√	√	√	√	√	5/5	√
3.	Baxter et al. (2022)	MX	UK	√	√	√	√	√	5/5	√
4.	Capuno et al. (2022)	QN	Philippines	√	√	√	X	√	4/5	√
5.	Aldhafeeri & Alotaibi (2022)	QN	Kuwait	√	√	√	√	√	5/5	√
6.	Herawati et al. (2022)	QN	Indonesia	√	√	√	√	√	5/5	√
7.	Toto & Limone (2021)	QN	Italy	√	√	√	√	√	5/5	√
8.	Poultsakis et al. (2021)	QN	Greece	√	√	√	√	√	5/5	√
9.	Hafiza Hamzah et al. (2021)	QN	Malaysia	√	√	√	√	√	5/5	√
10.	Cai et al. (2021)	QN	China		√	√	√	√	5/5	√
11.	Valantinaitė & Sederevičiūtė-Pačiauskienė (2020)	QN	Lithuania	X	√	X	√	√	3/5	√
12.	Abenes et al. (2020)	QN	Philippines	√	√	√	X	√	4/5	√
13.	Selwyn et al. (2020)	MX	Australia	√	√	√	√	√	5/5	√
14.	Karunanayaka & Weerakon(2020)	QN	Sri Lanka	√	√	X	√	√	4/5	√
15.	Shute et al. (2020)	QN	USA	√	√	√	√	√	5/5	√
16.	Tavares & Melo (2019)	QL	Brazil	√	√	√	√	√	5/5	√
17.	Sze Yean (2019)	QN	Malaysia	√	√	√	√	√	5/5	√
18.	Olofsson et al. (2019)	QL	Sweden	√	√	√	√	√	5/5	√
19.	Mulhayatiah et al. (2019)	QN	Indonesia	√	√	√	X	√	4/5	√
20.	Syafryadin et al. (2019)	QN	Indonesia	√	√	√	√	√	5/5	√

21.	Tzima et al. (2019)	QL	Greece	√	√	√	√	√	5/5	√
22.	Batuyong & Antonio (2018)	QN	Philippines	√	√	√	√	√	5/5	√
23.	Liliarti & Kuswanto (2018)	QN	Indonesia	√	X	C	√	√	3/5	√
24.	Tiernan and O'Kelly (2017)	MX	Ireland	√	√	√	√	√	5/5	√
25.	McLeod & Carabott (2017)	QL	Australia	√	√	√	√	√	5/5	√
26.	Ramma et al. (2017)	QL	UK	√	√	√	√	√	5/5	√
27.	Furberg (2016)	QN	Norway	√	√	√	√	√	5/5	√
28.	Atwa et al. (2016)	MX	Malaysia	√	√	√	√	√	5/5	√
29.	Nielsen et al. (2015)	QL	Australia	√	√	√	√	√	5/5	√
30.	Lai & Hwang (2015)	QN	Taiwan	√	√	√	√	√	5/5	√

QA= Quality assessment; QN= Quantitative; QL= Qualitative; MX= Mixed Method; C= Can't tell

Results

Background of the selected studies

There were 19 studies that concentrated on quantitative analysis and seven other studies that concentrated on qualitative analysis. The strategy using mixed methods was used in four experiments (Fig. 2).

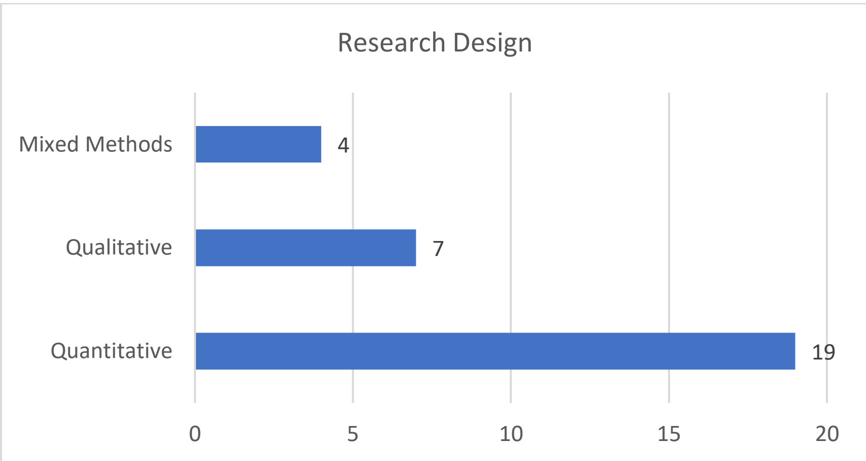

Fig. 2 Research design of selected studies

There were two papers published in 2015, two studies published in 2016, three articles published in 2017, two articles published in 2018, six publications published in 2019, five publications published in 2020, four publications published in 2021, and six publications published in 2022, according to the year of publication (see Figure 4). The COVID-19 pandemic, which forced the reformation and integration of digital education into educational systems across the globe, boosted the trend of article publication over the last three years, from the end of 2019 to 2022. (Fig. 3).

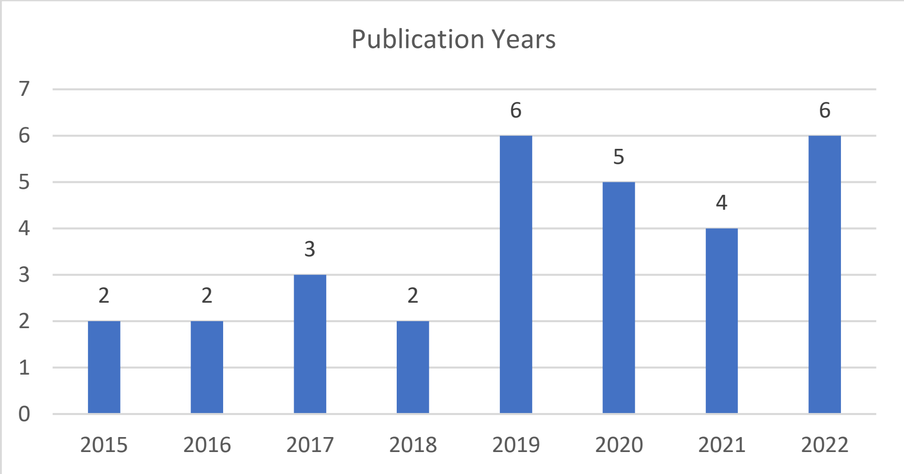

Fig. 3 Publication years of selected studies

How is digital education defined in science teaching and learning?
Digital education is the practice of enhancing learning and teaching using technology. It involves incorporating digital resources, such as computers, tablets, cell phones, and the internet, into the educational curriculum to provide students with dynamic and engaging learning experiences. According to studies by Woltran et al. (2022) and Syafryadin et al. (2019), digital education refers to the utilization of digital tools and technology to improve and support the processes of teaching and learning. To enhance learning outcomes, digital tools, and platforms, including computers, laptops, iPads, and other devices, are integrated into the classroom. Digital education, also known as the utilization of digital technology, to enhance teaching and learning, encompasses various aspects of integrating digital tools and resources into educational settings (Toto & Limone, 2021; Karunanayaka & Weerakoon, 2020; Sze Yean, 2019). Within the realm of digital education, the incorporation of digital learning objects (DLOs) and digital simulation tools (DSTs) plays a crucial role in science instruction, offering innovative ways to facilitate learning (Guzzo et al., 2022). Furthermore, the integration of computers and other digital learning technologies in digital education supports computer-supported collaborative learning (CSCL), which emphasizes collaborative learning experiences mediated by technology (Furberg, 2016). Collectively, these notions underscore the increasing impact of digital technology on education, showcasing its potential to revolutionize teaching and learning processes through the integration of digital learning objects, simulation tools, and collaborative learning environments.

According to a study by Aldhafeeri and Alotaibi (2022), digital education is the use of technology to offer educational information and promote learning. Online courses, virtual classrooms, educational apps, and digital textbooks are just a few examples of the many different shapes it can take. McLeod and Carabott (2017), on the other hand, define digital education as the integration of information and communication technology (ICT) in education, which encompasses technical, pedagogical, and content knowledge (TPACK). Digital education, according to Capuno et al. (2022), is the use of technology by teachers to respond to the difficulties brought on by the COVID-19 pandemic. Similarly, Herawati et al. (2022) concur that digital education requires educators to employ innovative instructional methods and technology.

In summary, digital education in the context of science teaching and learning involves the integration of technology and digital tools into the process to enhance the quality and enjoyment of learning. It is important to utilize technologies as teaching aids to create a more relevant learning environment and foster effective teaching and learning practices. By embracing the digital revolution, the educational sector can progress and indirectly support the educational process.

Table 4
Findings of challenges of digital education in science teaching and learning

No	Writer (Year)	Technical Difficulties	Lack of Motivation	Lack of Teacher Training and Support
1.	Guzzo et al. (2022)	√		
2.	Woltran et al. (2022)	√		
3.	Baxter et al. (2022)	√		
4.	Capuno et al. (2022)			
5.	Aldhafeeri & Alotaibi (2022)		√	
6.	Herawati et al. (2022)			
7.	Toto & Limone (2021)		√	
8.	Poultsakis et al. (2021)	√		
9.	Hafiza Hamzah et al. (2021)			
10.	Cai et al. (2021)			√
11.	Valantinaitė & Sederevičiūtė-Pačiauskienė (2020)		√	
12.	Abenes et al. (2020)	√		
13.	Selwyn et al. (2020)			
14.	Karunanayaka & Weerakon (2020)	√		
15.	Shute et al. (2020)			
16.	Tavares & Melo (2019)			√
17.	Sze Yean (2019)			
18.	Olofsson et al. (2019)			√
19.	Mulhayatiah et al. (2019)	√		
20.	Syafryadin et al. (2019)			
21.	Tzima et al. (2019)			√
22.	Batuyong & Antonio (2018)			
23.	Liliarti & Kuswanto (2018)			
24.	Tiernan and O'Kelly (2017)			
25.	McLeod & Carabott (2017)	√		
26.	Ramma et al. (2017)			
27.	Furberg (2016)			
28.	Atwa et al. (2016)			√
29.	Nielsen et al. (2015)			
30.	Lai & Hwang (2015)		√	

What are the challenges of digital education in science teaching and learning?
Multiple studies have highlighted the challenges associated with implementing digital education, particularly in the context of science teaching and learning. The research findings have identified four key areas that encompass the challenges faced in this domain. These areas are as follows: technical difficulties, lack of learning motivation and engagement, and insufficient teacher training and support (as presented in Table 4).

Technical difficulties
Several articles have highlighted the challenges faced in implementing digital education in science classrooms. Despite teachers' dedication to designing and delivering technologically advanced learning environments, several factors pose difficulties in their implementation (Nielsen et al., 2015). Technical difficulties, including issues with internet connectivity, device accessibility, and software and hardware problems, have been identified as significant challenges in digital education (Guzzo et al., 2022). Insufficient resources in schools and among students have also been identified as barriers to the use of digital media in the classroom (Woltran et al., 2022). Poultsakis et al. (2021) have emphasized the lack of technological equipment and limited resource availability as major challenges in implementing digital education. Baxter et al. (2022) have stressed the importance of addressing access to devices and internet connectivity in all households as part of digitizing education.

The lack of access to Android phones for Digital Game-Based Learning among some students (Abenes et al., 2020) and the absence of computer and internet facilities at school, along with slow internet connections (Karunanayaka & Weerakoon, 2020), are among the primary challenges faced in applying digital education with the use of digital tools. Collectively, these factors highlight that technical difficulties are a major issue in discussing the challenges of integrating digital education in science teaching and learning.

Lack of Learning Motivation and Engagement
The lack of motivation presents a significant hurdle in the implementation of digital tools in educational settings. Two articles specifically address the challenges related to motivation during the COVID-19 pandemic. Toto and Limone (2021) highlight the adverse impact of digital technology on teacher motivation and perceived stress during the pandemic. Aldhafeeri and Alotaibi (2022) identify the absence of student engagement as a major issue in digital education during COVID-19, resulting from teachers' physical absence and limited direct communication with students.

According to Valantinaitė and Sederevičiūtė-Paiauskienė (2020), the negative effects of e-learning can be attributed to asynchronous digital content and a lack of development in communication and delivery skills. Students' nervousness and insecurity have been linked to prolonged use of online learning environments. These difficulties have made it difficult to effectively incorporate digital education into the teaching and learning processes, which has had an impact on both teacher and student motivation. Therefore, in order to successfully integrate digital technologies into science education, these challenges must be addressed.

Selwyn et al. (2020) emphasize the need for educators to gain a deeper understanding of how students utilize digital technology. Additionally, Lai and Hwang (2015) highlight the importance of offering students flexible and adaptive learning opportunities, personalized support, and adaptive learning materials to enhance motivation. Furthermore, McLeod and Carabott (2017) assert that the success of implementing information and communication technology (ICT) in tutorials heavily relies on students' willingness to participate, while Mulhayatiah et al. (2019) identify limited student knowledge in navigating digital modules and time constraints during question-and-answer sessions as hindrances to student engagement with digital tools.

To overcome these challenges, it is crucial to address motivation-related issues, foster active student participation, and provide appropriate support and resources for the effective integration of digital education in science teaching and learning (Toto & Limone, 2021; Aldhafeeri & Alotaibi, 2022; Valantinaitė & Sederevičiūtė-Paiauskienė, 2020; Selwyn et al., 2020; Lai & Hwang, 2015; McLeod & Carabott, 2017; Mulhayatiah et al., 2019).

Lack of teacher training and support

Tzima et al. (2019) shed light on the challenges associated with the integration of digital education in science teaching and learning, including inadequate teacher training, limitations within the curriculum, and a lack of collaboration among teachers across different disciplines. Tavares and Melo (2019) provide additional support to these challenges by highlighting the resistance to depart from traditional teaching methods and underscoring the significance of teacher support and training in successfully integrating digital technologies. Atwa et al. (2016) reinforce these arguments by asserting that teachers need to enhance their understanding of pedagogical practices throughout the entire process of planning, implementing, and evaluating to successfully integrate information and communication technologies (ICT) into teaching and learning.

Implementing advanced technologies such as virtual reality (VR) and augmented reality (AR) in education often demands significant investments in hardware, software, and training for both educators and learners (Cai et al., 2021). Correspondingly, Olofsson et al. (2019) discovered that teachers in Sweden encounter several hurdles concerning their digital proficiency. These obstacles include difficulties in navigating restricted Learning Management Systems (LMS), as well as determining appropriate access to digital tools and comprehending how these tools can effectively enhance teaching and learning activities.

Recognizing these challenges, it is crucial for stakeholders in the education sector to acknowledge and address them appropriately. By addressing technical difficulties, enhancing student motivation and engagement, providing comprehensive teacher training and support, and allocating sufficient resources, the potential benefits of digital education in science teaching and learning can be fully realized. The successful implementation of digital tools in science education hinges on effectively addressing challenges related to teacher training and support. This includes adapting to new technologies, integrating them effectively into the curriculum, bridging the digital divide, and providing continuous professional development opportunities (Lai & Hwang, 2015). By overcoming these challenges, the education sector can harness the full potential of digital education and create an engaging and effective learning experience for students.Table 5: Findings of the strategies for using digital education in science teaching and learning

No	Writer (Year)	Teaching Method	Digital Tool
1.	Guzzo et al. (2022)		
2.	Woltran et al. (2022)		
3.	Baxter et al. (2022)		
4.	Capuno et al. (2022)		
5.	Aldhafeeri & Alotaibi (2022)	√	
6.	Herawati et al. (2022)		
7.	Toto & Limone (2021)		
8.	Poultsakis et al. (2021)		
9.	Hafiza Hamzah et al. (2021)		
10.	Cai et al. (2021)		√
11.	Valantinaitė & Sederevičiūtė-Pačiauskienė (2020)	√	
12.	Abenes et al. (2020)		√
13.	Selwyn et al. (2020)		
14.	Karunanayaka & Weerakon (2020)	√	
15.	Shute et al. (2020)		√
16.	Tavares & Melo (2019)	√	
17.	Sze Yean (2019)	√	
18.	Olofsson et al. (2019)		
19.	Mulhayatiah et al. (2019)		
20.	Syafryadin et al. (2019)		
21.	Tzima et al. (2019)		
22.	Batuyong & Antonio (2018)		√
23.	Liliarti & Kuswanto (2018)		√
24.	Tiernan and O'Kelly (2017)		
25.	McLeod & Carabott (2017)	√	
26.	Ramma et al. (2017)	√	
27.	Furberg (2016)		
28.	Atwa et al. (2016)	√	
29.	Nielsen et al. (2015)		
30.	Lai & Hwang (2015)		

What are the strategies for incorporating digital education in science teaching and learning?
Existing research offers suggestions for ways to improve teaching and learning with digital education. Several themes seem to summarize existing research related to the following codes: teaching methods and the use of appropriate digital tools in the science teaching and learning process. (Table 5).

Teaching and Learning Method

Tavares and Melo (2019) emphasize the importance of embracing new teaching and learning approaches within the context of digital education. They argue that education should be open to adopting innovative practices that leverage changes in the spatiotemporal aspects of learning. For instance, they highlight the use of distance learning platforms that overcome physical and time constraints through technological support, enabling more flexible and accessible educational experiences. These platforms leverage digital media, such as computers, tablets, smartphones, and the Internet, to deliver educational content, teaching materials, and training programs. By utilizing these advancements, educators can create flexible learning opportunities and overcome the limitations of traditional classroom settings.

In the field of education, particularly in science education, McLeod and Carabott (2017) assert that there are two distinct approaches to integrating information and communication technology (ICT) into educational units. The first approach primarily utilizes ICT as a tool for delivering educational material, essentially augmenting traditional teaching methods. On the other hand, the second approach encourages pre-service teachers to engage in experiential learning by developing digital learning objects as part of assessment assignments. This innovative approach fosters active student engagement and hands-on learning experiences, promoting the advancement of new pedagogical practices. By incorporating digital learning objects, educators can create interactive and immersive learning environments that facilitate a deeper understanding of scientific concepts. Overall, these articles underscore the importance of transitioning from conventional teaching methods to embrace new approaches enabled by digital education. Through the effective utilization of technology and the integration of experiential learning, educators can create engaging and impactful learning experiences for students, particularly in the field of science education.

To increase student involvement and the efficiency of digital education, Aldhafeeri and Alotaibi (2022) develop the Digital Education Shift (DES) model, which emphasises the value of student-teacher collaboration, student teamwork, and increasing the fundamental elements of digital learning. The C-DELTA programme is suggested by Karunanayaka and Weerakoon (2020) to improve digital literacy, encourage changes in teachers' and students' digital thinking and behaviour, and build teachers' leadership capacities in the context of digital education. Through this programme, instructors and students will be given the tools and resources they need to effectively use digital tools and resources in the classroom.

The Pedagogical Technology Integrated Medium (PTIM) framework, put forth by Ramma et al. (2017), was created expressly for developing and executing interactive web-based science lessons. The effectiveness of this paradigm in fostering engagement and boosting student motivation in science teaching has been established. To promote the use of digital tools in the teaching and learning process, the educational community needs to embrace a more open approach. It is critical to use teaching strategies that are in line with technological developments since they could improve students' skills and boost educational excellence. Adopting these suggested strategies will enable educators to make the most of digital resources and provide students with compelling and lasting learning opportunities.

The use of the flipped Classroom approach to improve science teaching and learning methodologies has been investigated in three articles. Atwa et al. (2016) claim that the flipped Classroom is a student-centred strategy that uses digital technologies to tailor the educational experience. It fosters individualised learning and enables active student participation in the subject matter. The usefulness of the Flipped Classroom is further highlighted by Sze Yean (2019), particularly when combined with information and communication technology (ICT). This combination encourages independent, active learning and the growth of analytical and problem-solving abilities. The article offers evidence in favour of the claim that the Flipped Classroom and ICT can improve student engagement and promote higher-order cognitive abilities. The flipped classroom method is used by Valantinait and Sedereviit-Paiauskien (2020) to combine in-class instruction with extracurricular activities. They place a strong focus on the necessity of fostering favourable attitudes among instructors towards the online learning environment as well as the development of teacher competencies. The authors want to assure long-term growth and improvement in scientific teaching and learning by implementing the Flipped Classroom technique.

These three articles collectively demonstrate that the implementation of flipped learning strategies in science education has several benefits. These strategies can enhance students' critical thinking skills, promote active and independent learning, and indirectly contribute to the professional growth of teachers by improving their competence in leveraging digital tools and the online learning environment.

Digital Tools Resources

According to Cai et al. (2021), using Augmented Reality (AR) technology as a teaching aid will increase students' confidence in their ability to study physics. Students can obtain advice on more complex physics ideas and feel more motivated to learn more by using AR. Similar to this, Abenes et al. (2020) emphasise the value of using digital games to teach physics concepts like sound, heat, and light. The ADDIE Model, which the authors adopt, emphasises the development of learning activities that are simple to use, effective, appropriate, and enjoyable. Students have a pleasant and interesting platform to interact with physics principles thanks to digital games.

In the study conducted by Shute et al. (2020), a silent assessment of physics understanding was found to be a valid approach. The researchers also discovered that a physics animation known as the Physics Playground served as the most effective in-game support for predicting learning outcomes and performance within the game. This suggests that well-designed physics animations can enhance learning experiences and outcomes. These articles present strategies for increasing the utilization of digital tools in science education, specifically focusing on Physics. Augmented Reality, Digital Game-Based Learning, and physics animations offer innovative approaches to enhance students' learning experiences, self-efficacy, motivation, and understanding of complex Physics concepts. By incorporating these digital applications, educators can create engaging and effective learning environments in science education.

Batuyong and Antonio (2018) highlight the effectiveness of PhET®ISbA as a teaching material for Physics, specifically focusing on Electromagnetism. They find that the use of PhET®ISbA leads to a significant improvement in the academic performance of Physics students. Furthermore, students provide positive feedback regarding their learning experiences with this digital tool. The study demonstrates the positive effects of utilizing PhET®ISbA in enhancing student learning outcomes and engagement in Physics education.

In another study by Liliarti and Kuswanto (2018), Android-Based Learning Media is employed, specifically using Othok-Othok toy ships as local content. This approach proves beneficial in improving students' diagram representation and argumentative competence in learning Physics. By integrating local content through Android-based learning media, students can effectively grasp Physics concepts and enhance their abilities in representing diagrams and constructing arguments.

Collectively, these four articles highlight the positive effects of incorporating digital applications in the teaching and learning of Science subjects. Digital tools, such as PhET®ISbA and Android-Based Learning Media, provide opportunities for a student-centered teaching atmosphere and offer enjoyable learning experiences. These advantages contribute to more effective student understanding and engagement in science education. By leveraging digital applications, educators can create dynamic and interactive learning environments that enhance student outcomes and foster a deeper understanding of scientific concepts.

Discussion

Recommendations for practice

To strengthen the education system in the era of globalization and the era of the industrial revolution, the application of digital education in teaching and learning especially involving Science subjects has become an important issue in the effort to develop educational content and teaching tools that enrich the educational environment with interesting and necessary methods and techniques by students. It is highly expected because the findings from many studies are relatively comparable in terms of challenges, and strategies to implement digital education in the classroom and in the teaching and learning process. Teachers need professional development support to improve knowledge and overcome problems in the integration of digital education. While students need continuous support from parents and in terms of infrastructure that helps in realizing the digitization of education. Officials such as the Ministry of Education need to provide continuous space and opportunities in terms of technical support to help schools apply digital education.

Teachers need to be encouraged to work together and cooperate to create innovative ways to successfully integrate digital education in schools. A digital application based on Educational Game Learning that can be used on smartphones is a very effective way of encouraging student participation and improving understanding.

Recommendations for future research

It will be beneficial to encourage teachers if there is more research demonstrating the effectiveness of digital education programs with diverse and low-ability student populations. Teachers must be convinced that integrating digital education will benefit all students. As teachers observe the positive outcomes and achievements of their students in the classroom through the integration of digital technology, their motivation to engage in teaching and learning activities with the aid of these tools will increase. However, further research is necessary to delve into the assessment of digital education in science teaching and learning. This research will allow for a comprehensive evaluation of the effectiveness of utilizing digital education in the science teaching and learning process. Moreover, it will aid in identifying suitable assessment methods that can be employed to assess the impact and outcomes of incorporating digital education in science education.

Conclusion

Based on the literature review, it can be concluded that digital education yields numerous positive outcomes when incorporated into the teaching and learning process. With teachers serving as facilitators, digital teaching fosters active learning among students (Hafiza Hamzah et al., 2021). In today's era of industrial globalization, the significance of technology cannot be disputed. Traditional classroom methods should be replaced by digital technology, allowing teachers and students to engage across borders while equipping teachers with enhanced knowledge and skills. The online teaching and learning process effectively delivers knowledge through the knowledge channel approach, both inside and outside the classroom. Implementing digital education in science teaching requires commitment and effort from all stakeholders. Through adequate training, utilization of high-quality digital learning resources, and a focus on balanced learning, digital education enhances students' comprehension of science and prepares them to navigate the challenges of the digital world.

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