Transforming High School Education with Digital Tools: A Systematic Review

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Abstract. This systematic review comprehensively examines the impact of digital tools on high school education, drawing from 23 peer-reviewed studies published between 2018 and 2023. The study explores a wide range of research methodologies, including randomized controlled trials, quasi-experimental designs, and experimental studies, to assess the effectiveness of digital technologies in enhancing education outcomes. The findings indicate that digital tools, particularly those integrated using the substitution augmentation modification and redefinition model, significantly improve student autonomy, engagement, and academic performance across diverse geographic and demographic contexts. However, the review also identifies challenges, such as the complexity of content, technological disparities, and the necessity for well-planned and context-sensitive implementation strategies. Furthermore, it highlights the importance of professional development for educators and the need for infrastructural support to ensure equitable access to technology. The study underscores the critical role of collaboration among educators, policymakers, and stakeholders to maximize the benefits of digital education. The review calls for ongoing research into innovative educational technologies and their long-term effects, and advocates for a strategic and well-supported approach to integrating these tools into high school settings.

1. Introduction

The integration of digital tools in high school education has emerged as a pivotal factor in transforming teaching and learning paradigms. Since the advent of diverse digital technologies, educators have unparalleled opportunities to enhance instructional delivery and engage students more effectively. This shift is not merely an augmentation of existing pedagogical methods but represents a fundamental reevaluation of educational practices so that they align with the digital competencies required in the contemporary world. The significance of digital tools extends beyond the classroom, and prepares students to navigate the complexities of a technology-driven society (Dooley et al., 2016; Torbaghan et al., 2022).

Central to this transformative journey is the application of the substitution augmentation modification and redefinition (SAMR) model, which is a framework that categorizes the degree of technology integration in educational settings. Developed by Puentedura (2010), the SAMR model challenges educators to transcend traditional uses of technology by advocating for its employment in ways that modify and redefine learning experiences. This model serves as a guide for educators to critically assess and elevate the use of digital tools, thereby aiming to foster learning environments that are engaging, efficient, and tailored to individual learner needs. The influence of digital tools as underpinned by the SAMR framework facilitates a move toward learning environments characterized by greater collaboration, flexibility, and innovation. Technologies such as learning management systems (e.g., Google Classroom) and educational content platforms are at the forefront of this change, and aim to showcase how digital integration can offer personalized learning experiences and promote a culture of collective knowledge construction among students and teachers alike (Lozada et al., 2022; Sari et al., 2022; Yusrianti et al., 2024).

Despite the well-documented benefits, there remain significant gaps in understanding the nuanced impacts of digital tools on high school education. For instance, while many studies highlight the positive outcomes associated with digital tool integration, the variability in success across different contexts and the challenges faced by educators in effectively integrating these tools have not been comprehensively explored (Backfisch et al., 2021). Moreover, the long-term effects of digital tool use on student outcomes and the specific conditions under which these tools are most effective warrant further investigation.

The theoretical significance of this review lies in its contribution to the existing body of knowledge on the SAMR model and its practical implications for high school education. By systematically analyzing the application of digital tools with this framework, this review provides a comprehensive understanding of how these tools can be optimized to enhance learning outcomes. Practically, the findings offer actionable insights for educators and policymakers aiming to implement effective digital strategies in high school settings.

This systematic review seeks to meticulously evaluate the application and impact of digital tools in high school education through the lens of the SAMR model. By methodically analyzing a broad spectrum of literature, the review aimed to dissect the transformative capacity of digital technologies, delineate obstacles to their effective integration, and derive actionable insights for optimizing the use of digital tools in high school settings. The focus was on identifying empirical evidence that supports the various levels of technology integration as defined by the SAMR model, thereby offering a nuanced understanding of how digital tools can enhance educational outcomes in high schools.

The research questions addressed in this review are:
1. How do different digital technologies, such as computer simulations, virtual reality, and game-based learning platforms, affect student learning outcomes in high school educational settings?
2. How do digital tools, as framed by the SAMR model, impact high school students' academic performance and engagement?
3. What contextual and pedagogical factors contribute to the varying effectiveness of these digital technologies across diverse educational environments?
4. What are the barriers to effective technology integration in high school education?
5. How can educators and policymakers optimize the use of digital tools to enhance educational outcomes?

The review highlights the transformative potential of digital tools and underscores the importance of comprehensive strategies, which include professional development for educators, infrastructural advancements, and equitable access to resources. By addressing these factors, the review advocates for a collaborative approach to refining digital learning environments and maximizing the potential benefits of digital education.

2. Methodology
This systematic review critically examined the employment of digital tools in high school educational environments and their subsequent impact on pedagogical practices. The investigation centers on the deployment of these tools by educators and the role of the digital tools in fostering an advanced teaching–learning nexus.

2.1 Search Strategy
A structured search of literature published from 2018 to 2023 was undertaken across several leading databases, including Google Scholar, JSTOR, ScienceDirect, and PubMed. The search was informed by a precise strategy that utilized a combination of keywords tailored to the high school context, to ensure a broad yet relevant sweep of the academic field. The search terms and results are outlined in Table 1, which highlights the tailored approach utilized for each database.

Table 1: Search Queries Used for Various Databases

| Keywords	Database	Date accessed	Articles
"digital tools", "high school education", "teaching methodologies", "learning outcomes"	Google Scholar	March 15, 2024	42
("digital tools" OR "educational technology") AND ("learning outcomes" OR "teaching methodologies") AND "high school"	JSTOR	April 1, 2024	60
("digital tools" OR "educational technology") AND ("learning outcomes" OR "cognitive development" OR "student engagement") AND ("high school" OR "secondary education" OR "adolescents") AND ("2018" [Date-Publication]: "2023" [Date-Publication])	Science Direct	April 17, 2024	25
("digital tools" OR "educational technology") AND ("learning outcomes" OR "student engagement") AND "high school" AND ("2018" [Date-Publication]: "2023" [Date-Publication])	Pub Med	April 7, 2024	1

2.2 Inclusion and Exclusion Criteria

The initial inquiry elicited 128 pertinent records. Following the PRISMA protocol, each record underwent a rigorous screening process (see Figure 1). The review team used Zotero to ensure effective bibliographic management, which facilitated the efficient removal of duplicate entries, leading to 84 articles being shortlisted for more detailed scrutiny. The study upheld strict methodological integrity by implementing a dual-review system. Two independent reviewers critically assessed each article against the established criteria specified in Table 2. The criteria were designed to focus on empirical research related to innovative teaching methodologies and the integration of digital tools in high school education. Any disagreement about article selection was resolved through discussion with a third impartial adjudicator to ensure the reliability of the selection process.

Table 2: Inclusion and Exclusion Criteria

Criteria category	Inclusion criteria	Exclusion criteria
Document type	Journal articles	Conference papers, book chapters
Dependent variable	Digital technology intervention	Pedagogical approaches
Educational setting	High school classrooms	Primary and secondary school classrooms
Study outcomes	Student success metrics	No performance analysis
Research methodology	RCT, experimental, quasi-experimental designs	Methodologically weak studies
Publication Range	2018 to 2023	Before 2018 and after 2023
Comparative analysis	Comparison of technology-aided instruction and conventional methods	No comparative element
Measurement of learning	Use of standardized assessments	Anecdotal evidence or testimonials
Language	English	Any other language
Sources	Database sources only	Any other

Note. RCT = Randomized controlled trial
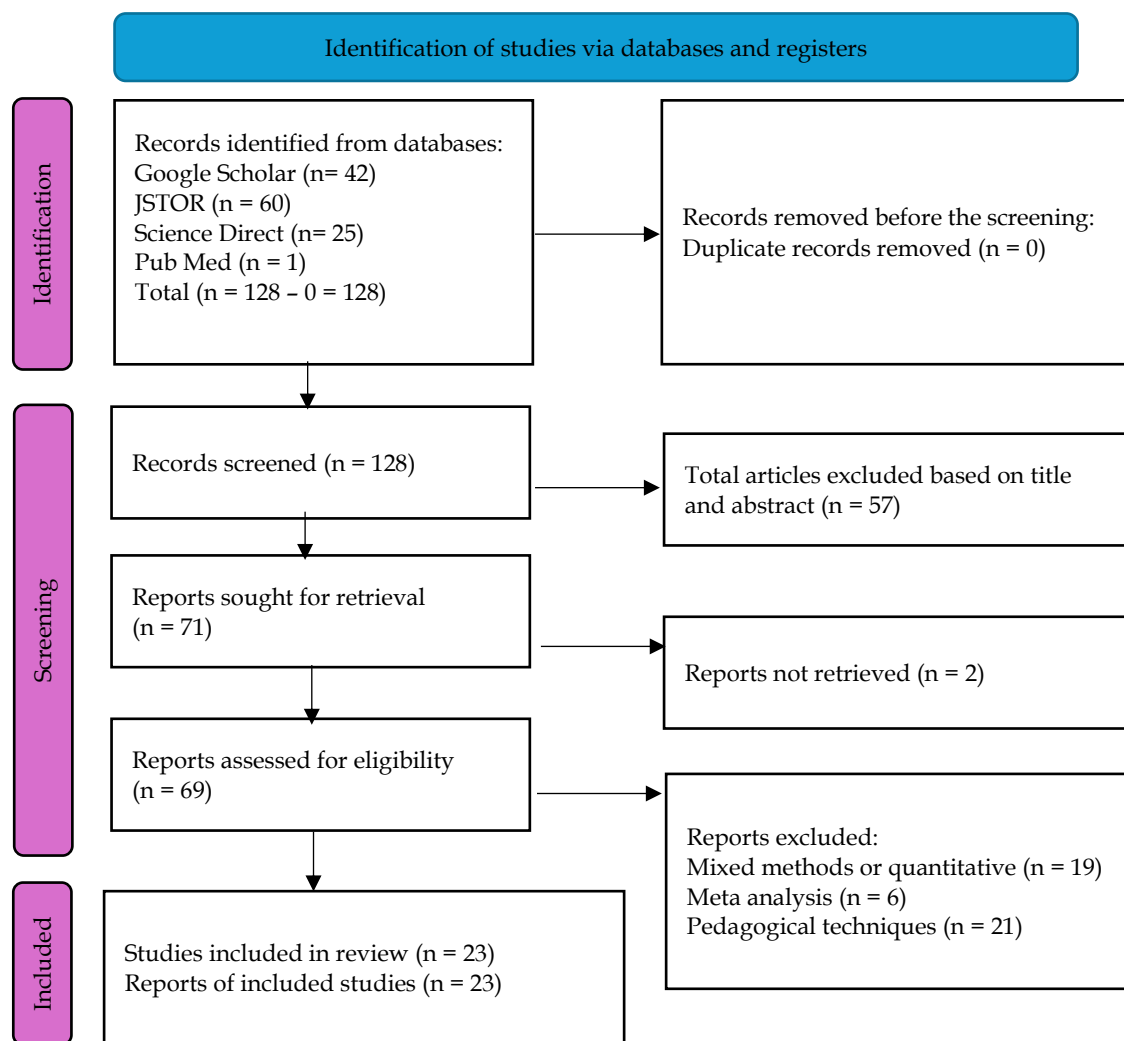
Figure 1: PRISMA Guideline Flowchart

2.3 Data Extraction and Analysis

The meticulous review process identified 71 articles that aligned closely with the research intent. After a comprehensive full-text assessment, the researchers distilled this number to 23 studies that met all inclusion criteria and addressed the research question directly. Upon finalizing the literature selection, two researchers proceeded with the data extraction from 23 qualified studies. Utilizing specifically designed Excel templates, the researchers captured an array of data points, including the type and functionality of digital tools used, the strategies described for integrating technology in high schools, the effects on student learning outcomes reported, and the pedagogical techniques used. The reviewers recorded the data systematically and compiled it into Table 3, which offers a transparent and comparative view of the findings.

Table 3: Summary of Studies Included in the Review

Source	Methodology	Educational technology	Outcome	Country
Azam et al. (2019)	QE	Game-based learning platform (Kahoot) and online learning platform (Pin Up)	PE	Malaysia
Cai et al. (2020)	E	Augmented reality	PE	China
Cai et al. (2019)	E	Augmented reality	ME	Taiwan & China
Faour and Ayoubi (2018)	E	Computer simulations	PE	Lebanon
Homer et al. (2019)	E	Game-based learning platform - All You Can E.T. (AYCET)	NE	United States
Hsiao et al. (2018)	QE	3D technology	PE	Taiwan
Kühl and Münzer (2019)	RCT	Computer animations	PE	Germany
Kunnath and Kriek (2018)	RCT	Guided Computer Simulations	PE	South Africa
Nikou and Economides (2018)	QE	Mobile-based microlearning and assessment (MbmlA)	PE	Europe
Raes et al. (2020)	E	Online platform	NE	Belgium
Shadiev et al. (2018)	QE	Mobile multimedia learning system (MMLS)	PE	N/A
Stenberdt and Makransky (2023)	E	Virtual reality	PE	Denmark
Tong et al. (2022)	QE	Blended learning (interactive boards and Google Classroom)	PE	Vietnam
Wang et al. (2018)	QE	Online platform (modern technology, flipped classroom)	PE	China & Taiwan
Weintrop and Wilensky (2019)	E	Online programming environment (Pencil.cc)	ME	United States
Wen et al. (2020)	E	Interactive simulation environment (CoSci)	PE	Taiwan
Winkler et al. (2021)	QE	Smart personal assistants (Amazon's Alexa)	PE	Germany
Xing et al. (2023)	E	Mobile app and thermal camera	PE	United States
Yang et al. (2020)	QE	Game-based learning platform (English vocabulary)	PE	China
Zakaria and Aziz (2019)	QE	Digital computer stories	PE	Malaysia
Zheng et al. (2019)	E	Virtual learning environment (electronics)	PE	US
Zhong and Wakat (2023)	QE	Corpus-integrated lessons (AntConc and Ant Word Profiler)	PE	China
Zhuoluo et al. (2019)	E	Virtual learning environment (Haptic Lab Device)	PE	China

3. Results

This section presents the findings of the systematic review and focuses on the effect of digital tools on high school education through the lens of the SAMR model. The review synthesized data from 23 selected studies to provide insights into how digital technologies influence educational outcomes, and the factors that mediate the effectiveness of digital technologies.

3.1 Effect of Digital Technologies on Learning of High School Students (Question 1)

The systematic review critically evaluated the specific effects of digital tool integration in high school education by synthesizing data from 23 carefully selected studies. These studies, conducted between 2018 and 2023, reveal substantial, positive effects of various technological interventions on educational outcomes. The technologies that were examined included computer simulations, mobile-based learning, and game-based platforms.

3.1.1 Assessment of Outcomes Across Research Studies

An examination of the influence of digital tools on high school education by the systematic review reveals a predominant trend of positive outcomes in 19 studies, which suggests that such integrations can enhance student learning experiences significantly. For example, Kunnath and Kriek (2018) report a high effect size in a guided learning group that used computer simulations, which demonstrates effective learning. Similarly, Hsiao et al. (2018) found that teaching with 3D technology significantly improved students' learning outcomes. These studies corroborate the notion that tailored educational technology interventions can lead to substantial gains in student performance and engagement.

However, the integration of digital tools in educational settings is not without its challenges. Homer et al. (2019) report a small effect size and that game-based learning platforms had the potential to increase anxiety, which suggests that the effect of technology is multifaceted and context-dependent. This finding is echoed by Raes et al. (2020), who report lower motivation levels in hybrid-virtual settings than in face-to-face interactions, thereby underlining the necessity of strategic technology-enhanced learning (TEL) management.

The nuances of the role of technology in education is illustrated further by two studies with mixed effects. Weintrop and Wilensky (2019) investigated block-based programming and found that, while there was an initial improvement in student performance, outcomes eventually equalized between different instructional approaches. Similarly, Cai et al. (2020) discovered mixed effects on students' cognitive skills after an augmented reality intervention, with some abilities improving and others not.

These findings signal the importance of a critical and nuanced approach to TEL application. As such, there is a clear need for educational strategies that recognize individual student differences, the nature of the learning task, and the context in which TEL is implemented. This perspective advocates for ongoing adjustment and refinement of digital tools in education to ensure that the tools serve the diverse needs of students, as highlighted by the research conducted by Zheng et

al. (2019) and Wen et al. (2020). Collectively, this body of evidence underscores the transformative potential of TEL when it is applied thoughtfully, and suggests that, while digital tools can catalyze education improvements, their deployment must be calibrated carefully to fully harness their benefits and mitigate any unintended negative effects.

3.1.2 Distribution of Research Studies by Digital Technologies Used
The systematic review of 23 studies presents a comprehensive overview of the array of digital technologies utilized in high school educational settings, spanning seven categories of technological tools. These studies report a variety of outcomes, thereby contributing rich insights into the effectiveness of these digital interventions. Among the categories of outcomes, computer simulations and animations are the most represented – four studies examined their role in enhancing pedagogical practices. Virtual reality and game-based learning platforms are each explored in three studies that investigated immersive and gamified learning experiences, respectively. Mobile-based learning systems are also detailed in three studies that highlight the adaptability of learning through handheld devices. Web-based learning platforms and augmented reality are featured in two studies apiece, which demonstrate their growing influence in educational environments. Finally, interactive learning environments round out the categorization with two studies, thereby signifying a shift toward more engaging and collaborative forms of technology-enabled education. The breadth of these categories, ranging from single-study representations to those with multiple investigations, showcases the diverse landscape of digital tools in contemporary high school education. Figure 2 categorizes these technologies according to the number of studies and demonstrates the varied implications for educational delivery.
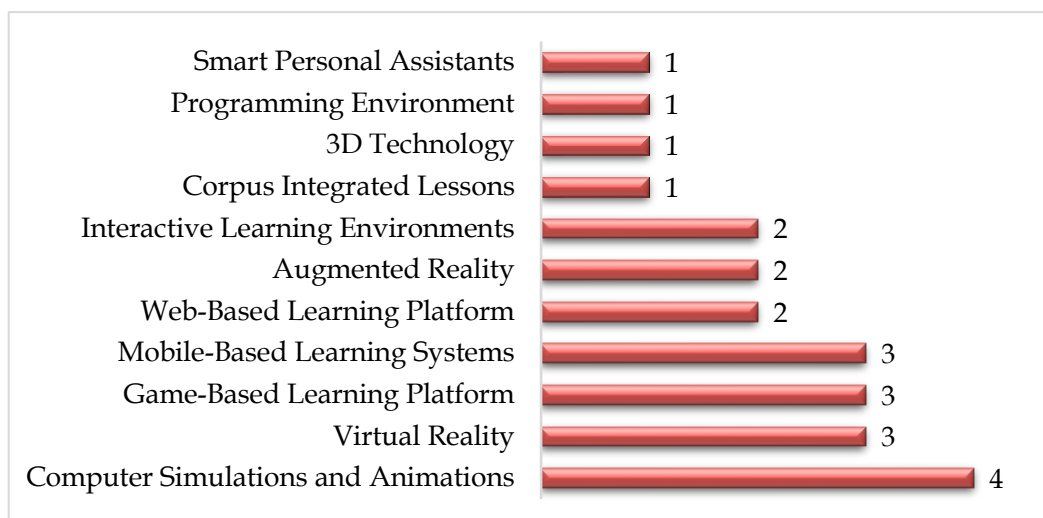
Figure 2: Categories of Educational Technology used by Studies

Computer simulations and animations, which encompass guided learning systems and animated educational content, featured in four studies (Faour & Ayoubi, 2018; Kühl & Münzer, 2019; Kunnath & Kriek, 2018; Zakaria & Aziz, 2019). These technologies enable dynamic visualization and interaction with complex concepts, and enhance understanding and retention. Virtual reality was

explored in three distinct studies (Stenberdt & Makransky, 2023; Zheng et al., 2019; Zhuoluo et al., 2019) that show that providing immersive environments enable students to engage deeply with content through simulated experiences. Game-based learning platforms also appear in three studies (Azam et al., 2019; Homer et al., 2019; Yang et al., 2020). These platforms introduce competitive elements and interactive scenarios to facilitate learning, and show the value of gamification in maintaining student interest and participation.

Mobile-based learning systems, including microlearning and multimedia learning systems, are addressed in three studies (Nikou & Economides, 2018; Shadiev et al., 2018; Xing et al., 2023). These studies emphasize the flexibility and accessibility of mobile platforms, which make learning at any time and anywhere possible. Web-based learning platforms were investigated by two studies (Raes et al., 2020; Wang et al., 2018). These platforms often include features such as flipped classrooms and blended learning environments and show a blend of traditional and digital methods.

Augmented reality, as reported by two studies – Cai et al. (2019) and Cai et al. (2020) – merges digital elements with the physical world to offer an enhanced, interactive learning experience. Interactive learning environments are documented in two studies. Tong et al. (2022) and Wen et al. (2020) report that technology-facilitated environments foster collaborative and practical engagement with learning materials. Individual technologies are represented by a single study each: 3D technology by Hsiao et al. (2018), a programming environment by Weintrop and Wilensky (2019), and smart personal assistants by Zhong and Wakat (2023). These unique instances reflect innovative applications of technology that are tailored to specific education needs.

The range of technologies signals a move toward personalized educational experiences, with digital tools becoming central to modern pedagogical strategies. The aggregated data underscore the diversification of educational technology and its measurable effect on learning outcomes to indicate the pivotal role these tools play in shaping contemporary education. Each category and the individual studies within it contribute to a layered understanding of the multifaceted influence of technology across various teaching and learning contexts. Table 4 categorizes the various educational technologies examined in the systematic review and lists the number of studies associated with each category to provide a clear reference for the prevalence of topics in and focus of the current research landscape.

Table 4: Distribution of Studies by Educational Technology

Educational Technology	Count	Sources
Computer simulations and animations	4	Faour and Ayoubi (2018); Kühl & Münzer (2019); Kunnath and Kriek (2018); Zakaria and Aziz, (2019)
Virtual reality	3	Stenberdt and Makransky (2023); Zheng et al. ((2019)
Game-based learning platform	3	Azam et al. (2019); Homer et al. (2019); Yang et al. (2020)
Mobile-based learning systems	3	Nikou & Economides (2018); Shadiev et al. (2018); Xing et al. (2023)
Web-based learning platform	2	Raes et al. (2020); Wang et al. (2018)
Augmented reality	2	Cai et al. (2019); Cai et al. (2020)
Interactive learning environments	2	Tong et al. (2022); Wen et al. (2020)
Corpus-integrated lessons	1	Winkler et al. (2021)
3D technology	1	Hsiao et al. (2018)
Programming environment	1	Weintrop and Wilensky (2019)
Smart personal assistants	1	Zhong and Wakat (2023)

3.2 Effect of Digital Tools on Academic Performance and Engagement (Question 2)

3.2.1 Effect of Digital Tools on Academic Performance and Engagement

The majority of studies reviewed reported digital tools having a positive effect on student performance and engagement. Specifically, digital tools were found to enhance various aspects of the learning experience, including student autonomy, engagement, and academic performance. The systematic review reveals a predominant trend of positive outcomes from 19 studies, suggesting that such integrations can significantly enhance student learning experiences (Figure 3). For example, Kunnath and Kriek (2018) report that guided computer simulations significantly improved learning; similarly, Hsiao et al. (2018) found that teaching with 3D technology significantly improved students' learning outcomes. These studies corroborate the notion that tailored educational technology interventions can lead to substantial gains in student performance and engagement.
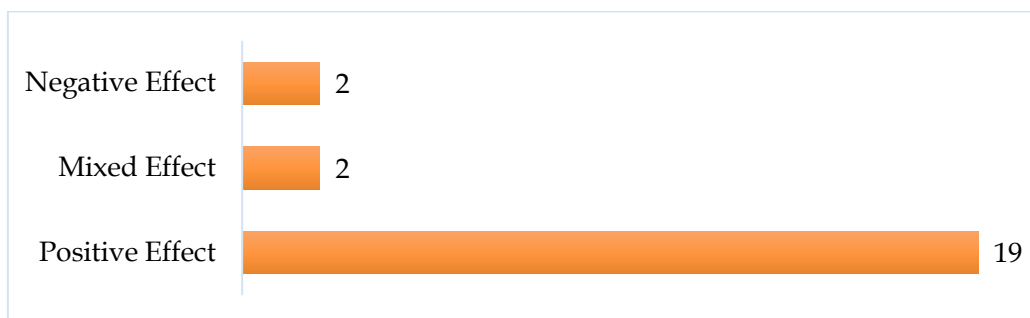
Figure 3: Measurement of Effects Across Studies

3.2.2 Effect of Digital Tools on Student Autonomy

Digital tools such as mobile-based microlearning platforms and digital storytelling enabled students to take control of their learning pace and style, leading to increased autonomy and motivation. For instance, Nikou and Economides (2018) report that using mobile-based microlearning allowed students to access learning materials at their convenience, thereby significantly enhancing their self-regulated learning capabilities. Similarly, Zakaria and Aziz (2019) found that digital storytelling fostered a sense of ownership of and personal connection with the learning material, and motivated students to engage more deeply with the content.

3.2.3 Effect of Digital Tools on Engagement

Interactive technologies such as 3D simulations and game-based learning platforms significantly boosted student engagement and participation in the learning process. Hsiao et al. (2018) demonstrate that 3D simulations in science lessons not only captured students' attention but also made complex concepts more accessible and easier to understand, thereby increasing engagement scores compared to traditional teaching methods. Similarly, Azam et al. (2019) found that game-based learning platforms such as Kahoot increased student engagement by introducing elements of competition and instant feedback, which encouraged active participation by and collaboration among students.

3.2.4 Effect of Digital Tools on Academic Performance

Studies utilizing guided computer simulations and virtual learning environments report notable improvements in academic performance, because these tools facilitated a deeper understanding of complex concepts. Kunnath and Kriek (2018) show that guided computer simulations in physics lessons helped students visualize and experiment with physical phenomena, leading to better comprehension and retention of the material. Zhuoluo et al. (2019) found that virtual learning environments enhanced students' academic performance by providing interactive and immersive experiences that reinforced learning through practice and repetition.

3.3 Contextual and Pedagogical Factors (Question 3)

While integrating digital tools in high school education has generally resulted in positive outcomes, the systematic review found that their success is contingent on thoughtful implementation. The studies that were reviewed reveal that factors such as content complexity, technology exposure, and the specific educational

context played crucial roles in determining the effectiveness of these interventions.

3.3.1 Spatial Distribution of Research Studies

Figure 4 presents a visualization of the global distribution of research on educational technology interventions. It underscores the significant international scope of this field, with China and the United States leading the way, each contributing four studies to the body of research. Following closely are Taiwan and Germany, each with two studies, and Malaysia also presenting a strong investment in the field, with two studies. The chart acknowledges individual contributions from South Africa, Europe, Lebanon, Belgium, Vietnam, and Denmark, each contributing one study to demonstrate their unique interest in advancing education technology. One study did not specify the country that was studied (Shadiev et al., 2018). These varied contributions from countries around the world reflect a collective and strategic effort to employ technology to improve educational practices and outcomes.
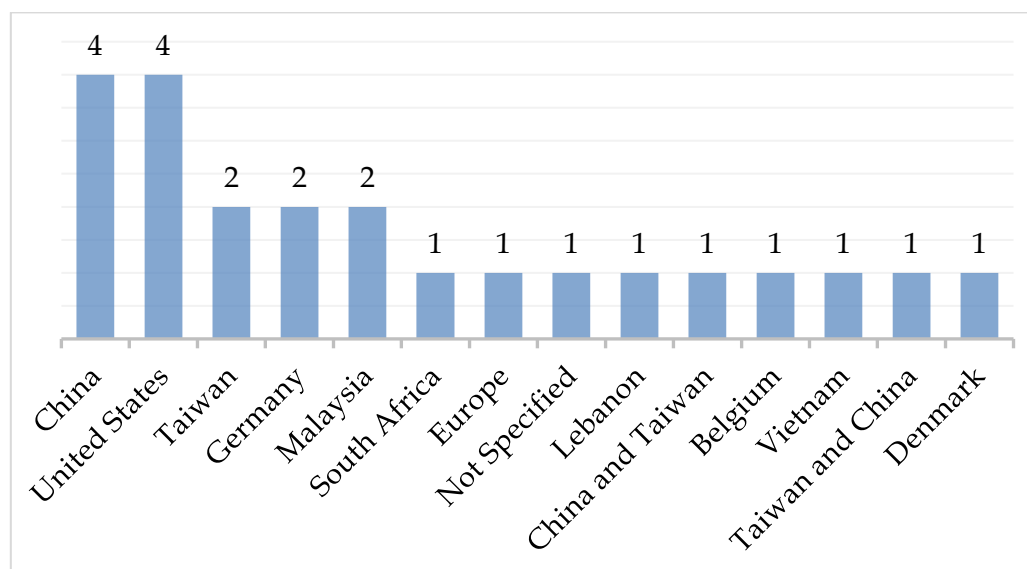

Figure 4: Distribution of studies by country

The diversity revealed by this research mapping emphasizes the extensive and varied international interest in education technology. The commitment by scholars in a variety of nations, from those contributing multiple studies to those with single contributions, highlights the dynamic, inclusive, and globally collaborative nature of research in education technology. It indicates a shared recognition of the potential for technological tools to propel educational advancements worldwide.

3.3.2 Chronological Distribution of Research Studies

By reflecting on the recent insights of scholarly inquiry, Figure 5 encapsulates the research trajectory on the role of digital tools in enhancing educational practices from primary through to senior high school levels. The chart shows a research peak in the years 2018 and 2019, with six and eight studies, respectively. These years indicate a time of a heightened scholarly pursuit of integrating technology

in pedagogy, which coincided with the promotion of progressive education theories that championed the adoption of TEL. The data of these studies align with a shift of education toward the SAMR model, to emphasize the role of technology in redefining the teaching and learning experience, and fostering environments that are ripe for collaboration and innovative learning.
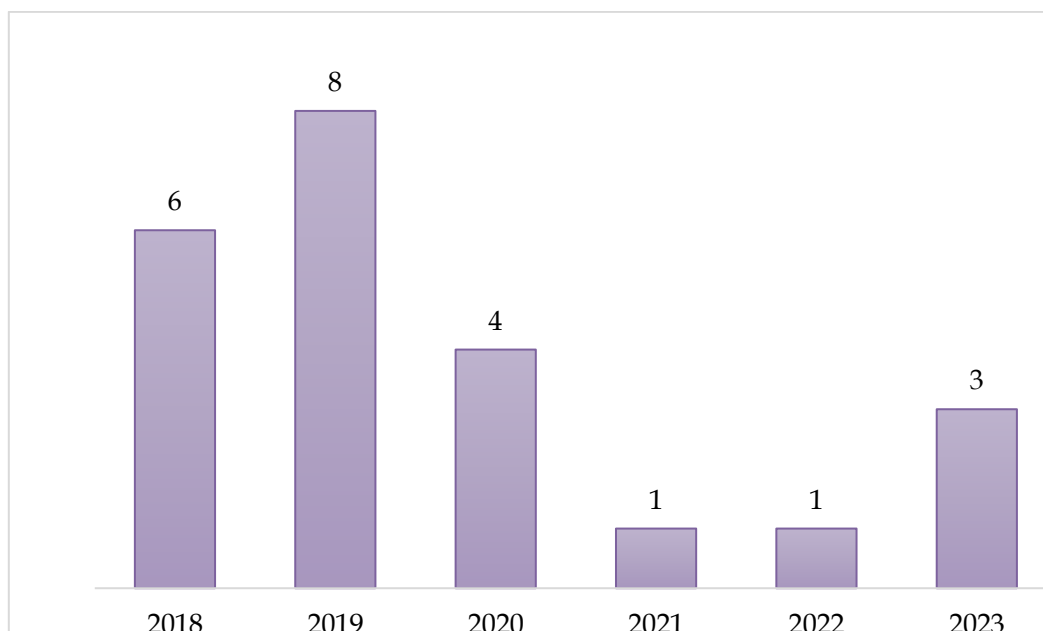

Figure 5: Number of studies published per year

Post-2019, the research landscape depicts a gradual decrease in studies published on this topic, with four studies in 2020, trailing down to one study in each of 2021 and 2022, and rebounding slightly to three studies in 2023. The observed decline in the number of studies published can be attributed to several interrelated factors, primarily influenced by the global COVID-19 pandemic. The onset of the pandemic necessitated a swift pivot in education priorities toward addressing the immediate challenges of remote learning, including issues of connectivity and the digital divide, thereby redirecting research focus away from traditional pedagogical integration of digital tools toward emergency remote teaching strategies. Concurrently, the strain caused by the pandemic on university budgets has led to a redirection of resources toward pandemic-related research areas, thereby affecting the capacity for new studies on digital tool integration. The logistical challenges of lockdowns and social distancing hampered research activities further, particularly studies requiring in-person data collection, which slowed research output.

3.3.3 Distribution of Studies by Research Methodology
This systematic review stands on a foundation of stringent selection criteria, which emphasizes the diversity of research methodologies and provides a comprehensive overview of the effects of digital tools on high school education. This conscientious methodological appraisal led to the inclusion of 23 studies, each carefully chosen based on their experimental framework. Within the array of selected studies, three are classified as randomized controlled trials (RCTs), while

10 followed quasi-experimental designs, and another 10 are categorized as experimental studies (see Figure 6).
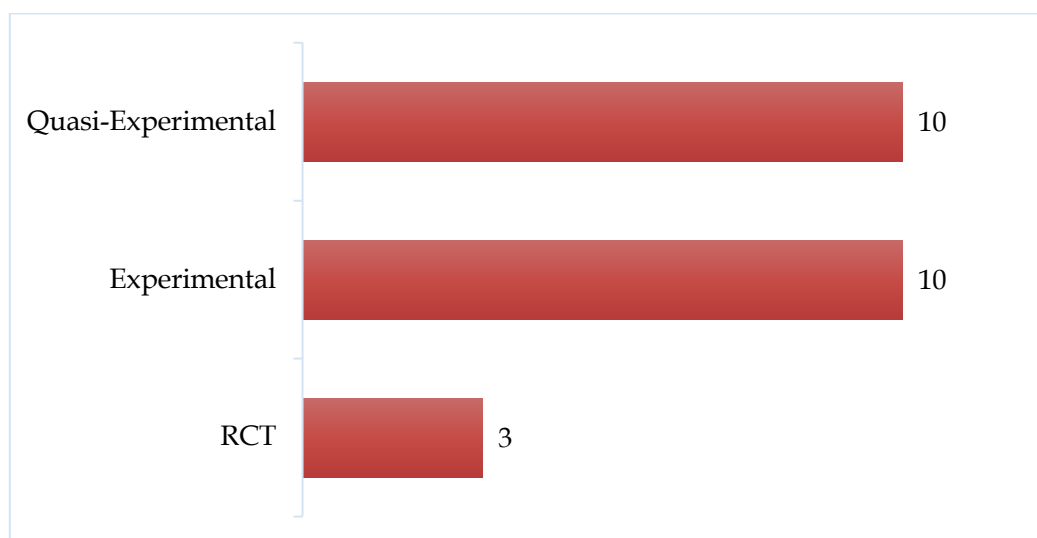
Figure 6: Number of Studies Using a Particular Methodology

The inclusion of three RCTs in the review is indicative of the high-quality evidence base. RCTs are particularly esteemed for their ability to reduce selection bias and provide a robust causal link between interventions and outcomes. These trials serve as a cornerstone for evidence-based practice and contribute significantly to the review by providing highly reliable data.

Complementing the RCTs, the systematic review incorporated 10 studies employing experimental designs. Experimental research is crucial for its capacity to meticulously control and manipulate independent variables while observing the resultant changes in dependent variables. This methodological approach enables a granular analysis of how specific digital tools can influence educational outcomes, with the controlled conditions enabling a clear interpretation of the effects. The review integrated 10 quasi-experimental designs. The flexibility of quasi-experimental studies is their hallmark, which makes them particularly relevant for educational settings in which random assignment may be impractical or unethical. These designs are adept at examining the effects of interventions in naturalistic settings, and offering insights into how digital tools perform in real-world education scenarios.

This methodological diversity enriches the systematic review by providing a multifaceted perspective on the adoption and efficacy of digital tools in high schools. The inclusion of both highly controlled (RCTs and experimental) and more naturalistic (quasi-experimental) studies enables the review to capture the complexity and contextual factors that influence the success of technology integration in education. Moreover, this blend of methodologies ensures a balance between internal and external validity, thereby facilitating a nuanced understanding of the potential of educational technologies in various settings and conditions. Overall, the methodological rigor and comprehensive scope of the

research design spectrum of the review form a robust framework for the evaluation of digital tools in educational settings.

3.4 Barriers to Effective Technology Integration in High School Education (Question 4)

3.4.1 Barriers to Effective Technology Integration in High School Education
Despite the positive outcomes reported, several studies highlight barriers to the effective integration of digital tools in high school education. Homer et al. (2019) identified a small effect size of the effect of game-based learning platforms, which, they report, have the potential to increase anxiety. This finding suggests that the effect of technology is multifaceted and context-dependent. This finding is echoed by Raes et al. (2020), who reports decreased motivation levels in hybrid-virtual settings compared with face-to-face interactions, which underlines the necessity of strategic TEL management.

The role of technology in education is illustrated further by the two studies with mixed effects. Weintrop and Wilensky (2019) investigated block-based programming and found that, while there was an initial improvement in student performance, outcomes eventually equalized for different instructional approaches. Similarly, Cai et al. (2020) discovered mixed effects in students' cognitive skills after an augmented reality intervention, with some abilities improving and others not.

These findings signal the importance of a critical and nuanced approach to TEL application. As such, there is a clear need for educational strategies that recognize individual student differences, the nature of the learning task, and the context in which TEL is implemented. This perspective advocates for ongoing adjustment and refinement of digital tools in education to ensure they serve the diverse needs of students, as highlighted by the research conducted by Zheng et al. (2019) and Wen et al. (2020).

3.4.2 Technological Infrastructure
Inadequate infrastructure and limited access to digital devices were significant barriers, particularly at under-resourced schools. Faour and Ayoubi (2018) found that schools in Lebanon faced challenges in providing sufficient computers and reliable internet connections, which hindered the effective use of digital tools. Kunnath and Kriek (2018) identified similar issues in South Africa, where many schools had inadequate technological infrastructure.

3.4.3 Teacher Training
A lack of comprehensive training for teachers on the use of digital tools hindered their effective implementation and integration into the curriculum. Shadiev et al. (2018) report that many teachers were not adequately trained to utilize mobile multimedia learning systems, resulting in underutilization and ineffective integration of these tools. Kühl and Münzer (2019) found that, even in technologically advanced countries such as Germany, teachers often lacked the necessary skills and confidence to integrate computer animations and other digital tools into their teaching practices.

3.4.4 Equity and Access

Disparities in access to digital tools among students from different socio-economic backgrounds posed challenges to equitable learning opportunities. Nikou and Economides (2018) observed that students from lower-income families had limited access to mobile devices and reliable internet, which affected their ability to engage with mobile-based microlearning. Azam et al. (2019) report similar findings for Malaysia, where students from rural areas faced significant barriers to accessing game-based learning platforms and other digital resources.

3.5 Strategies for Optimizing Digital Tool Integration (Question 5)

3.5.1 Strategies for Optimizing Digital Tool Integration in High School Education

The review identified several strategies that can enhance the effectiveness of digital tool integration in high school education. Providing ongoing professional development and support for teachers is crucial to ensuring they have the necessary skills and confidence to utilize digital tools effectively. Collaboration among stakeholders, including educators, policymakers, and technology providers, is essential to address infrastructural challenges and ensure the equitable distribution of resources. Additionally, tailoring digital tools and teaching strategies to the specific cultural and contextual needs of the educational setting can enhance the effectiveness and relevance of the tools and strategies, and promote better educational outcomes for all students.

3.5.2 Professional Development

Providing ongoing professional development and support for teachers is crucial for the successful implementation of digital tools. Shadiev et al. (2018) emphasize the importance of regular training sessions and workshops. Kühl and Münzer (2019) recommended peer collaboration and mentoring programs – many teachers found peer support beneficial.

3.5.3 Collaborative Efforts

Collaboration among stakeholders, including educators, policymakers, and technology providers, is essential for addressing infrastructural challenges and ensuring the equitable distribution of resources. Azmi Zakaria and Aziz (2019) highlight the success of collaborative initiatives in Malaysia, where government–private partnerships increased the availability of digital tools in many schools. Zhong and Wakat (2023) suggest that similar efforts in Japan bridged the digital divide between urban and rural schools, and improved access in rural schools.

3.5.4 Contextual Adaptation

Tailoring digital tools and teaching strategies to the specific cultural and contextual needs of the educational setting can enhance their effectiveness and relevance. Nikou and Economides (2018) found that adapting mobile-based microlearning content to reflect local cultural contexts increased student engagement. Zhuoluo et al. (2019) report that linguistic and cultural differences must be considered when virtual learning environments are designed, to make them more effective in diverse settings.

4. Discussion

The discussion section interprets the findings of the systematic review in the context of the existing literature and the SAMR model. It explores the implications of these findings for educational practice and policy and identifies areas for future research.

4.1 Impact of Digital Technologies on High School Students (Question 1)

The integration of digital tools in high school education, as examined in 23 key studies, provides a comprehensive overview of the transformation these technologies bring to teaching and learning paradigms. The potential of these tools is substantiated by quantitative evidence and the SAMR model explains the integration of digital tools in education.

Kunnath and Kriek (2018) unveiled the significant potential of using computer simulations in guided learning, with an impressive effect size of .794. This highlights the remarkable possibility of these simulations to modify the educational experience beyond traditional means. Complementing this finding, Hsiao et al. (2018) harnessed the power of 3D technology to augment spatial learning, which improved student performance.

Nikou and Economides (2018) exemplify the transition to autonomy in learning through mobile-based microlearning and assessment (MBmLA), and report substantial student empowerment with an effect size of .22. Similarly, the substantial effect size of .372 in the study by Shadiev et al. (2018) indicates the profound benefits of mobile multimedia learning systems for language proficiency.

Animations and digital storytelling have redefined educational content delivery, as evidenced by Kühl and Münzer (2019) and Zakaria and Aziz (2019), with their studies yielding positive effects on engagement and comprehension, respectively. Azam et al. (2019) extended this innovation to game-based learning platforms to enhance writing skills; they indicate a significant leap toward the redefinition stage of the SAMR model.

Further exploration of the application of the SAMR model was done by Zhuoluo et al. (2019), whose implementation of haptic feedback in virtual learning environments shows the modification level of the model as having a p-value of .032. Zhong and Wakat (2023) added to this discourse by reporting an improvement in corpus-integrated lessons, signifying the redefinition stage of the model.

The utilization of virtual learning environments by Zheng et al. (2019) encouraged collaborative group learning and successful task execution strategies, which resonates with the collaborative potential fostered by digital tools. Notably, the studies by Homer et al. (2019) and Raes et al. (2020) provide cautionary perspectives on the challenges of technology integration, such as increased anxiety and lower motivation, which emphasizes the need for strategic deployment of these resources.

Tong et al. (2022) investigated the role of blended learning and found that interactive boards and Google Classroom facilitated improvements in self-study skills and academic achievement. In the same vein, Winkler et al. (2021) observed the potential of smart personal assistants to redefine the learning environment; they report an effect size of. 5178.

Transformative learning experiences with augmented reality are articulated by Cai et al. (2020) and Cai et al. (2019), who report substantial post-test score increases, while Wen et al. (2020) presents a technology-enhanced environment conducive to scientific literacy improvements. Xing et al. (2023) rounds out the discussion with mobile apps and thermal cameras, to reflect innovation at the forefront of education technology.

Each of these studies enriches the academic discourse, and contributes unique insights to the efficacy and transformational capacity of digital tools. The collective data drive home the message of a paradigm shift in educational practice that is aligned with the need for digital competencies that are essential for thriving in a technologically advanced society.

This spectrum of studies, from augmented reality to mobile apps, emphasizes the support that digital tools provide, and not only for traditional educational approaches. Digital tools also have the ability to introduce novel, interactive methods to encourage student engagement and knowledge comprehension. However, they also serve as reminders of the nuanced challenges in digital tool integration. Ensuring that technology complements, rather than complicates learning processes, is paramount, and necessitates a holistic approach to digital tool implementation.

In essence, these studies, through the prism of the SAMR model, provide empirical evidence that supports the diverse levels of technology integration in high school education. This insight informs a broader understanding of how digital tools can redefine educational outcomes and offer actionable insights for future pedagogical strategies. The exhaustive discourse of the systematic review underscores the essential role of empirical evidence in the continuous evolution of educational practices, to ensure that technology integration is both effective for and sensitive to the varying needs of the educational landscape.

4.2 Effect of Digital Tools on Academic Performance and Engagement (Question 2)

The review demonstrates that digital tools have a significant positive effect on high school students' academic performance and engagement. These findings align with the SAMR model, which posits that technology can transform learning by augmenting and redefining traditional educational practices. When they are effectively integrated into the curriculum, digital tools can enhance both the quality and effectiveness of education.

4.2.1 Interpretation of Positive Outcomes

The predominant trend of positive outcomes across 19 studies suggests that integrating digital tools can significantly enhance student learning experiences. For example, Kunnath and Kriek (2018) report a considerable effect size in a guided learning group that used computer simulations, thereby demonstrating effective learning. Similarly, Hsiao et al. (2018) found that teaching with 3D technology significantly improved students' learning outcomes. These studies corroborate the notion that tailored educational technology interventions can lead to substantial gains in student performance and engagement.

4.2.2 Impact on Student Performance and Engagement

Tools such as mobile-based microlearning platforms and digital storytelling enhance student autonomy by enabling personalized learning experiences. Interactive technologies, such as 3D simulations and game-based learning platforms, increase engagement by making learning more interactive and enjoyable. The improvements in academic performance reported by the studies suggest that digital tools can facilitate a deeper understanding of complex concepts through interactive and immersive learning experiences.

These findings align with the SAMR model, which posits that technology can transform learning by augmenting and redefining traditional educational practices. The positive outcomes observed in the studies reviewed suggest that, when digital tools are effectively integrated into the curriculum, they can enhance both the quality and effectiveness of education.

4.3 Contextual and Pedagogical Factors Influencing the Effectiveness of Digital Technologies (Question 3)

The results from the systematic review provide a comprehensive understanding of how contextual and pedagogical factors play a crucial role in the effectiveness of digital tools in high school education. The discussion that follows interprets these findings in relation to the goals and design of the research study, to highlight the implications for educational practice and future research.

4.3.1 Influence of Geographical Context

The global distribution of research studies underscores the diverse contexts in which digital tools are applied and the varying degrees of success observed. The significant contributions by countries like China and the United States, each with four studies, reflect the robust interest in these regions to explore the potential of digital technologies in education. This finding suggests that well-established technological infrastructure and supportive national education policies in these countries may contribute to more effective integration of digital tools.

However, the effectiveness of these tools is not uniform across all contexts. The studies done in regions with less developed technological infrastructure, such as certain parts of Asia and Africa, indicate that, while the potential for digital tools is recognized, challenges such as limited access to technology and differing cultural attitudes toward education can hinder the successful implementation of digital tools. This disparity highlights the importance of tailoring digital tool integration to the specific needs and capabilities of each educational environment.

The variations in geographical context also suggest that global collaboration and sharing of best practices could be instrumental to overcoming certain barriers. For instance, lessons learned from successful implementations in technologically advanced regions could inform strategies in less developed areas, potentially leading to more equitable educational outcomes globally.

4.3.2 Impact of Temporal Factors and External Events

The peak in research activity during 2018 and 2019, followed by a decline during the COVID-19 pandemic, reveals the significant impact of external events on the focus and priorities of education research. The decline in the number of publications on the topic during the shift toward emergency remote teaching during the pandemic suggests that the traditional pedagogical integration of digital tools was deprioritized in favor of finding immediate, pragmatic solutions to ensure continuity in education.

This shift emphasizes the adaptability required by digital tool integration. While the pandemic led to rapid adoption of technology, it also exposed the limitations of using digital tools without sufficient preparation and support. The decline in research output during this period may reflect the challenges faced by researchers in conducting studies under unprecedented conditions, such as restrictions on in-person data collection and shifts in funding toward pandemic-related issues.

From a pedagogical perspective, the pandemic underscores the need for flexible and resilient education technologies that can be adapted quickly to changing circumstances. It also raises questions about the long-term impact of the pandemic on education technology research and whether the lessons learned during this period will influence future pedagogical strategies and research designs.

4.3.3 Methodological Considerations and Their Implications

The methodological diversity observed in the studies, which ranged from RCTs to quasi-experimental designs, provides a nuanced understanding of the effectiveness of digital tools across different educational contexts. The use of RCTs, while valuable for establishing causal relationships, may not fully capture the complexity of real-world educational settings where random assignment is often impractical. This limitation suggests that, while RCTs provide robust evidence, their findings need to be interpreted with caution when they are applied to broader educational contexts.

Quasi-experimental designs, in turn, offer insights into how digital tools perform in natural settings. These studies are particularly valuable for understanding the practical challenges and contextual factors that influence the success of digital interventions. The inclusion of both experimental and quasi-experimental studies in the review reflects a balanced approach to research design, to ensure that the findings are both internally valid and externally applicable.

The results also highlight the need for future research to consider mixed method approaches that combine the strengths of both experimental rigor and contextual relevance. Such approaches could provide a more comprehensive understanding

of how digital tools can be effectively integrated in diverse educational environments.

4.4 Barriers to Effective Technology Integration in High School Education (Question 4)

Despite the positive outcomes, several barriers to the effective integration of digital tools were identified. Inadequate infrastructure and limited access to digital devices, particularly at under-resourced schools, significantly hinder the use of technology in education. Additionally, a lack of comprehensive training for teachers on the use of digital tools prevents effective implementation and integration of these tools into the curriculum. Disparities in access to digital tools among students from different socio-economic backgrounds pose further challenges to equitable learning opportunities. These barriers highlight the need for targeted strategies to address infrastructure, training, and access issues.

4.4.1 Technological Infrastructure
Inadequate infrastructure and limited access to digital devices were significant barriers, particularly in under-resourced schools. Faour and Ayoubi (2018) report that many schools in Lebanon faced challenges to provide students with sufficient computers and reliable internet connections, which hindered the effective use of digital tools. Kunnath and Kriek (2018) identified similar issues in South Africa, where many schools had inadequate technological infrastructure.

4.4.2 Teacher Training
A lack of comprehensive training for teachers on the use of digital tools hindered effective implementation and integration of tools into the curriculum. Shadiev et al. (2018) highlight that many teachers were not adequately trained to utilize mobile multimedia learning systems, which resulted in underutilization and ineffective integration of these tools. Kühl and Münzer (2019) found that, even in technologically advanced countries such as Germany, teachers often lacked the necessary skills and confidence to integrate computer animations and other digital tools in their teaching practices.

4.4.3 Equity and Access
Disparities in access to digital tools among students from different socio-economic backgrounds posed challenges to equitable learning opportunities. Nikou and Economides (2018) observed that students from lower-income families had limited access to mobile devices and reliable internet, which affected their ability to engage with mobile-based microlearning. Azam et al. (2019) reported similar findings for Malaysia, where students from rural areas faced significant barriers to accessing game-based learning platforms and other digital resources.

4.4.4 Mixed and Negative Effects
While the majority of studies reported positive outcomes, a few highlighted potentially negative effects. For instance, Homer et al. (2019) identified the potential for increased anxiety when game-based learning platforms were used. Raes et al. (2020) reports lower motivation levels in hybrid-virtual settings than in face-to-face interactions, which underlines the necessity of strategic TEL management. The mixed effects reported by studies by Weintrop and Wilensky

(2019) and Cai et al. (2020) emphasize the importance of a critical and nuanced approach to TEL application.

4.5 Strategies for Optimizing Digital Tool Integration (Question 5)

The review identified several strategies to enhance the effectiveness of digital tool integration in high school education. It is crucial to provide ongoing professional development and support for teachers, to ensure they have the necessary skills and confidence to utilize digital tools effectively. Collaboration among stakeholders, including educators, policymakers, and technology providers, is essential to address infrastructural challenges and ensure the equitable distribution of resources. Additionally, tailoring digital tools and teaching strategies to the specific cultural and contextual needs of the education setting can enhance their effectiveness and relevance, and promote better educational outcomes for all students.

4.5.1 Professional Development

For the successful implementation of digital tools, it is crucial to provide ongoing professional development and support for teachers. Shadiev et al. (2018) emphasize the importance of regular training sessions and workshops, and report that many teachers expressed a need for ongoing professional development. Kühl and Münzer (2019) also recommend peer collaboration and mentoring programs, and that many teachers find peer support beneficial.

4.5.2 Collaborative Efforts

Collaboration among stakeholders, including educators, policymakers, and technology providers, is essential to address infrastructural challenges and ensure the equitable distribution of resources. Azmi Zakaria and Aziz (2019) highlight the success of collaborative initiatives in Malaysia, where partnerships between government and private entities increased the availability of digital tools at many schools. Zhong and Wakat (2023) suggest that similar efforts in Japan bridged the digital divide between urban and rural schools to improve access for rural schools.

4.5.3 Contextual Adaptation

Tailoring digital tools and teaching strategies to the specific cultural and contextual needs of the educational setting can enhance their effectiveness and relevance. Nikou and Economides (2018) found that adapting mobile-based microlearning content to reflect local cultural contexts increased student engagement. Zhuoluo et al. (2019) emphasize considering linguistic and cultural differences when designing virtual learning environments, to make them more effective in diverse settings.

4.6 Brief Overview

In the context of high school education, the continued exploration and application of digital tools as outlined in this systematic review attest to the ongoing endeavor to enhance learning outcomes and align teaching practices with the demands of a digital era. The review findings suggest that, while technology integration must be approached with an understanding of contextual and pedagogical nuances, its potential to revolutionize the education landscape remains significant. By offering a thorough analysis of the literature and empirical evidence for various settings

and conditions, the review contributes a comprehensive understanding, guided by the principles of the SAMR model, of the transformative effect of digital tools on high school education.

4.7 Limitations

While this systematic review provides valuable insights into the integration of digital tools in high school education, it operates within a scope bounded by specific limitations. The heterogeneity of study designs – from RCTs to quasi-experimental setups – introduced a degree of variability that could affect the metasynthesis of data. The diverse array of digital tools analyzed, each with unique functionalities and educational objectives, made it challenging to generalize the effectiveness of TEL interventions in different contexts.

Moreover, the geographical and demographic variances among the participant groups limit the generalizability of the findings, potentially rendering them less applicable to educational settings outside those studied. Given the rapid evolution of technology, the relevance of findings associated with specific tools or platforms may diminish as newer, more advanced solutions emerge. This review is also constrained by its temporal scope. It encompasses studies published between 2018 and 2023, which means it may not reflect the most current trends or account for very recent innovations in education technology.

Another notable constraint is the underrepresentation of studies with negative or mixed results. This limitation points to the possibility of publication bias in the field, which may mean that studies yielding positive outcomes are more readily published. Consequently, this review may not fully capture the range of possible effects, both beneficial and detrimental, associated with TEL. Additionally, the focus on high school education means that the findings may not translate directly to primary school settings, where developmental differences could affect how students interact with and benefit from digital technologies.

4.8 Implications for Practice and Policy

The findings of this review have several implications for educational practice and policy. First, they highlight the potential of digital tools to enhance learning outcomes and support student engagement. Educators should receive appropriate support and training to encourage them to integrate digital tools in their teaching practices. Fundamental to this progression is the development of a comprehensive digital infrastructure, as identified by Lawless and Pellegrino (2007), which not only supports the technological requirements of modern education, but also promotes the availability of open educational resources that cater to various learning needs across socio-economic spectrums.

Second, the barriers identified in the review suggest that policymakers need to invest in technological infrastructure and professional development for teachers. Collaborative engagement with a broad spectrum of education stakeholders is vital to inform a holistic policy narrative that responds to the evolving digital education landscape (Selwyn et al., 2017). Ensuring equitable access to digital tools for all students, regardless of their socio-economic background, is crucial for addressing disparities in educational outcomes.

Finally, the review underscores the importance of a flexible and context-sensitive approach to technology integration. This involves adapting digital tools and teaching strategies to the specific needs and contexts of students and teachers, and continuously evaluating and refining these approaches based on feedback and outcomes.

4.9 Future Research Directions
While this review provides valuable insights into the effects of digital tools on high school education, it also highlights several areas that warrant further investigation. Future research should include longitudinal studies to examine the long-term effects of integrating digital tools on student performance and engagement. This would provide a more comprehensive understanding of how these tools influence learning outcomes over time (Mishra & Koehler, 2006).

There is a need for more research in diverse educational settings, including under-resourced schools and diverse cultural contexts. This would help to identify best practices and strategies for technology integration that are effective in various environments. Further research is needed to explore the effectiveness of specific digital tools and pedagogical approaches, including examining how different tools and strategies affect various aspects of learning, such as critical thinking, creativity, and collaboration.

More research is required to understand the emotional and psychological effects of digital tool use on students. This includes investigating how these tools can be designed and implemented to support students' well-being and reduce negative effects, such as anxiety and decreased motivation.

5. Conclusion
The findings of this systematic review underscore the transformative potential of digital tools in high school education by emphasizing their ability to significantly enhance both teaching and learning processes. However, successful integration of these technologies extends beyond mere access. It requires a holistic approach that includes professional development for educators, infrastructure improvements, equitable access to resources, and supportive education policies. These elements are crucial for overcoming the inherent challenges of digital education and ensuring that technology serves as a powerful complement to traditional pedagogical methods. The review also underscores the importance of collaborative engagement among key stakeholders in fostering an education ecosystem that is adaptive to technological innovations. This collaborative effort is vital for addressing the educational, technological, and policy-related challenges identified in the review. Moreover, continued research is essential to assess the long-term effects of digital tools on educational outcomes and to guide the ongoing refinement of digital learning environments. By embracing a multifaceted and collaborative approach, the vast potential of digital education to empower diverse learners and promote educational excellence can be fully realized, thus marking a significant step forward in the evolution of education in the digital age.

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