

A Systematic Literature Review on the Use of Technology Tools Used in Game-Based Learning

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Abstract

This study aims to examine the function and impact of the use of technology tools in game-based learning through a systematic literature review from 2019 to 2023. The primary objective of this study is to identify the functions of technology tools used in game-based learning and to determine their impact on student achievement and learning effectiveness. The PRISMA methodology was employed to identify, screen, and select relevant articles from the Web of Science, Scopus, and Science Direct databases. A total of 14 articles were selected for analysis based on specific criteria. The study results show that technology tools such as Scratch, Lego Mindstorms, Augmented Reality, Flash animation, video games, Virtual Reality (VR), and interactive quizzes like Kahoot and Quizizz play various roles in game-based learning. The main functions of these tools include content creation, simulation, interactive learning, and assessment. The study found that the use of these technology tools not only increased student motivation but also improved their academic performance, particularly in subjects like programming, science, and language. Game-based learning combined with technology has proven to offer a more enjoyable and interactive learning experience, while also helping to develop critical skills such as critical thinking and problem-solving. In conclusion, this study recommends that technology tools continue to be integrated into the learning process to harness the potential for more holistic and effective learning.

Keywords: Game-Based Learning, Digital Game-Based Learning, Technology Tools, Education Technology, Learning Effectiveness

Introduction

The use of technology in the field of education is not a new concept; rather, it has long been introduced in developed countries, where educational technology refers to a specific process that applies advanced technology to the existing education system. Therefore, the integration of technology is a crucial and ongoing element in education (Jiménez et al., 2019), as it expands teaching to various real-world learning situations, enabling students to acquire higher knowledge, skills, and competencies. Students cannot master technology usage skills without

engaging with actual technology inside and outside the classroom through various activities that require the use of computers and other computing tools or without access to the internet (Rombaoa, 2019).

Additionally, at present, various software programs and mobile applications that have been introduced have encouraged more educators to adopt interactive teaching and learning approaches, where game-based learning strategies are among the strategies frequently integrated with technology, as they can enhance student learning. For instance, findings from Denham (2018), show that digital games designed for learning purposes are capable of improving student learning.

Game-based learning is a learning process where students utilize games to achieve learning objectives by solving problems and overcoming challenges encountered during gameplay (Yeh et al., 2019). Well-developed game-based learning can positively impact users, as evidenced by the study of Assapun & Thummaphan (2023), which demonstrated an improvement in students' problem-solving behavior and skill scores after participating in game-based learning. Meanwhile, the study by Olayvar (2023), found that game-based learning can increase students' interest in learning and significantly influence their academic performance.

In addition, game-based learning combined with digital multimedia technology can increase students' interest in learning and allow them to gain experiences that resemble real-world situations (Chen et al., 2020). Therefore, teaching and learning approaches that integrate the use of technology have become increasingly popular and preferred in recent years (Othman & Mohamed, 2023), and equally important to the role of technology in education is the need to examine how technology can assist students in game-based learning. Specifically, this systematic literature review aims to answer the following research question:

- RQ1: What is the function of technology tools used to support game-based learning processes?
- RQ2: Does the use of technology tools in game-based learning have an impact on student achievement and learning effectiveness?

Implications and Contributions of the Research

This study provides significant implications and contributions to game-based learning through the use of advanced technology tools. The integration of technology tools such as Scratch, Lego Mindstorms EV3, Augmented Reality (AR), as well as interactive quizzes like Kahoot and Quizizz has been shown to enhance student motivation through more interactive and enjoyable learning experiences. This offers substantial benefits to students, especially in subjects considered difficult, such as science and programming. Furthermore, the use of virtual reality (VR) technology provides a deeper learning experience, which not only stimulates students' interest but also helps to improve their level of understanding of the subject matter.

From the perspective of enhancing cognitive skills, technologies such as VR and AR play a crucial role in reinforcing students' computational thinking, problem-solving, and critical thinking. These technologies allow for direct interaction with learning materials, improving retention and academic performance. Furthermore, digital and multimedia technologies

provide learning flexibility, enabling students to tailor the learning process to individual needs, in line with the demands of 21st-century education that emphasizes more flexible learning responsive to technological advancements.

In conclusion, this study contributes by identifying the functions of technology tools in supporting game-based learning processes, supported by empirical evidence demonstrating a positive impact on student achievement and learning effectiveness. Through the PRISMA methodology approach, this study provides a solid foundation for further research, as well as guidance for policymakers and educators in developing inclusive strategies that integrate technology into the education curriculum, aimed at empowering students with relevant 21st-century skills.

Literature Review

Technology in Education

Technology has long been used in the field of education and is defined as the disciplined application of knowledge aimed at improving student performance (Vidanaralage et al., 2022). In fact, technology has a significant impact on the teaching and learning process, where it now serves as an advanced learning aid that provides a richer learning experience for students (Romli et al., 2022), making it a crucial element in enhancing the teaching and learning process (Fernández-Batanero et al., 2021), and is practically applied in almost all areas of education (Nasution, 2022).

Educational technology is designed to enhance the level and quality of education through improvements in information delivery techniques, the development of new learning environments, as well as the use of interactive learning that has the potential to increase productivity and efficiency within the education system (Mayilyan, 2019). The integration of these elements has had a positive impact on the teaching and learning process. Previous studies have proven that technology-supported learning not only produces more innovative forms of teaching but also enhances learning capacity (Mayilyan, 2019).

Additionally, the study by Falah et al. (2022), also showed that lecturers' attitudes toward the use of educational technology in the classroom are positive, and they also support the idea that such technology has the potential to enhance learning outcomes and advance the educational process. Based on past studies, there are several approaches that use technology as teaching material both inside and outside the classroom. One of the teaching and learning approaches that integrates technology is game-based learning, as games combine multimedia elements such as video, audio, and images to create a virtual environment that simulates real-life situations (Chen et al., 2019).

Game-Based Learning

Game-based learning is a fun tool with educational objectives, where players develop knowledge and train their skills by solving challenges encountered during gameplay (Jääskä et al., 2021). If game-based learning is well-designed, it can offer advantages to users; for example, a study by Wang (2019) shows that the use of game-based learning strategies can result in positive learning effects.

In addition, a study by Idris et al. (2020), found that game-based learning improved participants' performance in the post-test compared to the pre-test. Furthermore, a study by Mee Mee et al. (2021), showed that game-based learning can enhance student participation in a more enjoyable learning experience with the addition of entertainment elements. In fact, game-based learning can also help students shift from passive learning to active learning through the application of knowledge while interacting with peers and experiencing real-world situations in the game (Tsai et al., 2020). This is because, when students learn in groups, they have the opportunity to engage in face-to-face interaction with one another while participating in the assigned tasks (Azhar & Jalil, 2022).

In addition, scenario-based simulations in game-based learning, which are difficult to implement in real-life situations, can promote effective learning by providing a safe environment for students to develop their skills (Chen et al., 2019). Therefore, game-based learning is a teaching method that can foster creativity and attract students' interest in the subjects being taught (Azid et al., 2019). Moreover, game-based learning can enhance critical thinking, problem-solving, and decision-making skills through the challenges encountered in the game (Dimitra et al., 2020), encourage collaboration and teamwork as students work together to achieve common goals (Dimitra et al., 2020), and stimulate student motivation and interest in learning (Zhong, 2019).

Digital Game-Based Learning

In the rapidly evolving digital era, technology plays a crucial role in various aspects of life, including the field of education. One approach that has gained attention among educators is Digital Game-Based Learning. Digital Game-Based Learning refers to a student-centered approach where educational objectives and content are integrated into game activities to motivate students to learn and develop their skills and knowledge through an interactive and enjoyable learning environment (Hussein et al., 2022).

Initially, digital games were designed for the mass market without a specific educational purpose, but they are now recognized as potential tools in enhancing student learning through increased motivation and engagement (Sadera et al., 2014). This is because, past studies on Digital Game-Based Learning, such as the study conducted by Parthasarathy et al. (2023), have shown that Digital Game-Based Learning (DGBL) can improve cognitive skills such as working memory, cognitive flexibility, and planning. Furthermore, the study by Hussein et al. (2022) indicated that students are more interested and actively engaged in the learning process when digital games are used as teaching tools.

Next, Digital Game-Based Learning is capable of improving student achievement. For example, research in Mathematics learning found that Digital Game-Based Learning can enhance students' conceptual understanding and arithmetic skills (Hussein et al., 2022). Additionally, Digital Game-Based Learning also has the potential to empower 21st-century skills such as creativity and critical thinking (Hussein et al., 2022). Meanwhile, in the context of engineering and technology, Digital Game-Based Learning can help students develop reasoning and problem-solving skills that are critical to achieving the goals of Industry Revolution 4.0 (Talib et al., 2019), while also providing a more flexible learning environment that can be adapted to students' needs (Okta Riyandi et al., 2023).

Methodology

A methodological approach called PRISMA, which is suitable for studies utilizing the systematic review method was employed, with eligibility and exclusion criteria conducted through the process steps of review (identification, screening, inclusion), as well as data extraction and analysis. This method follows the PRISMA Statement (The PRISMA 2020 statement: an updated guideline for reporting systematic reviews) (Page et al., 2021). The PRISMA approach offers three key advantages: (1) it formulates clear research questions to facilitate systematic investigation, (2) it establishes specific inclusion and exclusion criteria, and (3) it aims to comprehensively analyze a large body of scientific literature within a defined timeframe.

As presented in Fig. 1, this systematic review involved four main steps: (1) identification, (2) screening, and (3) inclusion. This study adhered to the PRISMA criteria because the analysis is evidence-based, promoting the transparent and comprehensive reporting of systematic literature reviews. The transparency and completeness of reporting ensure the quality of research, as it allows readers to assess the research procedures and the credibility of the studies conducted (Sarkis-Onofre et al., 2021). This study aims to identify the technology tools implemented in supporting game-based learning processes. It also aims to identify the impact of using technology tools in game-based learning on student achievement and learning effectiveness.

The following keywords were used in the database search: "game-based learning", "technology", and "school". The search was conducted in Web of Science, Scopus and Science Direct. The search produced 50 hits, but only 14 were considered relevant to the study based on the following criteria: (1) the study should state that the game-based learning and learning technology tools, (2) the study was published between the year 2019 and 2023, and (3) the study should have empirical data. After analysing using a systematic literature review based on the method adapted from (Page et al., 2021), this study was summarised as shown in Table 1.

Table 1

Search strings used for the systematic review process

Database	Boolean Operator Used
Web of Science	(TS=("game-based learning" AND "technology" AND "school")) AND (PY=("2019" OR "2020" OR "2021" OR "2022" OR "2023")) AND DT=("ARTICLE") AND TASC=("EDUCATION EDUCATIONAL RESEARCH") AND LA=("ENGLISH") AND SJ=("EDUCATION EDUCATIONAL RESEARCH") AND OAJ=("ALL OPEN ACCESS"))
Scopus	TITLE-ABS-KEY (("game-based learning") AND ("technology") AND ("school")) AND PUBYEAR > 2019 AND PUBYEAR < 2024 AND (LIMIT-TO (OA , "all")) AND (LIMIT-TO (SUBJAREA , "SOCI")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (EXACTKEYWORD , "Game-based Learning"))
Science Direct	Title, abstract, keywords:"game-based learning" AND "technology"

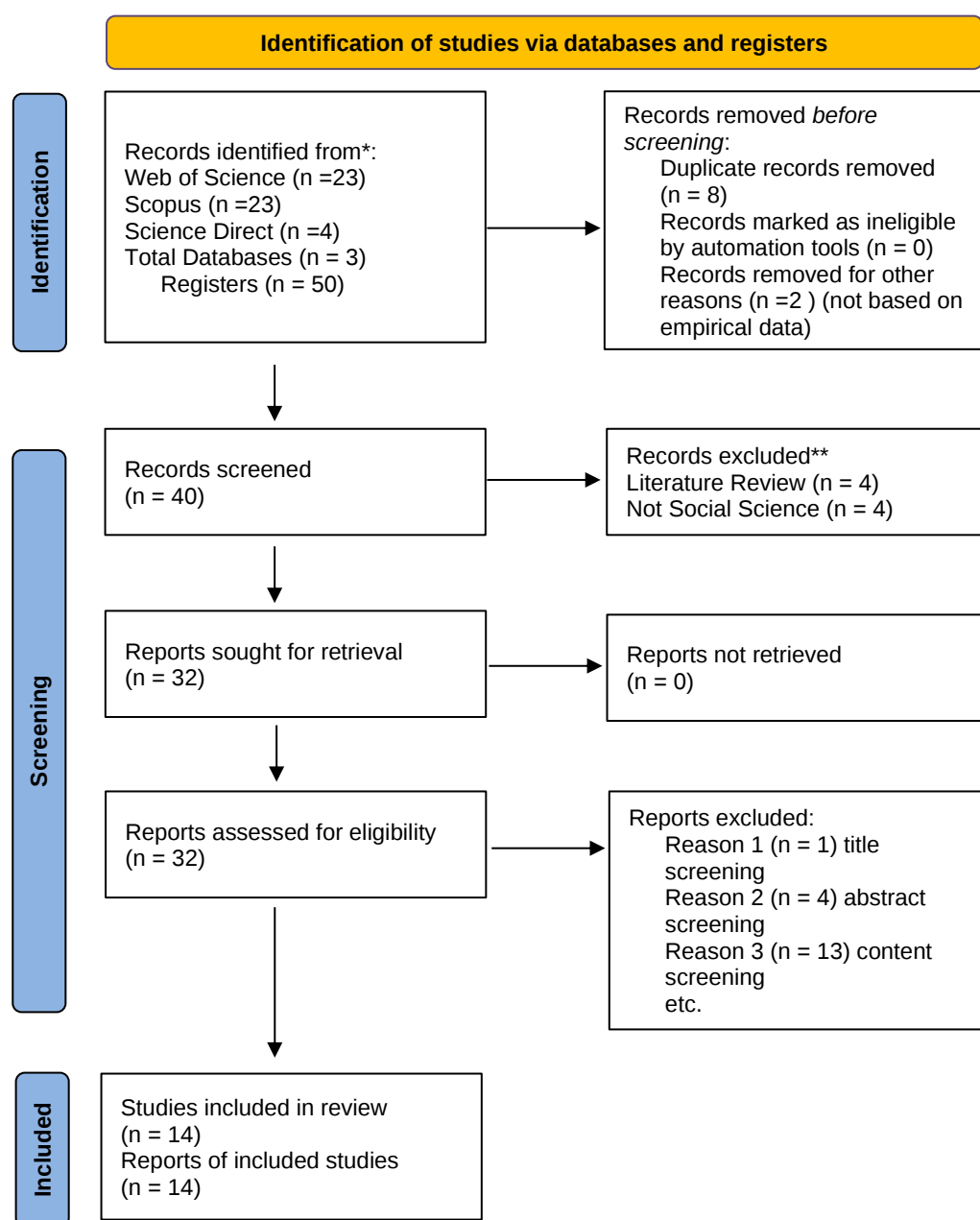


Figure 1: Flow diagram of the study (Adapted from Page et al., 2021)

In the systematic review, as outlined in the flowchart above, a total of 50 articles were gathered from various databases for consideration. These databases included Web of Science, contributing 23 articles, Scopus with 23 articles, and ScienceDirect with 4 articles. To ensure the reviewed articles were relevant and met high standards, strict filtering criteria were applied in the article selection process. At the identification stage, 8 duplicate articles were removed, leaving 42 articles for consideration. Subsequently, 2 additional articles were excluded as they were not based on empirical data.

At the screening stage, another 8 articles were excluded for various reasons, including the type of publication such as literature reviews or articles outside the scope of social sciences. The process then moved to a more detailed eligibility assessment, where 32 articles were carefully

examined. Of these, 18 articles were excluded due to topics irrelevant to the research questions or outside the scope of the field under study, abstracts indicating that the study was too general or not based on empirical data, and content unrelated to the research questions, where the data or findings did not align with the research objectives, or the use of weak methodologies. This careful and systematic selection approach led to the final inclusion of 14 studies in the review. The application of these strict criteria ensured that the review was based on relevant and high-quality evidence, providing readers with clarity regarding the methodology used in the selection of articles for the review.

Identification

The initial step in the systematic review involves the identification phase, where the PRISMA approach is used to conduct a comprehensive search across reputable online databases, including Web of Science, Scopus, and ScienceDirect. The selection of these databases, known for their strict quality standards, provides researchers with confidence in the reliability of the publications used as sources. This search focuses on publications from 2019 to 2023, using specific keywords such as "game-based learning", "technology", and "school". The screening process involves a thorough review of 50 articles initially identified, aiming to eliminate duplicate articles and those that do not meet relevance and quality criteria. A total of 8 duplicate articles were removed, and 2 additional articles were excluded for not being based on empirical data, leaving 42 articles for consideration. This phase plays a crucial role as it lays a solid foundation for gathering a spectrum of studies relevant to the research question on the use of technology tools in game-based learning and its impact on student achievement and learning effectiveness.

Screening

At the screening stage, 8 articles were excluded for various reasons, including the type of publication being in the form of literature reviews or outside the scope of social sciences. This process continued with an eligibility assessment, where 32 articles that passed the initial screening were thoroughly evaluated based on the title, abstract, and content to ensure quality and relevance to the research questions. A total of 18 articles were excluded due to irrelevant topics, abstracts that were too general or not based on empirical data, as well as content that did not align with the research objectives or had weak methodologies.

Inclusion

The final phase, which is inclusion, resulted in the selection of 14 studies for review based on strict criteria that required the studies to clearly state the use of technology tools in game-based learning on student achievement and learning effectiveness, published between 2019 and 2023, and containing empirical data. This phase culminated in the completion of the systematic review. The selected studies provide in-depth insights into the technology tools implemented in game-based learning and the impact of their use on student achievement and learning effectiveness. The rigor in this three-step process ensures the credibility of the systematic review, thereby providing a solid foundation for analyzing the use of technology tools in the game-based learning process.

The systematic literature review, following the methodology adapted from Page et al. (2021), is summarized as shown in Table 2.

Table 2

Summary of the Reviewed Studies

No	Author/s	Subject	Technology Tools	Functionality	Finding
1	Panskyi & Rowińska, (2021)	Programming	-Scratch programming software -Lego Mindstorms EV3 robotic kit -Arduino open-source platform	-Problem-Solving - Programming	Regardless of the number of students, the season, or the specific edition, the general quality of the programming classes using the integrated DGBL approach stays good.
2	Chen et al., (2020)	Science	Augmented reality app	Simulation	In terms of game difficulty and content retention, a questionnaire reveals that the game has positive results.
3	Wang, (2021)	Classical Chinese	Animated story developed by Flash 2D games developed by HTML5 game creator and Construct 2	Content Creation	It was discovered that the game-based learning materials enabled the students to grasp the entirety of the text swiftly. In the meantime, the animated story material was useful for improving learners' understanding of crucial classical Chinese sentences and language
4	Merino-Campos et al., (2023)	Physical education	Video game	Interactive Learning	The results show that students' acceptance of video games as educational tools and how the factors influence this positive relationship results in improved academic performance in physical education studied, which are accessibility, enjoyment, technological competence, and

					learning through video games.
5	Oyelere et al., (2023)	Computational thinking education	Virtual reality	Simulation	The qualitative research indicated that users considered the VR mini-games engaging and immersive, which offered a chance to develop students' computational thinking abilities. The quantitative analysis showed that regular mini-game play can improve students' computational thinking skills. The VR game's expedition component also piqued players' attention, sustaining their learning progress. The user also discovered fresh information and found the mini-games to be instructive.
6	España-Delgado, (2023)	English	-Kahoot -Quizizz -Quizalize	Assessment	The study found that students perceived Kahoot, Quizizz, and Quizalize as useful, entertaining, fun, and engaging tools, which increased their motivation and attainment in language learning.
7	Hsu et al., (2022)	Mandarin	-Social Robots -E-book lectures	-Content Creation - Programming	The study found no gender differences in self-efficacy in programming, attitudes towards employing social robots (SRs), or Mandarin learning (ML) in interdisciplinary activities. Following their involvement in interdisciplinary activities, both boys and

					girls significantly increased their knowledge of ML
8	Leal Uhlig et al., (2023)	Reading Literacy	Lettera Web Platform	Content Creation	The findings showed that the Lettera platform significantly improved students' proficiency in writing literary, informational, and argumentative texts. Additionally, it encouraged them to engage in the suggested tasks.
9	Slattery et al., (2023)	History and English	Minecraft Education	Simulation	Students indicated Minecraft Education was fun, easy to use, and offered good learning opportunities, especially for creativity and teamwork.
10	Kabak & Korucu, (2021)	English	Scratch (a block-based programming tool)	Problem-Solving	The study found that the experimental group, where an innovative application was used, had significantly different academic success values. Additionally, the cutting-edge tools employed in this study can potentially enhance students' academic performance, attitudes toward English classes, and attitudes toward computer-assisted instruction given the right preparation.
11	Decker-Woodrow et al., (2023)	Mathematics	Game-based application -From Here to There (FH2T) -DragonBox 12+	-Assessment -Interactive Learning -Problem-Solving	Compared to the Active Control condition, students who used From Here to There and DragonBox 12+ had significantly higher post-test results (hierarchical linear modeling analyses

			Online problem sets -ASSISTments (Immediate Feedback condition and Active Control condition)		of the final analytic sample, N=1850). The Immediate Feedback condition showed no significant shift.
12	Ferro et al., (2021)	STEM	-Professor App -Professor Virtual Board -Opedia 3-D virtual game (3DVG) -Video	-Interactive Learning -Content Creation - Collaboration	Positive results indicated that the game experience was attractive for the learners, even in constrained classroom environments.
13	Chen et al., (2023)	Computational Thinking	Code. org	Programming	According to the study, the self-regulation group engaged in more peer interactions and had higher learning results in terms of computational thinking skills than the guided-learning group.
14	Yang et al., (2021)	Science	Question-Observation-Doing - Explanation (QODE) Application download on smartphones	Content Creation	The finding indicated that cognitive anxiety was inversely correlated with scientific self-efficacy, namely scientific learning ability and scientific learning behaviour. Additionally, it was discovered that cognitive anxiety negatively correlated with the four different ways people engage with science: cognitively, emotionally, behaviorally, and socially via smartphone interaction.

Figure 2 illustrates the frequency of technology tool functions used to support game-based learning in the analyzed studies. Based on the analysis, the most frequently used function is Content Creation, followed by Interactive Learning, Programming, Simulation, and Problem-Solving.

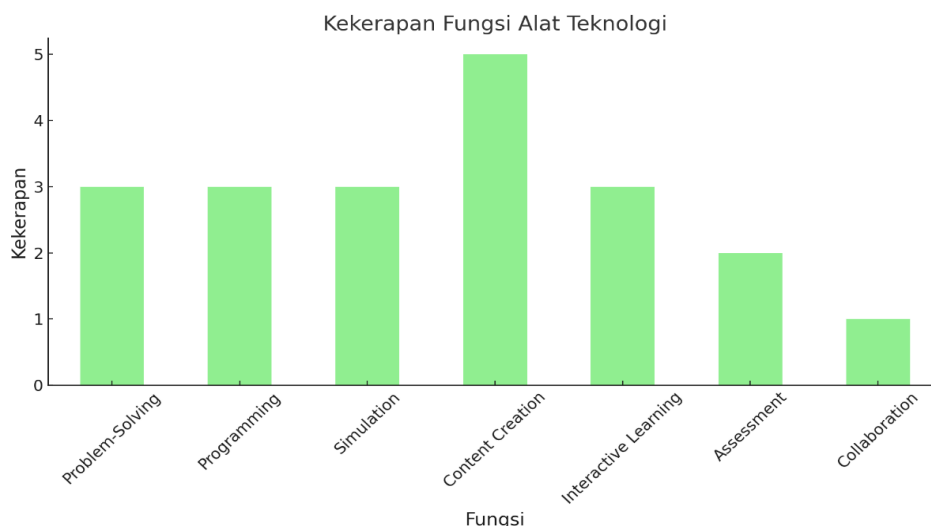


Figure 2: Frequency of technology tool functions used in the analyzed studies

The graph depicting the frequency of the functions of technology tools used to support the game-based learning process shows that content creation is the most dominant function. The use of technology in content creation aids in producing interactive and engaging learning materials, encouraging students to be more creative and actively involved in the teaching and learning process. This enhances their understanding of the topics studied and provides opportunities for students to explore concepts in greater depth. In addition, other functions such as interactive learning, simulation, problem-solving, and programming also support the learning process, but the main focus remains on content creation. However, assessment and collaboration are less emphasized in educational technology, indicating that there is still room to strengthen both aspects. The main challenge is how technology can be strategically applied to integrate both aspects to support more holistic learning. Therefore, the balance of technology functions should be considered to ensure its more optimal use in various learning contexts.

Results and Discussion

Based on the analyzed literature review, the technology tools used in supporting game-based learning function in various aspects. The main functions identified are content creation, simulation, interactive learning, and assessment. For example, Panskyi & Rowińska (2021) used Scratch, Lego Mindstorms, and Arduino in teaching programming, focusing on problem-solving and computational thinking. Additionally, Chen et al. (2020) demonstrated how augmented reality applications were used in science subjects for simulations, where the study found that Augmented Reality technology not only enhanced students' understanding of science content through deeper interaction but also had a positive impact on content retention and increased interest in science learning, which is often considered challenging by students.

Meanwhile, Wang (2021), found that animation storytelling technology developed using Flash and 2D games through HTML5 and Construct 2 in classical Chinese language learning not only helped students with content creation and faster comprehension of complex texts but also enhanced mastery of key sentences in classical Chinese. This animation technology serves as an effective medium to improve students' understanding of subjects requiring high cognitive engagement. Merino-Campos et al. (2023), used video games as a tool in physical education. Their study found that video games help increase students' receptiveness to learning, consequently improving their academic performance. This demonstrates that video game technology has the potential to be applied in various subjects, including those based on physical activities, with a focus on the aspects of enjoyment and student engagement. In the study by Oyelere et al., (2023), virtual reality (VR) games were used to develop students' computational thinking skills. VR technology has been shown to provide an immersive and interactive learning experience, which not only enhances students' cognitive skills but also captures their attention and maintains engagement in the learning process. Students involved in the VR games reported increased focus and progress in their computational thinking skills. España-Delgado (2023), utilized Kahoot and Quizizz technology in English language teaching. These quiz tools were found to enhance student motivation and achievement in language learning. This study demonstrates that the use of interactive game-based quiz tools is not only enjoyable but also effective in increasing student interest and engagement in learning.

All these findings indicate that the technology used in game-based learning, such as Scratch, Lego Mindstorms, Augmented Reality, Flash animation, video games, VR, and interactive quizzes like Kahoot and Quizizz, plays a significant role in enhancing various aspects of student learning. These technologies not only increase student motivation but also enrich their learning experience by providing a more interactive, engaging, and enjoyable environment.

Conclusion

This article presents a systematic literature review that analyzes the functions of technology tools used in game-based learning and their impact on student learning from 2019 to 2023. The PRISMA methodology was used as a guideline to identify and select articles from the Web of Science, Scopus, and Science Direct databases, resulting in 14 articles being included in this study's analysis. Based on the first research question in this systematic literature review, it can be concluded that technology tools used in game-based learning, such as Scratch, Lego Mindstorms, Augmented Reality, Flash animation, video games, virtual reality (VR), and interactive quizzes like Kahoot and Quizizz, function in various aspects such as content creation, simulation, interactive learning, and assessment, where these tools support multiple aspects of learning in subjects like programming, science, and languages, while providing a more interactive and enjoyable learning experience. For example, Scratch and Lego Mindstorms successfully maintain the quality of learning in programming despite varying student numbers, while Augmented Reality applications enhance students' understanding and interest in science subjects.

Next, the answer to the second research question regarding the impact of using technology tools in game-based learning on student achievement and learning effectiveness reveals that the use of technology tools such as video games and game-based quiz applications, such as Kahoot and Quizizz, enhances student motivation, engagement, and academic achievement. For example, students using Kahoot and Quizizz in English learning reported increased

motivation and language proficiency. In addition, virtual reality (VR) technology has also been reported to have a positive impact on students' computational thinking skills, particularly in enhancing focus and understanding. Therefore, the use of technology in game-based learning not only enriches the learning experience but also improves student achievement and learning effectiveness, as well as develops essential cognitive skills such as problem-solving and critical thinking. In summary, there is room for further research in integrating the use of technology tools with game-based learning, which has the potential to significantly impact the quality of education, particularly in the learning process.

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