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EFFECTS OF DIGITAL GAME-BASED LEARNING IN STEM EDUCATION ON STUDENTS' MOTIVATION: A SYSTEMATIC LITERATURE REVIEW

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Abstract. *STEM education, which includes science, technology, engineering and mathematics, has been expanding for the past two decades. This study aimed to map new trends and the possibility of implementing digital game-based learning (DGBL) in STEM education. For this purpose, a systematic literature review was conducted. The resulting sample was further selected according to PRISMA guidelines, with screening and eligibility processes conducted based on the inclusion criteria defined concerning the research objective. This review consisted of twenty-eight studies. The findings revealed a growing interest in DGBL in STEM education from 2018 to 2023. Furthermore, most studies have focused on the K-12 education system and universities. According to the review, educational games for digital learning and simulation technology are the most promising tools used in research. The analysis is launched by studying the effects that influence the increase of student motivation in DGBL teaching STEM education. The findings support the conclusion that prior experience in gaming has a positive impact on increasing students' motivation to learn in DGBL STEM teaching. In addition, students' previous knowledge of a STEM subject increases engagement and motivation. Implementing educational computer games, therefore, showed a great interest in students in STEM education.*

Keywords: *digital game-based learning, students' motivation, STEM education, systematic literature review*

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Introduction

STEM education is increasingly popular and present at all levels of education. The acronym STEM stands for four scientific disciplines, science, technology, engineering, and mathematics (Aykan & Yıldırım, 2022). These scientific disciplines can be observed and implemented independently, the most common case in many educational systems, or as an interdisciplinary combination of individual STEM disciplines (Nadolny et al., 2022). Learning STEM disciplines presents various difficulties to students, primarily due to scientific disciplines' complex, multidimensional and abstract nature. The solution to these difficulties is introducing digital video games into the curriculum. It has been noted that digital games can successfully meet the challenges of STEM education. Researchers have shown that integrating digital games into STEM education serves various purposes (Fadda et al., 2021; LeRoy 2022; Hussein et al., 2022).

Researchers have noticed that introducing digital games into STEM education achieves multiple intents. Along with promoting and developing STEM education, the critical role of motivation as a driving force and outcome of STEM learning is widely recognized. Dedication and a high level of student motivation are necessary for successful learning. Digital game-based teaching has quickly found its place in many educational systems (Gui et al., 2023; Hussein et al., 2022; Ross et al., 2022). The increasing prevalence and availability of video games among children and young people have led to the need to see the possibility of using digital video games beyond entertainment and leisure. As a recent trend in education, it has shown positive effects on student engagement and motivation. In recent years, digital educational games have become more common. There are specially designed digital educational games. Conversely, various digital or video games intended for commercial purposes have undergone remastering to cater to the educational sector. Minecraft, for example, has been adapted into an educational version known as Minecraft Education Edition. Educational video games, especially becoming popular in the last fifteen years, are the subject of interest to many researchers, although the term has yet to be recent (LeRoy 2022; Tablatin et al.,2023; Voštinár et al., 2022).

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Two independent studies by Landers and Welbers showed positive results of video game-based learning compared to traditional learning, where students receive all the necessary instructions from the teacher (Landers, 2014; Welbers et al., 2019). So far, several studies have been published on the effects of STEM education on students learning motivation. However, there is some disagreement among researchers. Some talk about the positive impact of digital video games in STEM education, such as Hussein et al. (2022) have pointed out that the use of digital games has a positive effect on increasing students' motivation to learn mathematics. On the other hand, this claim is supported by other authors such as Ross et al. (2022), Gladstone and Cimpian (2021) and Fadda et al. (2022). However, several researchers reported that the introduction of video games into the teaching process of STEM subjects did not affect the increase in student motivation. Dondio et al. (2023) have pointed out that playing games in mathematics lessons did not significantly improve students' motivation to learn mathematics. From this discrepancy arises the need for a more extensive assessment of whether digital-game-based learning positively impacts students' motivation in STEM subjects. This research aims to analyze scientific studies on the effect of digital game-based learning in STEM education on student motivation. Given that the STEM concept is quite complex, this study considered sub-disciplines, mathematics, science, and engineering (especially programming and computer science). As educational games are widely used, there is a clear need to analyze how the effect of digital game-based learning in increasing motivation has been studied and how such studies can inform and encourage teachers and practitioners to improve it. For theorists, the degree of acceptance of digital video games for educational purposes is of great importance, on the one hand, but also the response of teachers and students, which directly influence the effective further development and use of educational video games in teaching practice.

Aim

This analysis has aimed to address the problems of incomplete and imprecise empirical studies on student motivation in digital game-based learning in STEM education. Considering that STEM education is a composition of four scientific disciplines, it should be taken into consideration what is the attitude of the students towards individual disciplines, whether they are more biased towards a particular subject, whether attention was equally maintained in the classes of mathematics, science, technology and/or engineering. In order to maintain objectivity during the analysis, the following research questions guided the conduct of this study:

1. Does engagement and motivation increase when utilizing digital game-based learning in STEM education?
2. Does the level of student's knowledge of a given STEM discipline increase or decrease learning motivation?
3. Does prior knowledge about the game affect students' motivation to learn?

Theoretical Backgrounds of Digital Game-Based Learning in STEM Education

One of the essential features of digital educational games (DEGs) is their potential for application outside of STEM education and their benefits in improving student motivation for learning and engagement during learning. Many authors define educational digital games and digital game-based learning differently (Clark & Mayer, 2016; Prensky, 2003; Sailer & Homner, 2020). One thing is expected in the sea of different interpretations of explanations and definitions. Essentially, educational digital games are designed to encourage and improve the student's achievement as an individual and then the student as an equal member of the community class. Regarding STEM education, digital games are significant for student achievement and cognitive development. Educational digital games provide an innovative, exciting and interactive approach to learning, creating an environment that encourages student activity while allowing students to develop problem-solving skills and critical thinking, which is essential for achieving STEM education goals. In this way, the increasingly significant development of 21st-century skills and the expansion of STEM learning and knowledge are encouraged (Stehle & Peters-Burton, 2019). At the center of game-based learning is a game (digital, computer, educational game) that supports the learning of students with different competencies and prior knowledge. Educational games or video games modified for educational purposes with their interface positively affect the sustainability of students' attention. An important feature is that they are often flexible, and teachers can respond relatively quickly to teaching challenges. Feedback is essential for the learning process and is available at any time. Numerous scientists suggest that using educational games could be of multiple benefits for improving students' knowledge levels and the overall outcome of teaching (Gui et al., 2023; Vanbecelaere et, al., 2019). By introducing educational games into the teaching process, student engagement,

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learning achievements and student motivation for learning increase (Arztmann et al., 2022).

Learning is a multifaceted cognitive process, and numerous scholars emphasize the significance of motivation as a critical factor in successful learning (Fortus & Touitou, 2021). While it is widely acknowledged that motivation is indispensable for quality education, educational systems worldwide have grappled with student apathy. An essential aspect of learning based on digital educational games is the motivation of students to learn. Motivated students tended to engage during the teaching process (in the classroom or online).

The growing number of students engrossed in video games has prompted researchers to explore the potential of games as an innovative educational tool. Games offer the opportunity to infuse learning with enjoyment. Reward systems, encompassing scores, assets, permissions, reputation, and more often drive motivation within games. These rewards typically stimulate and reinforce extrinsic motivation, derived from desired outcomes or external pressures, rather than intrinsic motivation, which stems from an individual's inherent interest in the activity. However, it is worth noting that extrinsic reward systems are associated with superficial learning rather than deep processing. Understanding student motivation during learning based on educational digital games in STEM education is challenging due to the nature and multidisciplinarity of the STEM concept. In the last two decades, many researchers have studied student motivation during the learning process in STEM education (Gustiani, 2020; Chiang et al., 2022; Ross et al., 2022). Earlier studies showed that students' motivation decreased with the transition to a higher grade, so students in higher grades avoided STEM subjects, and dropouts were mainly observed after the completion of K-12 schooling (Kuo, 2007; McDonald, 2016; Osborne et al., 2008; Vogel et al., 2006). Educational computer games have been recognized as a good way of providing a more engaging learning environment for acquiring knowledge. Learning supported by digital educational games has multiple effects on student achievement. Many researchers have reported that the existing potential of the new mediums can be used as a tool in education to improve students' motivation and provide a better learning experience (Puspitarini & Hanif, 2019). In general, students who possess a stronger sense of intrinsic motivation often gravitate towards digital learning environments. This preference arises from the ability to work at their own pace without relying on teacher support or the classroom environment for motivation (Taylor & McNair, 2018). Wang et al. (2022) confirmed that students at different educational levels react differently to the game but that the level of motivation did not depend on the type of game but on the difficulty of the teaching material. Motivation is closely related to achievement. Wang (2022b) found that students performed better and were more motivated to learn mathematics when the teaching material was presented using a digital educational game. Even students with worse prior knowledge showed more than expected interest in getting involved in the teaching process. STEM is based on a cohesive learning paradigm based on real-world applications in an interdisciplinary field. The concept of STEM disciplines is in a synergistic relationship, and it is often the case that if a student is interested in mathematics, it does not necessarily mean that he will be equally motivated to learn science. Here comes a slight departure from the assumption that STEM is an ideally conceived interdisciplinary paradigm (Saricam & Yildirim, 2021). Although educational games are generally believed to enhance student motivation, the impact of these games on motivation has yielded inconsistent and, at times, contradictory findings.

Moreover, more research needs to explore the influence of intrinsic and extrinsic motivations on game-based learning. Additional design measures, such as collaboration, have been implemented to improve peer communication and enhance the effectiveness of educational games. However, they have yet to demonstrate significant changes in motivation levels (Van der Meij et al., 2020). Situational games have shown promise in boosting students' motivation and performance, while competitive games have been found to frustrate students (Yang et al., 2020) potentially. Adaptive computer games, which assess student performance and adjust difficulty levels, accordingly, have not significantly improved children's motivation (Vanbecelaere et al., 2019). Although various studies have shown the benefits of using educational digital games in enhancing students' motivation to acquire STEM knowledge, a few have denied any educational digital games' contribution to STEM education (Gustiani, 2020; Safaruddin et al., 2020). In addition to motivation, students' activity should also be considered, which is directed towards learning, i.e. acquiring, and upgrading STEM knowledge. Thus, engagement, motivation and learning represent a unity directed towards learning based on digital educational games (Breien & Wasson, 2021).

Indicators of Student Motivation STEM Education

As a multidisciplinary concept, STEM must be understood as something other than material that is only conveyed through verbal and face-to-face teaching methods. All set goals can be achieved only when the student is active and equal in the teaching process. This is of particular importance when it comes to STEM subjects. Mo-

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tivation during the process of acquiring knowledge is fundamental for the learning outcome. Different views on motivation are often emphasized in the literature. According to Herder and Rau (2020), motivation is defined as a set of processes aimed at maintaining and encouraging students' activities directed towards the ultimate goal. Motivation is a complex and ongoing research subject, especially in disciplines such as tree education. We live in a world of constant technological progress; current information will already be outdated tomorrow, so we are trying to find new methods to transmit knowledge and information.

Motivation plays a leading role in the learning and teaching process, so innovative approaches to learning are needed to increase motivation. This is important because the factors that influence motivation are constantly changing and becoming outdated. It is necessary to maintain continuity to maintain the quality of education (Tisza et al., 2021). There are two types of motivation (Filgona et al., 2020). Internal motivation, as one type of motivation, is a characteristic of individuals. External factors do not determine internal motivation but directly depend on the needs and aspirations of the individual. In contrast to intrinsic motivation, extrinsic motivation is the desire to engage in an activity to achieve positive outcomes, such as rewards (often in the form of positive evaluations) or punishments (often in the form of negative evaluations).

The creators of video games know very well the psychology of the shell of the personality; this has proven to be especially important when it comes to educational digital games. Educational digital games have built-in motivational attributes that attract and maintain the player's or student's attention. Intrinsic motivation is emphasized for the use of digital gamers for educational purposes. With a well-designed story and game environment, some digital games gained worldwide popularity today. One example is Minecraft, which indicates that Minecraft has developed its educational version, Minecraft EDU.

Research has shown that intrinsically motivated students are more likely to persist in the face of learning challenges than extrinsically motivated students (Byun & Joung, 2018; Breien & Wasson, 2021; Liao et al., 2019). The central focus is the relation of the motivational appeal of digital game-based learning in the context of STEM education. In the domain of curriculum design, DGBL can serve as a powerful motivational tool for students and teachers, as it encourages peer collaboration and support in teaching.

Research Methodology

The preparation of this systematic review followed the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) guidelines by Moher et al. (2015), as shown in Figure 1. This systematic review process included the following stages: identification, screening, eligibility, and inclusion.

Identification

The Science Direct, Springer Open and Google Scholar databases were used in the identification process to search for relevant articles. For the search, keywords related to digital game-based learning, student motivation, gamification, digital educational games, and STEM education were used. A combination of keywords and Boolean operators AND and OR was used. After the initial process, the result was 201 articles from Science Direct, 153 from the Springer Open database and 127 from Google Scholar. However, 36 duplicate studies were removed, leaving 446 articles found. To guarantee that only studies meeting the standards of the scientific community were identified, we focused exclusively on peer-reviewed articles and excluded grey literature.

Screening

Considering the different databases and the relevance and eligibility of the published articles, the abstract of each article was first reviewed individually. The second stage continued with the screening process based on a set of criteria shown in Table 1. This study included the publication timeline between the years 2018 until the year 2023.

Only article journals and dissertation theses that used the English language were included, focusing on issues in STEM education and digital game-based learning. For the first screening process, out of 446 articles, 232 articles were excluded. Research topics were STEM education, including science, physics, mathematics, technology, and engineering education. The papers included in this research encompass empirical research, studies with control and comparison groups, as well as meta-analyses.

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Table 1
Screening Process

Criteria	Inclusion	Exclusion
Publication timeline	2018-2023	2019 and before
Document type	Article	Conference proceedings, chapters in books, dissertations, books, etc.
Language	English	Non- English
Nature of the study	Concentrate on the issues of learning supported by digital games.	Not focus issue of learning supported by digital games.

Eligibility and Inclusion in Research

Since the end of the first screening cycle, 148 papers have been excluded, and 166 papers have been completed. The next step is the second level of screening, the paper quality check. The criteria based on which the screening was performed are shown in Table 2. It is necessary to see whether the goals and objectives of the research are clearly defined and then implemented. The following substantial question is how the study was conducted. During the analysis of each article, the methodology used must be considered, including the method of analysis, collection, presentation of data, qualitative and quantitative, and how the research data were communicated and presented. It is also necessary to look at the target group covered by the research.

Table 2
The Criteria Quality Assessment of Articles

No	Criteria	Descriptions
1	Study context	Did the article effectively communicate the study's planning, implementation, and development aspects?
2	Objectives and purposes	Were the aims and objectives of the study clearly articulated in the article?
3	Methodology	Does the article comprehensively explain the research methodology, including the framework, data collection, and data analysis?
4	Data	Are there supporting materials such as schedules, interview or focus group transcripts, and observational feedback? Is the information presented in a clear and analyzed manner?
5	The results of the study are validated	Were the results of the study validated? Did the researcher utilize peer review, feedback, or other mechanisms to confirm the analysis?
6	Sample	Does the article offer an adequate sample size for the research conducted?

The next screening involves evaluating the quality of the articles. In order to make an authoritative assessment of the quality and suitability of architects, a table examining seven criteria was used. Each criterion is additionally evaluated from 1 to 4, depending on the degree of satisfaction of the criteria. If the score is 1, it means that it does not meet the standards, a score of two means that the standards have almost been achieved, a score of three means that the criteria have been met, and a score of four means that the required criteria have been exceeded.

After further analysis and evaluation of each article, each could receive a minimum number of points of 7 (no criteria met 7x1) or a maximum of 28 (all criteria were evaluated with 4 points each). Screening excluded articles with less than 14 points, so they only met some criteria.

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Table 3
Quality Assessment Table

Objectives and purposes	The problem, objective, rationale, and research questions are clearly articulated.	The problem, objective, rationale, and research questions are adequately articulated.	The problem, objective, rationale, and research questions are poorly articulated.	The problem, objective, rationale, and research questions are incomplete.
Theoretical or conceptual frameworks	Clearly articulated and described in detail. The frameworks align with the purposes of the study.	Articulated and aligned with the study's purposes.	Implied or described in vague terms or fails to align with the purposes of the study.	Absent (no mention or description of theoretical or conceptual frameworks).
Participants	It provides a detailed, contextual description of the population, sample, and sampling procedures.	The article provides a detailed description of the population, sample, and procedures in a contextual manner.	The article provides a basic description of the sample and procedures.	The description of the sample and procedures needs to be completed.
Review of literature	Critically examines the state of the field, clearly situating the topic within the broader field. Makes compelling connections to past work, discusses and resolves ambiguities in definitions, and synthesizes and evaluates ideas while offering new perspectives.	Discusses what has and has not been done, situates the topic within the broader field, connects to past work, defines critical vocabulary, and synthesizes and evaluates ideas.	Minimally discusses what has and has yet to be done, vaguely discusses the broader field, makes few connections to past work, needs more synthesis across the literature, and provides a minimal evaluation of ideas.	It fails to discuss what has and has yet to be done, the topic is not situated within the broader literature, and there are no connections made to past work.
Methods	The article provides a detailed description of the instruments used and their administration, along with evidence of validity, and reliability. It also documents the use of best research practices and considers potential bias.	The article describes the instruments used and their administration, provides evidence of validity or reliability, and shows some evidence of employing best research practices. Potential bias is considered.	The instruments are described, but more evidence of validity or reliability must be provided. The use of questionable research practices may be present.	The description of instruments and their administration needs to be completed.
Results and conclusions	The article provides detailed results, utilizes exceptional data displays, and the discussion connects the findings to past work. It also proposes future directions for research. The conclusions effectively address the problem or questions at hand.	The article presents complete results, utilizes good data displays, and the discussion connects the findings to past work. The conclusions adequately address the problems or questions.	The results provided are essential, and data displays must be used more. The discussion needs to establish connections to past work. The conclusions merely summarize the findings.	The results and conclusions must be completed, needing more detail or information.

The screening and selection process was divided into three main steps according to the PRISMA flow diagram (Page et al., 2021). In the first step, only the titles and abstracts of the articles were considered. Studies were included if their abstract was written in English and contained terms such as "learning based on digital games", "digital games and STEM education", "student motivation in DGBL teaching", and reported on the results of empirical research. Studies using methodologies other than surveys, not published in peer-reviewed academic journals, from areas other than education research, or not considering any K–12 level were excluded. After the first step, 144 documents were excluded.

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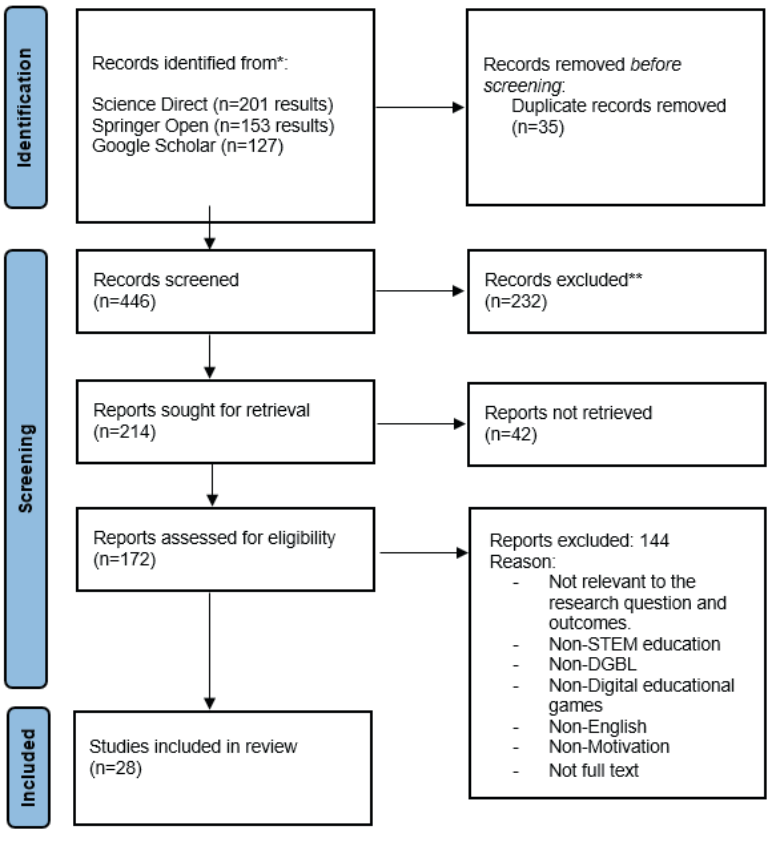
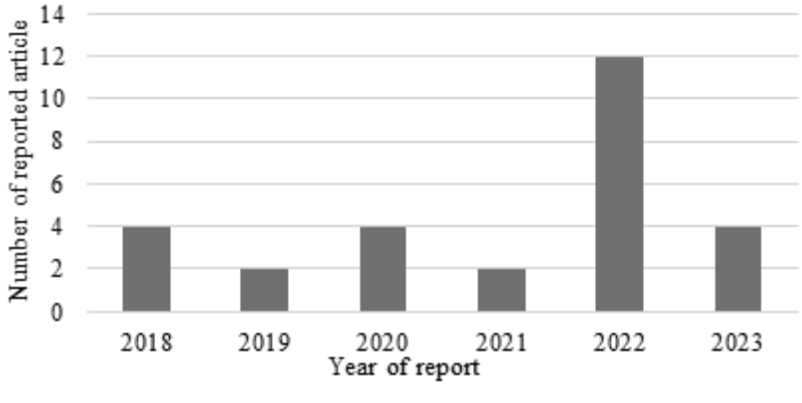
Figure 1
PRISMA Flow Diagram



The following screening step included checking the availability of documents. Excluded were those studies that could not be found entirely available online, or even after contacting the author, we did not have access to the article (= 42).

Finally, the last step involved reviewing the available articles and applying our exclusion and inclusion criteria. Based on the already mentioned exclusion criteria, the final number of excluded articles is = 144. Only studies that empirically addressed the issue of integrating learning based on digital games and examining students' attitudes and levels of motivation for learning based on digital games were included. During this phase, 28 studies were included. The following chart presents published articles by year (see Figure 2).

Figure 2
Distribution of the Articles by Year



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Data Extraction and Content Analysis

After a systematic review of the literature and the identification of 28 relevant studies from 2018 to 2023 (published by May 2023), an analysis of them was carried out using content analysis, with the focus being on the content and way of processing research questions (see Table 4).

Table 4
Summary of Included Articles

Year	Researcher	Findings
2023	Gui et al.	STEM digital games are more effective for developing cognitive skills than facilitating knowledge acquisition.
2023	Al-Said, K.	It was concluded that students in interventions with games achieve significantly better learning results and report greater motivation and change in behavior compared to students in traditional classrooms.
2023	Tablatin et al.	Persistence in problem-solving relies on students' proficiency and familiarity with the game environment.
2023	Yang	No single educational game can be used for all STEM disciplines and all levels of education.
2022	Wang et al.	Increased level of students' cognitive abilities during learning based on digital games.
2022	Nkadimeng & Ankiewicz	Visualization reduces the abstractness of concepts and increases student motivation. Knowledge of educational games is necessary to increase the possibility of success and increase students' level of achievement in developing knowledge and skills in digital-game-based learning.
2022	Tay et al.	Learning with digital technology-facilitated empathy: an augmented reality approach to enhancing students' flow experience, motivation, and achievement in a biology program.
2022	Wu, Liu, & Huang	The research discovered that, in STEM learning, one should maximally utilize a student's attitude, intrinsic motivations, and cognitive load to obtain knowledge in STEM fields effectively.
2022	Arztmann et al.	Reported that there was no difference in the impact of play-based learning between boys and girls but that they showed equal interest and motivation in DGBL.
2022	Poçan et al.	It increases students' motivation to learn and understand abstract concepts.
2022	Wang et al.	Digital game-based learning shows better results than other teaching methods.
2022	McLaren et al.	How instructional context can impact learning with educational technology: Lessons from a study with a digital learning game.
2022	LeRoy	The student's active involvement in the learning process is crucial, as it fosters a sense of ownership and belonging. This, in turn, positively impacts motivation, personal connection to the material, and a deeper comprehension of the information and the methods employed to acquire it.
2022	Andersen & Rustad	Digital educational games increase students' activity levels and desire to learn.
2022	Mawas et al.	The game's influence on student motivation may vary between the two countries due to the potential influence of students' pre-existing attitudes before the courses.
2022	Zhang et al.	Prior knowledge of students positively influenced the motivation for digital game-based learning in stem disciplines.
2021	Sómer, Moreira, & Casado	The Kahoot application, with elements of a digital educational game, showed high average effectiveness in evaluating motivation indicators, actively involving students in the learning process, improving content processing and increasing experience, motivation, attention and satisfaction.
2021	Fadda et al.,	The findings indicate that digital games are more practical than conventional teaching practices.
2020	Sabirli & Çoklar	The effect of educational digital games on education, motivation, and attitudes of elementary school students against course access
2020	Bertram, L.	Game-based learning interventions should offer students active opportunities for self-directed learning and positively influence attitudes, emotions, motivation and engagement.
2020	Wang & Tahir	The transition from traditional to online teaching led to decreased student motivation. With the introduction of DGBL in online teaching, student motivation has strengthened.
2020	Priyaadharshini et al.	Game-based learning helps all levels of learners, from beginners to experts.
2019	Ortiz-Rojas et al.	Prior experience playing games encourages students towards digital game-based learning in stem education.

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Year	Researcher	Findings
2019	Hosseini et al.	Game-based game learning strategy improves the self-efficacy of the learners. DGBL enabled a clearer insight into student engagement and, thus, motivation.
2018	Byun & Joung	Learning based on educational digital games has an encouraging effect on improving students' STEM skills.
2018	Touati & Baek	Previous experience playing commercial games increases interest in learning based on educational games.
2018	Zhao et al.	With traditional approaches to education, many students consider science subjects problematic and are often discouraged during the learning process.
2018	Prasetyo & Napitupulu	Digital game-based learning did not improve learning achievement and motivation in mathematics classes in K-12 students compared to traditional methods.

Table 5 provides an overview of all analyzed empirical research with critical data on the works. The table shows the age of the respondents, their number, and the country where the research was conducted. The following is data on the critical research questions and their answers (positive, negative, impact cannot be determined). It is also indicated if the paper should have discussed one of the questions.

Table 5
Summary of Included Articles

Years	Researcher	Age	STEM discipline	RQ1	RQ2	RQ3
2023	Gui et al.	K-12 and University	All	✓	✓	
2023	Al-Said, K.	University	Science and Technology	✓	✓	
2023	Tablatin et al.	University	Mathematics	✓	✓	✓
2023	Yang	K-12 and University	All		✓	✓
2022	Wang et al.	K-12	Science and Technology	✓	✓	
2022	Nkadimeng & Ankiewicz	K-12	Computer Science	✓	✓	✓
2022	Tay et al.	University	Technology and Mathematics	✓		
2022	Wu, Liu, & Huang	K-12 and University	Science and Technology	✓	✓	
2022	Arztmann et al.	K-12	All	✓	✓	
2022	Poçan et al.	K-12	Mathematics	✓	✓	
2022	Wang et al.	K-12	Technology and Computer Science	✓		
2022	McLaren et al.	University	Mathematics	✓	✓	
2022	LeRoy	K-12	Mathematics and Science	✓	✓	✓
2022	Andersen & Rustad	K-12	Mathematics	✓	✓	✓
2022	Mawas et al.	K-12	Technology and Computer Science	✓		
2022	Zhang et al.	K-12	Engineering and Technology	✓	✓	✓
2021	Sómer, Moreira, & Casado	University	Engineering	✓		
2021	Fadda et al.,	K-12	Mathematics	✓	✓	
2020	Sabirli & Çoklar	K-12	All	✓	✓	✓
2020	Bertram, L.	K-12	Mathematics and Computer Science	✓	✓	✓
2020	Wang & Tahir	University	All	✓	✓	
2020	Priyaadharshini et al.	University	Engineering	✓		
2019	Ortiz-Rojas et al.	University	Engineering	✓		
2019	Hosseini et al.	University	Computer Science	✓	✓	
2018	Byun & Joung	K-12	Computer Science and Mathematics	✓	✓	
2018	Touati & Baek	K-12	Computer Science and Mathematics	✓	✓	✓
2018	Zhao et al.	University	Computer Science	✓		
2018	Prasetyo & Napitupulu	K-12	Mathematics	✓		

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Research Results

Articles included in the sample were published from 2018 to May 2023. However, the random sample included only six articles published between 2017 and 2018. To respond to the research questions, the results section consists of three topics related to the level of education, country or province of research and type of educational digital games.

RQ1: Is the level of motivation higher when performing digital game-based learning in STEM education compared to teaching dominated by teaching aids such as textbooks, teaching sheets, demonstration methods, and teachers' oral presentations?

This systematic analysis includes 28 relevant articles on STEM education and student motivation. A large number of studies (= 21, 75%) confirm that digital games in STEM education increase the level of student motivation. A few studies (= 7, 24%) denied digital games' contribution to increasing students' motivation. The contribution of DGBL varied by level of education. Studies have shown that the level of motivation is higher among K-12 students (= 19, 67.8%) of the educational system than among university-level students (= 9, 32.2%). The level of motivation also depended on the lesson's content covered in class. Students were more motivated for more straightforward concepts (= 10, 35.7%) and lessons than abstract and unfamiliar concepts (= 7, 25%) (see Figure 3). In favor of DGBL, there are also data that from the total number of articles included in this analysis, as many as 54% of students over 15 years and 74% of students under 15 years want to use technology more, and therefore DGBL in the classroom when learning STEM subjects (see Figure 4).

Figure 3
Educational Level and Increasing Motivation

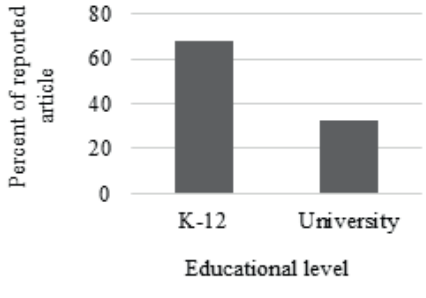
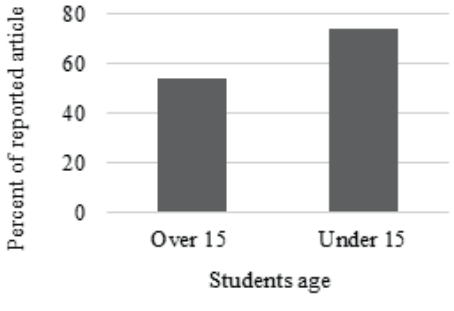
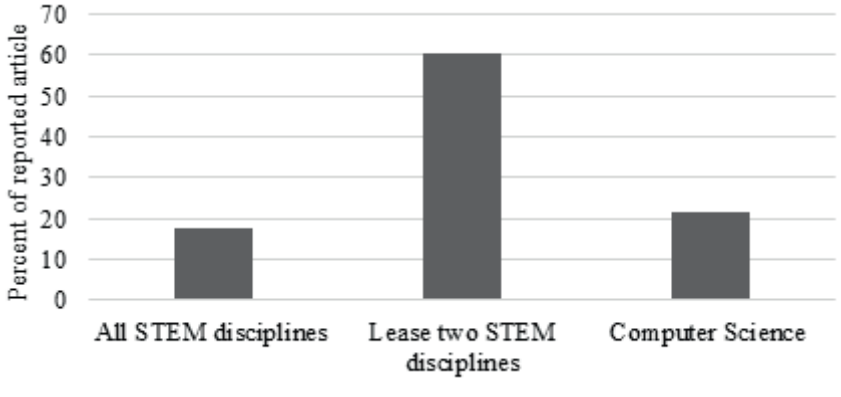


Figure 4
Selection for DGBL Based on the Age of the Student



The 28 articles that met the inclusion criteria had at least two STEM disciplines (= 17, 60.7%), while several dealt only with programming as a STEM discipline (= 6, 21.5%). A significant contribution was made by analyzing articles that looked at the overall contribution of the STEM concept education in DGBL, not referring to any specific STEM discipline (= 5, 17.8%). No articles were found that focused on all STEM disciplines.

Figure 5
Articles Based on the STEM Discipline in Reviews Studies



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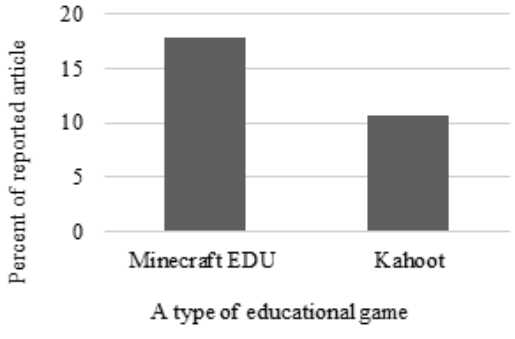
Several studies deal with the contribution and implementation of technologies suitable for DGBL in STEM disciplines (see Figure 6). The author identified two used game technologies directly related to motivation while learning STEM subjects from the reviewed literature. Three articles (10.7%) use the Kahoot application, whose contribution at the global level is 85% in favor of stimulating and maintaining student motivation. Other findings indicate that Minecraft EDU has positively affected student motivation (= 5, 17.8%).

Figure 6
Educational Digital Games in STEM Education

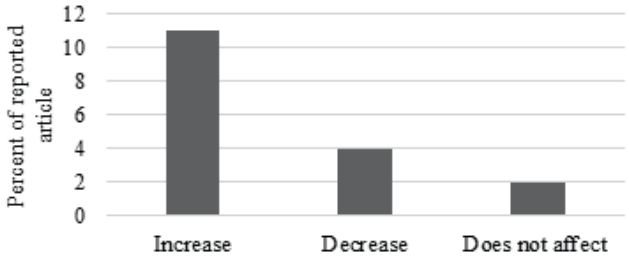


Considering the above findings, it is possible to confirm that the introduction of learning based on digital games contributes positively to increased student motivation than learning STEM disciplines using teaching aids such as a textbook, worksheets, and a projector followed by a teacher's oral explanation.

RQ2: Does the pre-knowledge of students given STEM discipline increase or decrease motivation?

One of the critical questions is whether the student's level of knowledge affects motivation. Research has shown that an increase in motivation was observed in the majority of respondents who already had prior knowledge of a specific STEM teaching subject (= 11, 39.3%). A decrease in motivation was observed in students with weaker knowledge or needing adequate digital devices to monitor DGBL (= 4, 14.3%). Several articles emphasized that the students' pre-knowledge was not essential for increasing students' motivation (= 2, 7.1%) (see Figure 7).

Figure 7
The Effect of Prior Knowledge on Student Motivation



Introducing educational games into the teaching process led to an inevitable increase in motivation. Students' prior knowledge of a specific STEM discipline favored the increase in student motivation in teaching STEM disciplines supported by Minecraft EDU (= 3, 10.7%). Students' prior knowledge combined with Kahoot proved good for delivering STEM lessons. A significant increase in motivation was observed among students (= 2, 7.14%), while a small number said that prior knowledge did not significantly affect the growth in motivation (= 1, 3.6%). Figure 8 illustrates the educational digital games used in the reviewed studies.

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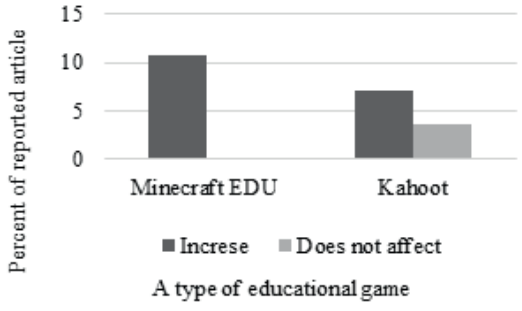
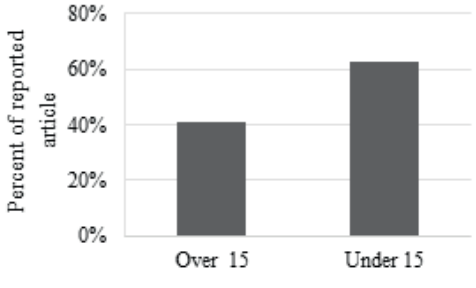
Figure 8
The Impact of Earlier Game Playing on Students' Motivation



Twenty-eight articles were included in this analysis from the total sample, 41% of students older than 15 emphasized that prior knowledge of STEM subjects increased their motivation. Meanwhile, 63% of students younger than 15 were more motivated for DGBL due to their quality knowledge of STEM subjects (see Figure 9).

Figure 9
The Influence of Prior Knowledge on Student Motivation, Age Selection



That prior knowledge influenced the motivation for further learning in DGBL STEM learning is confirmed by eight (28.6%) articles that included at least two STEM disciplines; six articles (21.4%) emphasize that prior knowledge is not crucial for student motivation. It has been shown that prior computer science or mathematics knowledge is significant for motivation and further progress in DGBL learning STEM subjects. It was not found that prior knowledge had equally positive effects on increasing motivation in all STEM disciplines.

RQ3: Does prior knowledge about the game affect students' motivation to learn?

Previous experience and knowledge of playing a game can be essential for further progress during learning. It turned out that students who had previous experience playing games found it easier and faster to get used to DGBL in STEM lessons than those who had not played games before (= 6, 21.5%). Students with no previous experience playing games did not show motivation for further progress and engagement in DGBL teaching STEM subjects (= 2, 7.14%). However, some have shown that previous experience of playing games is not decisive for increasing or decreasing students' motivation in DGBL teaching of STEM disciplines, i.e. 3.6% of the reviewed literature (see Figure 10).

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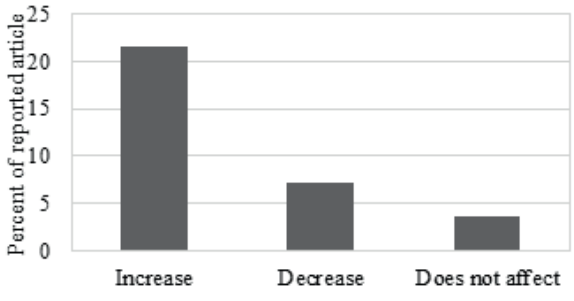
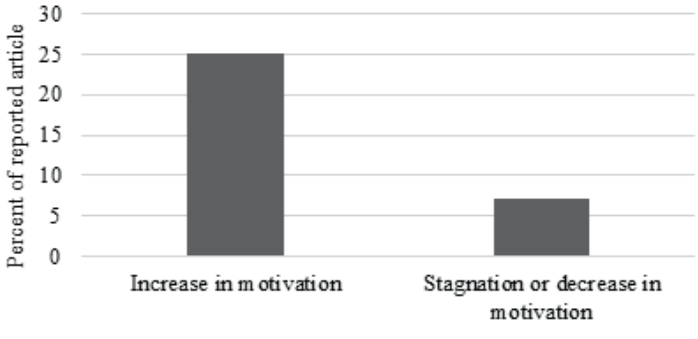
Figure 10
Effects of Prior Gaming Experience on Motivation



Since video games are a prevalent form of entertainment among students, the experience of playing games proved to be a good practice for increasing motivation in DGBL. Minecraft EDU (see Figure 11) significantly increased student motivation, especially among those with previous experience with this computer game's commercial version (= 7, 25%).

Figure 11
Impact of Prior Minecraft Gameplay Experience on Student Motivation



However, motivation remained the same or decreased in students without prior experience playing games. These students often gave up their studies (= 2, 7.14%). Students older than 15 years showed that their previous experience of playing games positively affected their maintenance and increased motivation for learning (= 5, 17.8%). No statistically significant contribution of experience was recorded for students under 15 years of age.

Discussion

Findings from this study may have implications for improving student motivation in digital-game-based learning in STEM Education.

Student motivation during learning is one of the most powerful driving forces towards achieving goals during teaching and learning. The effect of DGBL was investigated in terms of its ability to enhance motivation in learning STEM disciplines among students in the K-12 education system. To prevent a decrease in student motivation, educational technologies and teaching aids are constantly researched and sought after. Since each student is a microcosm for himself, creating and designing a quality environment is necessary to encourage the student to get involved in the teaching process.

The present study results suggest notable discrepancies between students who have played digital games before and those who have yet to. It implies that students with experience playing games are more open to adapting to new learning environments, leading to better learning outcomes. The findings of the study are in line with Prasetyo and Napitupulu (2018), who stated that prior experience in playing digital games has been found to contribute to an increase in motivation to learn. Still, it cannot be considered as the sole factor that increases student motivation.

On the other hand, due to the very nature of STEM disciplines, students are more suited to an innovative ap-

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proach, the implications of which can be seen in increasing motivation for learning. The minimizing of the traditional approach, which includes traditional teaching aids such as blackboards and textbooks, provides space for the integration of educational digital games and thereby establishes student interaction.

This result is similar to the results of Al-Said et al. (2023). For example, Al-Said et al. (2023) found that the interaction of students with digital educational games is an important factor in increasing motivation and raising the working atmosphere.

There is a significant number of educational digital games available in the market today. In this study, Minecraft and Kahoot were selected as representative examples. The analysis revealed that the educational version of Minecraft, a commercial game, has multiple positive effects on student motivation during the learning process. Many students showed a keen interest in learning through this educational digital game. The findings of this study are consistent with the results obtained by LeRoy (2022). Knowing how to play the game is not sufficient for sustaining and starting it. The level of motivation is largely dependent on the knowledge of a specific STEM discipline. By using Minecraft and Kahoot in her classes, the teacher discovered that the level of motivation consistently increases among students who have prior knowledge of specific STEM disciplines. However, it was also observed that prior knowledge of STEM disciplines does not significantly contribute to increasing motivation in a small number of students.

This result is partly similar to the results of Sómer et al. (2021). For example, integrating educational digital games in STEM education showed outstanding results in improving motivation among students with a solid background in STEM disciplines.

University and K-12 students have different biases, cognitive skills, and prior knowledge. Another important indicator for students' motivation to learn in DGBL STEM education is the age of the students. Research has shown that K-12 students are significantly more interested in learning through digital educational games than university students. On the other hand, we noticed that older students at the K-12 level have a greater affinity for digital games than younger students. The findings of this study were partially confirmed by Gui et al. (2023) because they pointed out that older students are at a higher cognitive level than younger ones and that games for educational purposes are not crucial for motivation. However, they are for further development of cognitive skills. Another group of researchers, Tai et al. (2022), pointed out that both groups of students showed increased motivation. However, K-12 new students showed a more noticeable increase in motivation and interest in DGBL classes.

Apart from imparting knowledge to students, a teacher has an equally important role in promoting the development of student motivation. With the help of modern teaching aids, a teacher's job has become much easier. Our study demonstrated that motivation can be improved through digital educational games, provided an appropriate selection of games. The most promising outcomes were observed in students with prior experience of playing games and a good understanding of STEM subjects.

Conclusions and Recommendations for Future Research

According to the study, prior experience in STEM subjects has a positive effect on student motivation. In the realm of STEM subjects, prior gaming proficiency does not significantly influence one's abilities. However, these disciplines necessitate an alternative pedagogical approach that emphasizes a higher degree of student involvement. Digital games offer superior prospects for engagement and learning in comparison to conventional teaching tools, such as textbooks, worksheets, and verbal lectures. This is because textbooks are limited in their teaching aims and do not offer adequate opportunities for student engagement. Consequently, incorporating digital games in the classroom can prove to be an efficacious means of enhancing student engagement.

The study also found that motivation, academic achievement, and engagement are the most extensively examined variables, with a subsequent focus on learning, enjoyment, and other cognitive factors. Academic motivation was identified as the most researched aspect, and the analyzed studies confirm that DGBL strategies positively affect student motivation. Current knowledge and findings indicate that students are more motivated to acquire knowledge and skills in DGBL STEM education classes than in classes not customized to the student and their characteristics. This review aimed to provide a synthesis of research on the effects of DGBL on STEM education. However, the study had limitations, as it only considered research articles published between 2018 and 2023.

Systematic literature reviews are recognized as effective approaches in social science research for their transparency and openness to criticism through the PRISMA methodology. However, like any research method, there are inherent limitations in the methodology and its application that apply to this review.

The STEM concept's complexity and interdisciplinary nature make it difficult for researchers to maintain focus on the entire content. During the preparation, collection, and research of the literature, several areas that could be

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improved were discovered. The authors focused mainly on one discipline or connected two, achieving a synergistic relationship (chemistry and biology; computer science and mathematics).

Student achievements can be seen within three domains, and a challenge arises due to insufficiently detailed information about the teaching of STEM education supported by educational digital games. Evaluations are described with different focuses and methods in various depths and variations. DGBL systems are often unavailable in playable form, and the reproduction and verification of results could be difficult.

Another shortcoming is that most studies assess student achievement, motivation, and engagement during instruction and evaluation. This study focuses only on student motivation. Other studies have positively evaluated DGBL in STEM education if one of the criteria is met.

This study excludes other factors to give the most authoritative results of DGBL's effect on student motivation. Although the potential and possibilities of DGBL are significant for the entire education, not only STEM education, there are still some limitations that we must keep in mind. It is necessary to single out limitations to minimize them in practice.

However, limitations should be seen as new topics for research and improvement. It is also necessary to monitor the effect of using digital games in education on students with limited financial resources who need access to digital devices at home. Another limitation of this study, but also an idea for future research, is the type of educational game. No one-size-fits-all educational game simultaneously examines the motivation of science, technology, engineering, and math students. Minecraft Education Edition is a good attempt, but only some of its potential has been used.

Declaration of Interest

The authors declare no competing interest.

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