

# Exploring the Impact of Digital Game-Based Learning on STEM Education a Comprehensive Review

Haoyang Fei \*

Computer science and technology, Jiangxi Normal University Science and Technology College,  
 JiuJiang, JiangXi

\* Corresponding author: angradmainyu@gmail.com

**Abstract.** Digital game-based learning (DGBL) has emerged as a promising approach to enhancing STEM (Science, Technology, Engineering, and Mathematics) education, drawing widespread attention in fields such as education, healthcare, wellness, and hazard prevention. However, discussions on the application of DGBL in STEM education remain insufficiently explored, with existing research largely focused on language learning and lower-grade subjects. Therefore, this study aims to systematically investigate the impact of DGBL on STEM learning outcomes. Researchers conducted a comprehensive search in the Web of Science database, considering factors such as experimental design, sample size, and comparability of study results. Through literature screening and analysis, 19 relevant studies meeting the inclusion criteria were identified. The findings from the included literature reveal that DGBL has a positive impact on STEM learning, encompassing various aspects such as increased learning motivation, improved academic performance, enhanced self-efficacy, and a positive learning experience. As an educational method, DGBL demonstrates significant potential in the STEM field. However, challenges remain, such as the effectiveness of game design, the selection of assessment tools, and the measurement of learning outcomes. Overall, DGBL positively influences STEM learning, and future research should focus on innovative game design, establishing evaluation standards, and more educational practice to further explore the potential of DGBL in STEM learning.

**Keywords:** STEM; DGBL; Educational Stage x.

## 1. Introduction

Games are a popular form of entertainment among adolescents [1]. Past psychological research on games has often focused on their negative impacts [2, 3]. However, it is undeniable that games can enhance individual motivation and engagement and are an important part of human society and culture [4].

### 1.1. The Concept and Current Application of Digital Game-Based Learning

Digital game-based learning (DGBL) is defined as a teaching method where digital games are used as tools to facilitate student learning and education. This approach emphasizes the interactivity, entertainment, and challenge of games to capture students' attention and provide a positive learning experience [5]. DGBL typically involves comprehensive considerations, including game design, learning objectives, instructional activities, and assessments, to ensure alignment between games and learning goals and to provide meaningful learning experiences for students [6].

Games are also considered complex learning environments where players need to learn various in-game knowledge to play the game and have a good experience. Thus, playing games is a learning process in itself, while DGBL focuses on learning the content of teaching materials. Students can explore, learn, and experiment within games to acquire rich knowledge and skills. Games can serve as teaching tools and become a learning method in the digital age [7].

Additionally, other research has shown that DGBL positively influences creativity development. For example, Behnamnia [8] explored the impact of DGBL technology (e.g., tablets and smartphones) on preschool children's creativity. The authors found that DGBL positively influences children's creative

thinking. Similarly, Aguilera & Roock [9] reviewed the concept and application of DGBL, examining the relationship between computer games and learning processes or outcomes and the interdisciplinary research background of DGBL. These studies suggest that DGBL can be an effective teaching tool, promoting student learning and creativity, indicating its broad application prospects in education.

## **1.2. The Concept and Characteristics of STEM Education**

STEM education is an interdisciplinary approach that integrates knowledge and skills from science, technology, engineering, and mathematics. Unlike traditional subject-based education, STEM education transcends disciplinary boundaries, encouraging students to explore connections between these fields and apply their knowledge and skills to solve real-world problems. According to a book "What Is STEM Education?", STEM education provides a comprehensive teaching environment aimed at fostering students' holistic understanding.

Aligned with the goals of STEM education, DGBL also aims to stimulate critical thinking, creativity, and innovation. Through DGBL, students can analyze problems, propose solutions, and design prototypes, closely related to the practical learning and problem-solving skills emphasized in STEM education. Thus, STEM education and DGBL share the goal of cultivating students' comprehensive abilities and application skills.

## **1.3. The Current Application of DGBL in STEM Education**

Anecdotal evidence and some empirical studies suggest that DGBL has potential benefits in improving STEM learning outcomes. Tisza [10] explored how the fun factor in games can enhance learning effects, motivation, self-efficacy, and learners' positive attitudes toward games. This study reviewed and analyzed existing literature to examine the impact of fun on learning and related factors in DGBL environments, aiming to provide theoretical and practical guidance for improving DGBL's educational effectiveness. However, it did not discuss the direct relationship between DGBL and academic performance. Krath [11] conducted a systematic literature review revealing the theoretical foundations of gamification, serious games, and game-based learning research and their impacts on practice and research. This study integrated theories related to gamification but lacked specific applications in learning tasks.

According to the expanded STEM+ concept, language learning is also part of STEM education. Some researchers have studied this issue, such as Hung [12], who conducted a comprehensive review of digital game-based language learning (DGBLL). The authors systematically analyzed empirical evidence from 2007 to 2016 on the application and impact of digital games in language education to promote emerging research in the DGBLL field. The study found that most DGBLL research adopts mixed methods to examine the educational applications of digital games, primarily using immersive games as experimental materials, especially massively multiplayer online role-playing games (MMORPGs), which are most common in current DGBLL literature. Most games for language learning are custom-made by DGBLL researchers. Most DGBLL studies reported positive learning outcomes, with the most commonly reported results related to emotional or psychological states, followed by language acquisition.

These findings reflect the diversity of the field and suggest that digital games generally support native and non-native language and literacy learning. Most DGBL-related research and experiments focus on elementary and preschool education. For example, a review of 23 experimental studies on DGBL's effectiveness in elementary science learning found that DGBL positively influences elementary science learning.

## **1.4. Research Questions**

Previous empirical studies have explored the relationship between the fun factor in games and learning outcomes, motivation, and self-efficacy[10]. However, there is a lack of research on the

connection between DGBL and specific disciplines. Researchers like Hung[12] attempted to depict a comprehensive picture of this issue through systematic literature reviews, but their selected studies were from 2007-2016 and could not reflect the latest research progress. Moreover, their study mainly focused on theoretical research and discussions, leaving the current trends of DGBL in education with some research value. Hussein[13] analyzed 23 experimental studies across six levels: topic, genre, game environment, study design, platform, and in-class/out-of-class settings, summarizing their research objectives, methods, and conclusions. The study concluded that DGBL could promote elementary students' science knowledge learning, motivation, and self-efficacy and help cultivate their interest and skills. However, research on other educational stages, such as middle school, high school, and university, remains insufficient. Therefore, a comprehensive analysis of existing literature is necessary to fill gaps in DGBL-related research.

In this study, researchers will approach from two different perspectives. First, the COVID-19 pandemic has forced educational institutions to adopt online teaching modes, presenting new challenges and opportunities for educational digitization. Online education has rapidly developed during the pandemic, with much online learning moving towards DGBL. Online teaching faces issues such as students' inability to concentrate, lack of engagement, and decreased motivation, leading to reduced learning efficiency [14]. These are problems that DGBL can effectively address [10]. However, existing experimental studies lack clear research design norms, and there are no specific requirements for the types of games used. For example, Hung [12] summarized the theories used in GBL in detail, while learning engagement, motivation, and flow play crucial roles in learners' academic achievement. Therefore, it is necessary to review existing research to understand the main findings of current DGBL studies and provide broader and more rigorous references for future research.

Second, our systematic literature review will focus on the impact of digital game-based learning (DGBL) on STEM learning. Although DGBL has been widely applied in language, learning theory, and motivation and shown positive effects, its impact on STEM learning has not been fully discussed. Existing literature mainly focuses on language and lower-grade science learning, with studies concentrated on theoretical research and learning enjoyment. There is still significant research space for DGBL's application in STEM subjects. Therefore, this study will investigate the relationship between DGBL and STEM education, expanding the research sample from elementary school to middle school and higher education. The study proposes the following four research questions:

- (1) What trends have emerged in DGBL applications in STEM education over the past ten years? (application regions/subjects)
- (2) What types of games are primarily used in existing DGBL research?
- (3) What research designs (experimental/quasi-experimental) are mainly adopted in existing DGBL studies?
- (4) What are the main findings of existing DGBL research?(learning performance/engagement/interest/ motivation)

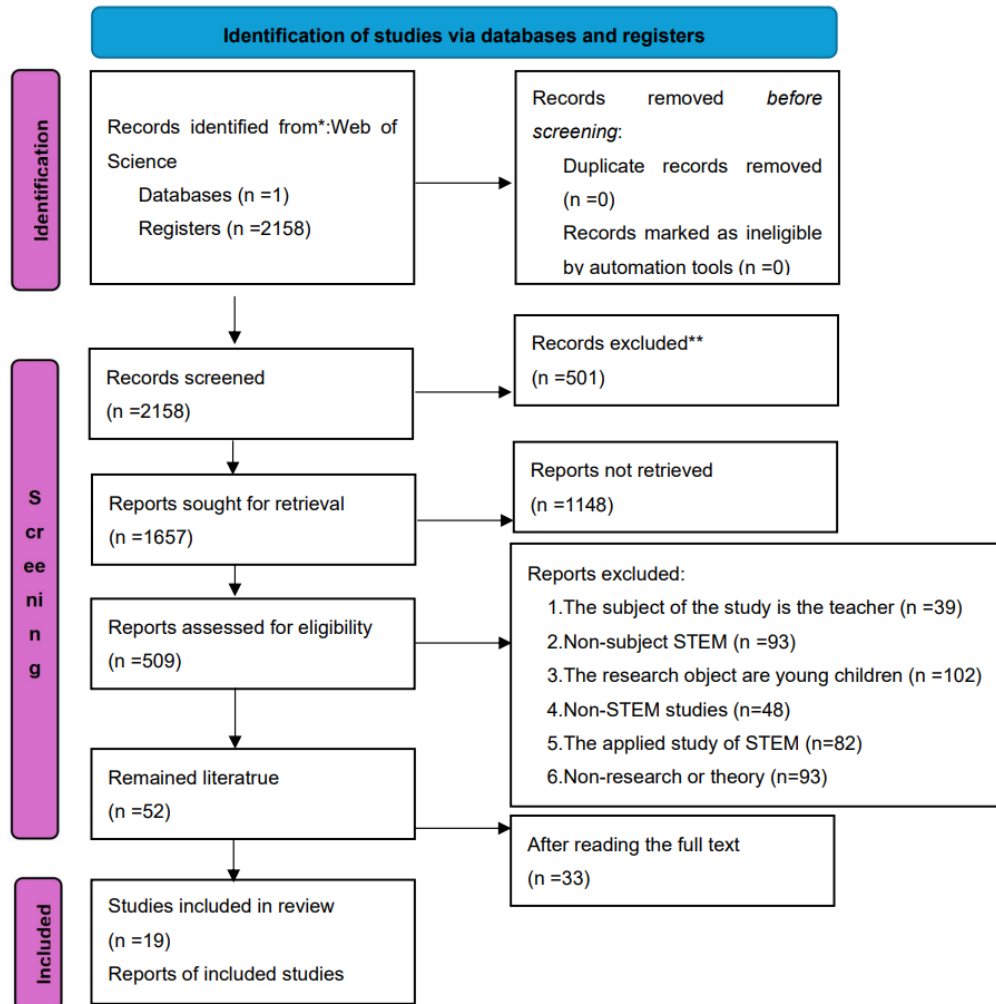
## **2. Research Design**

### **2.1. Research Objectives**

The aim of this theoretical research is to investigate the impact of Digital Game-Based Learning (DGBL) on elementary science learning by providing an overview and analysis of relevant research papers. The study systematically summarizes the current state, development trends, and key issues in the research field.

## 2.2. Research Procedure

The literature screening procedure followed the PRISMA flow diagram (Page et al., n.d.), as illustrated in Figure 1, with the inclusion and exclusion criteria detailed in Table 1. Inclusion and Exclusion Criteria: The literature search was performed in the Web of Science databases using relevant keywords "DGBL," "Digital Game-Based Learning," and "STEM."



**Figure 1.** PRISMA Flowchart

TS=(DGBL OR Digital Game-Based Learning) AND (STEM), This search yielded 2158 English-language papers. Because the quality of some literatures obtained by the search does not meet the research needs, it is necessary to evaluate and screen the original literature objects. The literature screening procedure of this study is the "evaluation of literature quality" step in systematic literature review.

**Table 1.** Inclusion and Exclusion Criteria for Literature

Inclusion Criteria	Exclusion Criteria
1. Studies published in English	1. Studies not published in English or duplicate studies
2. Full text available	2. Full text not available
3. Empirical studies	3. Theoretical or review studies
4. Subjects within the STEM	4. Subjects not within the STEM
5. Learning method is DGBL	5. Study participants not of middle school level or above
6. Participants are middle school students or higher	6. Participants are teachers or other community members
7. Published within the last 10 years	7. Study goals not related to DGBL
	8. Studies on DGBL applications outside of academic subjects

Ultimately, 52 papers were obtained. After reading the introduction, method, and results sections of these 52 papers, 19 studies were ultimately selected for the review.

### 2.3. Coding Standards

In the literature coding phase, this study developed the literature coding table based on the research questions, referring to the results of previous researchers[15], as shown in Table 2. Besides the researcher, a graduate student majoring in minor languages was invited to independently read and code the full text of 30% of the included literature. The coding results of the two researchers were calculated, yielding an 80% agreement, indicating a high level of consistency. Discussion revealed that the primary disagreements between the two researchers were on research types and game types. After the two researchers reached a consensus on the coding results, the remaining literature coding work was conducted by the author of this study alone.

**Table 2.** Coding Framework Table

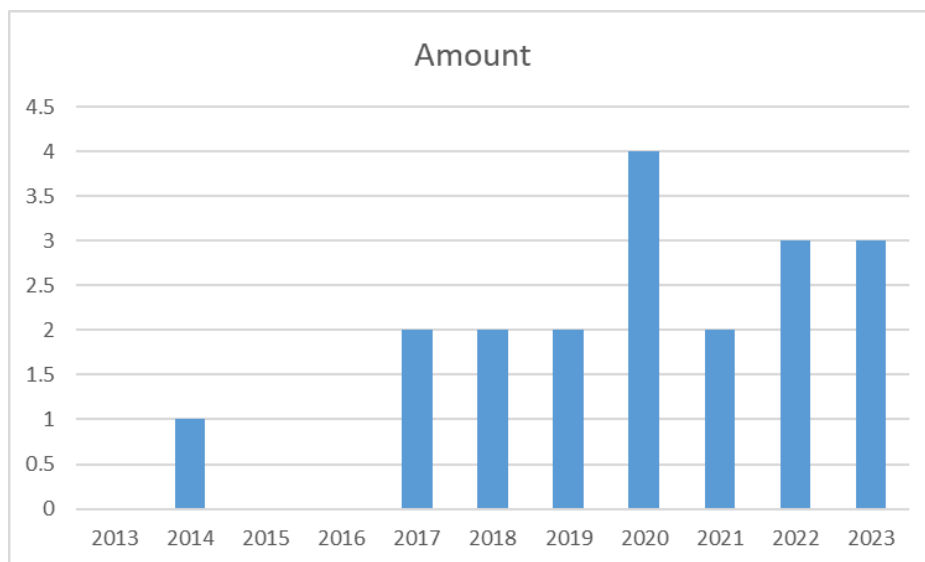
Dimension	Description	Code
Basic Information	Publication Year	Publication Year
	Author	First Author
	Journal	Title of Literature
	Country or Region	Country/Region of Study
Sample Information	Sample Size	Sample Size
	Educational Stage	Middle School
		High School
		University
		Master
Other		
Research Methods	Game Type	RPG/ACT/Puzzle
	Game Presentation	2D/3D
	Research Type	Experimental/Quasi-experimental/Action Research
	Duration of Study	Weeks/Seasons
	In-Class/Out-of-Class	In-Class/Out-of-Class
	Game Development	Commercial Game/Self-developed Educational Game

### 3. Results

#### 3.1. Trends of DGBL in STEM Education

Regarding the first research question: "What trends have emerged in DGBL applications in STEM education over the past ten years? (application regions/subjects)," this study included 19 English-language papers. The distribution of the included studies by publication year is relatively concentrated. Twelve papers were published between 2023 and 2020, two papers each were published from 2019 to 2017, and only one paper was published in 2014. No papers meeting the inclusion criteria were published in 2016, 2015, or 2013. This indicates that research on DGBL in STEM has shown a gradual upward trend in the past seven years. Before 2017, this research direction did not receive sufficient attention.

The locations of the studies included Spain, the United States, Taiwan, the United Kingdom, Kosovo, Egypt, Germany, Norway, Canada, Scotland, and the Netherlands. Among these, research was most frequently conducted in four countries: four studies in Spain, three in the United States, three in Taiwan, and three in the United Kingdom.



**Figure 2.** Trends in the References of Included Literature

Through statistical analysis, the educational levels in the included studies are categorized into middle school, university, and master's levels. Two studies involved mixed-age groups: one study's participants ranged from kindergarten to middle school children, and another study's participants were aged 18 to 33, with an average age of 23.6 years. Most experiments selected participants by class, resulting in sample sizes larger than 50 people. Only one study had a sample size of 10 people, but since each participant in that study corresponded to a different game for DGBL, this method was considered to have reference value and was ultimately retained.

Regarding the number of participants in the studies, the included research generally focused on single courses, with most studies involving fewer than 100 participants. This is because most of the research was conducted by class, and even when experimental and control groups were set up, the total number of participants did not exceed 100. Therefore, the sample sizes of most experiments did not exceed 100 participants. Detailed information can be found in Table 3.

**Table 3.** Basic Information and Sample Details of Included Studies

Basic information		Sample information	
Literature identification code	Location	Sample Size	Educational Stage
Ortiz-Martinez (2023) [16]	University of Murcia	392	Undergraduate
Man-Ying Chen (2023) [17]	Taiwan	187	Undergraduate
Manuel Ninaus (2023) [18]	Germany	85	Mix
Chioma Udeozor (2022) [19]	England	67	Undergraduate
Cook-Chennault (2022) [20]	America	201	Undergraduate
Camacho-Sánchez (2022) [21]	Spain	126	Undergraduate
Krenare Pireva Nuc i(2021) [22]	Kosovo	257	Master
Elkhamisy (2021) [23]	Helwan University	55	Undergraduate
Wells (2020) [24]	Kingston University	256	Undergraduate
Di Zou (2020) [25]	Hong Kong	90	Undergraduate
Hernández-Fernández (2020) [26]	University Politècnica de Catalunya	60	Master
Campillo-Ferrer (2020) [27]	University of Murcia	101	Undergraduate
Troiano (2019) [28]	America	317	Middle school student
Gaeta (2019) [29]	Madrid and Graz and Nottingham	600	Middle school student
Perin i(2018) [30]	Norway	265	Master
Hebert (2018) [31]	Canada	795	Mix
Pantoja (2017) [32]	America	10	Undergraduate
Barr (2017) [33]	The University of Glasgow	100	Undergraduate
Admiraal (2014) [34]	Amsterdam	458	Middle school student

### 3.2. Types of DGBL Games

To address research question 2: "What types of games are predominantly used in existing DGBL research?" this study categorizes the 19 papers into seven dimensions for clearer and more intuitive observation and analysis.

The results indicate that DGBL in the STEM education field demonstrates diverse applications, ranging from puzzle games to role-playing games (RPGs) and mobile games. Researchers have explored various types and forms of game environments. Among the data, seven experiments used RPGs, and twelve experiments used puzzle-type games. Specifically, twelve games were 2D: three were RPGs, the remaining nine were puzzle games. Among the seven 3D games: four were RPGs and three were puzzle games.

### 3.3. Types of Research Designs in DGBL Applications

Regarding research question 3: "What research designs (experimental/quasi- experimental) are predominantly used in existing DGBL research?" this study finds that among the 19 studies, seven utilized experimental research designs, with four conducted in classroom settings, accounting for more than half of the experimental studies. Twelve studies used quasi-experimental designs, with eight conducted out of the classroom, again accounting for more than half of the quasi-experimental studies. The data indicate that in-class experimental research is more common, while out-of- class quasi-experimental research is more prevalent.

Furthermore, all 19 experimental studies used self-developed games. Although some studies using commercial games might not have been included due to inaccessibility of full texts or other reasons, the data from this research suggest that using commercial games as DGBL in the field of STEM learning for middle school and above is extremely rare. Regarding the duration of the research, these 19 studies do not show a clear pattern. Aside from two studies that did not specify the research duration, only five studies lasted longer than one semester (Table 4).

**Table 4.** Research Methods of Included Studies

Periodical	Genre	Game environment	Study design	Independent research and development /Business game	In class/ out of class	Research period
Education and Information Technologies	Puzzle	2D	Experimental	Independent research and development	In class	18 weeks
Education and Information Technologies	RPG	3D	Quasi-experimental	Independent research and development	Out of class	4 weeks
Journal of Educational Computing Research	RPG	3D	Experimental	Independent research and development	Out of class	18 weeks
Education Sciences	Puzzle	2D	Quasi-experimental	Independent research and development	In class	2 hours
Applied Sciences	RPG	2D	Experimental	Independent research and development	Out of class	2 months
IEEE Access	Puzzle	2D	Quasi-experimental	Independent research and development	In class	4 months

Alexandria Journal of Medicine	Puzzle	2D	Quasi-experimental	Independent research and development	Out of class	5 months
Currents in Pharmacy Teaching and Learning	Puzzle	2D	Quasi-experimental	Independent research and development	Out of class	4 weeks
Sustainability	Puzzle	3D	Quasi-experimental	Independent research and development	Out of class	2 years
Educational Technology Research and Development	Puzzle	2D	Quasi-experimental	Independent research and development	Out of class	5 days
Sustainability	Puzzle	2D	Quasi-experimental	Independent research and development	Out of class	4 months
ACM Digital Library	Puzzle	2D	Quasi-experimental	Independent research and development	Out of class	2 years
Sensors	Puzzle	3D	Experimental	Independent research and development	In class	2 years
Learning and Collaboration Technologies	RP G	3D	Quasi-experimental	Independent research and development	In class	N/A
Media and Communication	RP G	2D	Quasi-experimental	Independent research and	In class	One week

				development		
Proceedings of the 3rd International Conference on Higher Education Advances	Puzzle	2D	Experimental	Independent research and development	In class	3 weeks
Computers & Education	RPG	3D	Experimental	Independent research and development	Out of class	8 weeks
International Journal of Inclusive Education	Mobile game	2D	Quasi-experimental	Independent research and development	Out of class	10 days
Australasian Journal of Educational Technology	RPG	2D	Experimental	Independent research and development	In class	N/A

### 3.4. Application Effects of DGBL in STEM Education

To address research question 4, "What are the main findings of existing DGBL research?" for more intuitive observation and analysis, the key points studied are categorized into 8 factors. Engagement: The level of student participation and involvement in the learning process. Appeal: The degree to which students are attracted to digital games or instructional methods. Learning Outcomes: The learning achievements obtained by students through digital games or gamified teaching. Motivation: The level of motivation among students during the learning process, including intrinsic and extrinsic motivation. Cognitive Development: The development of students' cognitive abilities, thinking processes, or problem-solving skills. Gender Differences: Differences in performance or perceptions between male and female students in digital game-based learning. Technology Acceptance: The degree to which students accept the use of digital games or instructional technology. Classroom Interaction: The impact of digital games or gamified teaching on classroom interaction and interaction among students. Game Genre Preference: Students' preferences for different types of games and their impact on learning outcomes.

After statistical analysis, there were three experiments each for Appeal, Motivation, and Classroom Interaction, while experiments on Engagement and Technology Acceptance reached four times. Five experiments studied Cognitive Development, and Learning Outcomes were researched as many as twelve times. It is evident that researchers are most concerned about the outcomes brought by DGBL. Only two experiments delved into Gender Differences, indicating relatively less research on the application differences among different genders. Among the twelve studies on Learning Outcomes, all twelve reported positive results. For instance, the study by Hebert[31] indicated that for beginners in computer programming, the effectiveness of DGBL is evident, but the study found that as students'

proficiency levels increase, the learning effectiveness of DGBL gradually decreases. Details can be found in the Table 5 below.

**Table 5.** Case Analysis Table of Included Factors in DGBL Studies

Literature	Engagement	Appeal	Learning Outcomes	Motivation	Cognitive Development	Gender Differences	Technology Acceptance	Classroom Interaction
[16]			√					√
[17]	√		√				√	
[18]			√		√			
[19]					√			
[20]		√				√	√	
[21]			√	√				
[22]			√					√
[23]	√				√			
[24]		√			√		√	
[25]	√		√					
[26]			√	√				
[27]				√	√			
[28]			√					
[29]		√	√					√
[30]			√					
[31]			√					
[32]	√						√	
[33]			√					
[34]						√		
Total	4	3	12	3	5	2	4	3

## 4. Conclusion and Discussion

### 4.1. Trends in STEM Education

The research trend of DGBL in STEM shows that there was only one study between 2013 and 2016, published in 2014. From 2017 to 2023, there were a total of 18 studies. Among these, there was an average of two studies per year in 2017, 2018, 2019, and 2021. In 2020, the number of studies peaked at four. In both 2022 and 2023, there were two studies each year. This indicates a progressive rise in research activity in this area over the years.

### 4.2. Types of Games Used

In terms of game types, most experiments utilize RPG games as learning platforms, which typically yield better feedback and results. However, developing RPG games requires more manpower and resources. Conversely, most Puzzle games are smaller in scale and are developed independently for teaching purposes, generally receiving positive feedback. RPGs offer a linear narrative flow, and the rewards and storyline immersion during gameplay can enhance student engagement and immersion. The longer storylines can facilitate deeper learning. On the other hand, Puzzle games require less time and are more conducive to group learning, such as the Kahoot gaming platform. Four studies utilized the Kahoot platform[27,23,22,16], indicating its educational effectiveness in some regions, excluding Asia. However, considering its educational achievements in DGBL, the Kahoot platform can be appropriately used in DGBL research in Asia. In Asia, research on DGBL is primarily concentrated in Hong Kong and Taiwan. Although there is only one study from Hong Kong and one from Taiwan

in this experiment, collaborative research involving Hong Kong and Taiwan has been observed. In these collaborative studies, RPG games were predominantly used, suggesting that RPGs may be more appealing to Asian students.

### 4.3. Research Designs Employed

Among the 19 selected studies, seven were conducted rigorously, employing scientific methods for comparison and control. Research methods varied, including pre-test and post-test comparisons, as well as experiments with control and comparison groups. However, among the remaining 12 quasi-experimental studies, some only involved a few hours of gameplay followed by a questionnaire survey, lacking rigor. This indicates a lack of standardized procedures and steps in the current research field of DGBL, leading to experiments with varying levels of credibility.

### 4.4. Limitations and Future Works

In this study, only one database was selected for the search, and many other databases were not included, which may result in insufficient understanding of the application of DGBL among students of different regions and age groups, potentially leading to sample bias. Moreover, only English-language literature was selected, which may pose issues regarding the representativeness of the sample.

This study analyzed the application of digital game-based learning (DGBL) in STEM education from multiple disciplinary perspectives including education, psychology, and technology. Future research can strengthen interdisciplinary collaboration to better understand the impact of DGBL on learning. Although this study analyzed the application trend of DGBL, there are also cases where experimental designs were not rigorous enough. Therefore, future research should focus more on the rigor of empirical research, employing scientific methods and comparison with control groups to ensure the credibility of research results.

## References

- [1] Nippold, M. A., Duthie, I. K., & Larsen, J. (2005). Literacy as a leisure activity: Free-time preferences of older children and young adolescents. *LANGUAGE SPEECH AND HEARING SERVICES IN SCHOOLS*, 36 (2), 93 – 102. [https://doi.org/10.1044/0161-1461\(2005/009\)](https://doi.org/10.1044/0161-1461(2005/009)).
- [2] Anderson, C. A., & Dill, K. E. (2000). Video games and aggressive thoughts, feelings, and behavior in the laboratory and in life. *JOURNAL OF PERSONALITY AND SOCIAL PSYCHOLOGY*, 78 (4), 772 – 790. <https://doi.org/10.1037//0022-3514.78.4.772>.
- [3] Funk, J. B., Buchman, D. D., & Germann, J. N. (2000). Preference for violent electronic games, self-concept, and gender differences in young children. *AMERICAN JOURNAL OF ORTHOPSYCHIATRY*, 70 (2), 233 – 241. <https://doi.org/10.1037/h0087738>.
- [4] Kirchgessner, M., & Ketelhut, D. J. (2012). Video Games and Learning: Teaching and Participatory Culture in the Digital Age. *SCIENCE EDUCATION*, 96 (5), 963 – 965. <https://doi.org/10.1002/sce.21020>.
- [5] Behnamnia, N., Kamsin, A., & Ismail, M. A. B. (2020). The landscape of research on the use of digital game-based learning apps to nurture creativity among young children: A review. *THINKING SKILLS AND CREATIVITY*, 37, 100666. <https://doi.org/10.1016/j.tsc.2020.100666>.
- [6] Becker, K. (2017). Digital Game-Based Learning: Learning with Games (pp. 25 – 61). [https://doi.org/10.1007/978-3-319-12223-6\\_2](https://doi.org/10.1007/978-3-319-12223-6_2).
- [7] Plass, J. L., Homer, B. D., & Kinzer, C. K. (2015). Foundations of Game-Based Learning. *Educational Psychologist*, 50 (4), 258 – 283. <https://doi.org/10.1080/00461520.2015.1122533>.
- [8] Behnamnia, N., Kamsin, A., Ismail, M. A. B., & Hayati, A. (2020). The effective components of creativity in digital game-based learning among young children: A case study. *CHILDREN AND YOUTH SERVICES REVIEW*, 116, 105227. <https://doi.org/10.1016/j.childyouth.2020.105227>.
- [9] Aguilera, E., & Roock, R. de. (2022). Digital Game-Based Learning: Foundations, Applications, and Critical Issues. In *Oxford Research Encyclopedia of Education*. <https://doi.org/10.1093/acrefore/9780190264093.013.1438>.
- [10] Falloon, G., Hatzigianni, M., Bower, M., Forbes, A., & Stevenson, M. (2020). Understanding K-12 STEM Education: A Framework for Developing STEM Literacy. *Journal of Science Education and Technology*, 29 (3), 369 – 385. <https://doi.org/10.1007/s10956-020-09823-x>.

- [11] Holmlund, T. D., Lesseig, K., & Slavit, D. (2018). Making sense of “STEM education” in K-12 contexts. *International Journal of STEM Education*, 5 (1), 32. <https://doi.org/10.1186/s40594-018-0127-2>.
- [12] Hung, H.-T., Yang, J. C., Hwang, G.-J., Chu, H.-C., & Wang, C.-C. (2018). A scoping review of research on digital game-based language learning. *COMPUTERS & EDUCATION*, 126, 89 – 104. <https://doi.org/10.1016/j.compedu.2018.07.001>.
- [13] Hussein, M. H., Ow, S. H., Cheong, L. S., Thong, M.-K., & Ale Ebrahim, N. (2019). Effects of Digital Game-Based Learning on Elementary Science Learning: A Systematic Review. *IEEE Access*, 7, 62465 – 62478. <https://doi.org/10.1109/ACCESS.2019.2916324>.
- [14] Coman, C., Tiru, L. G., Mesesan-Schmitz, L., Stanciu, C., & Bularca, M. C. (2020). Online Teaching and Learning in Higher Education during the Coronavirus Pandemic: Students’ Perspective. *SUSTAINABILITY*, 12 (24), 10367. <https://doi.org/10.3390/su122410367>.
- [15] Zhang Anqi, Chen Guangya, Liu Yuxin, & Cheng Wei. (2018). A review of current research on computational thinking assessment (2013-2017). In S.-C. Kong, D. Andone, G. Biswas, T. Crick, H. U. Hoppe, T. Hsu, R. Huang, R. K. Li, C.-K. Looi, M. Milrad, J. Sheldon, J. Shih, K. Sin, M. Tissenbaum, & J. Vahrenhold (Eds.), *Proceedings of the International Conference on Computational Thinking Education 2018* (pp. 133 – 136).
- [16] Ortiz-Martinez, E., Santos-Jaen, J. M., & Marin-Hernandez, S. (2023). Kahoot! And its effect on financial accounting marks at the university. *EDUCATION AND INFORMATION TECHNOLOGIES*, 28 (10), 12671 – 12686. <https://doi.org/10.1007/s10639-023-11612-z>.
- [17] Chen, M.-Y., & Tang, J. T. (2023). Developing a digital game for excel skills learning in higher education-a comparative study analyzing differences in learning between digital games and textbook learning. *EDUCATION AND INFORMATION TECHNOLOGIES*, 28 (4), 4143 – 4172. <https://doi.org/10.1007/s10639-022-11335-7>.
- [18] Ninaus, M., Cortez, R., Hazin, I., Kiili, K., Wortha, S. M., Klein, E., Weiss, E. M., & Moeller, K. (2023). The added value of game elements: Better training performance but comparable learning gains. *ETR&D-EDUCATIONAL TECHNOLOGY RESEARCH AND DEVELOPMENT*, 71 (5), 1917 – 1939. <https://doi.org/10.1007/s11423-023-10263-8>.
- [19] Udeozor, C., Russo Abegão, F., & Glassey, J. (2022). An Evaluation of the Relationship Between Perceptions and Performance of Students in a Serious Game. *Journal of Educational Computing Research*, 60 (2), 322 – 351. <https://doi.org/10.1177/07356331211036989>.
- [20] Cook-Chennault, K., Alarcon, I. V., & Jacob, G. (2022). Usefulness of Digital Serious Games in Engineering for Diverse Undergraduate Students. *EDUCATION SCIENCES*, 12 (1), 27. <https://doi.org/10.3390/educsci12010027>.
- [21] Camacho-Sanchez, R., Rillo-Albert, A., & Lavega-Burgues, P. (2022). Gamified Digital Game-Based Learning as a Pedagogical Strategy: Student Academic Performance and Motivation. *APPLIED SCIENCES-BASEL*, 12 (21), 11214. <https://doi.org/10.3390/app122111214>.
- [22] Nuci, K. P., Tahir, R., Wang, A. I., & Imran, A. S. (2021). Game-Based Digital Quiz as a Tool for Improving Students’ Engagement and Learning in Online Lectures. *IEEE ACCESS*, 9, 91220 – 91234. <https://doi.org/10.1109/ACCESS.2021.3088583>.
- [23] Elkhamisy, F. A. A., & Wassef, R. M. (2021). Innovating pathology learning via Kahoot! game-based tool: A quantitative study of students’ perceptions and academic performance. *ALEXANDRIA JOURNAL OF MEDICINE*, 57(1), 215–223. <https://doi.org/10.1080/20905068.2021.1954413>.
- [24] Wells, J., & Kayyali, R. (2020). Development and evaluation of an educational game to support pharmacy students. *CURRENTS IN PHARMACY TEACHING AND LEARNING*, 12 (7), 786 – 803. <https://doi.org/10.1016/j.cptl.2020.02.006>.
- [25] Di Zou. (n.d.). Digital game-based learning of information literacy: Effects of gameplay modes on university students’ learning performance, motivation, self-efficacy and flow experiences | *Australasian Journal of Educational Technology*. Retrieved April 22, 2024, from <https://ajet.org.au/index.php/AJET/article/view/6682>.
- [26] Hernandez-Fernandez, A., Olmedo-Torre, N., & Pena, M. (2020). Is Classroom Gamification Opposed to Performance? *SUSTAINABILITY*, 12 (23), 9958. <https://doi.org/10.3390/su12239958>.
- [27] Campillo-Ferrer, J.-M., Miralles-Martínez, P., & Sánchez-Ibáñez, R. (2020). Gamification in Higher Education: Impact on Student Motivation and the Acquisition of Social and Civic Key Competencies. *Sustainability*, 12 (12), Article 12. <https://doi.org/10.3390/su12124822>.
- [28] Troiano, G. M., Snodgrass, S., Argimak, E., Robles, G., Smith, G., Cassidy, M., Tucker-Raymond, E., Puttick, G., & Hartevelt, C. (2019). Is My Game OK Dr. Scratch? Exploring Programming and Computational Thinking Development via Metrics in Student-Designed Serious Games for STEM. *Proceedings of the 18th ACM International Conference on Interaction Design and Children*, 208 – 219. <https://doi.org/10.1145/3311927.3323152>.
- [29] Gaeta, E., Eugenia Beltran-Jaunsaras, M., Cea, G., Spieler, B., Burton, A., Isabel Garcia-Betances, R., Fernanda Cabrera-Umpierrez, M., Brown, D., Boulton, H., & Arredondo Waldmeyer, M. T. (2019). Evaluation of the Create@School Game-Based Learning-Teaching Approach. *SENSORS*, 19 (15), 3251. <https://doi.org/10.3390/s19153251>.

- [30] Perini, S., Oliveira, M., Margoudi, M., & Taisch, M. (2018). The Use of Digital Game Based Learning in Manufacturing Education – A Case Study. In P. Zaphiris & A. Ioannou (Eds.), *Learning and Collaboration Technologies. Learning and Teaching* (pp. 185 – 199). Springer International Publishing. [https://doi.org/10.1007/978-3-319-91152-6\\_15](https://doi.org/10.1007/978-3-319-91152-6_15).
- [31] Hebert, C., Jenson, J., & Fong, K. (2018). Challenges with Measuring Learning through Digital Gameplay in K-12 Classrooms. *MEDIA AND COMMUNICATION*, 6 (2), 112 – 125. <https://doi.org/10.17645/mac.v6i2.1366>.
- [32] Pantoja, M. (2017). Designing a New Video Game App as an aid for Introduction to Programming classes that use C Programming Language. In J. D. I. Soria, M. C. V. Vela, E. DeLa Poza, & D. Blazquez (Eds.), *PROCEEDINGS OF THE HEAD'17 — 3RD INTERNATIONAL CONFERENCE ON HIGHER EDUCATION ADVANCES* (pp. 10 – 16). Univ Politecnica Valencia. <https://doi.org/10.4995/HEAD17.2017.4606>.
- [33] Barr, M. (2017). Video games can develop graduate skills in higher education students: A randomized trial. *Computers & Education*, 113, 86 – 97. <https://doi.org/10.1016/j.compedu.2017.05.016>.
- [34] Admiraal, W., Huizenga, J., Heemskerk, I., Kuiper, E., Volman, M., & ten Dam, G. (2014). Gender-inclusive game-based learning in secondary education. *International Journal of Inclusive Education*, 18 (11), 1208 – 1218. <https://doi.org/10.1080/13603116.2014.885592>.