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The Effectiveness of Gamification in Teaching and Learning Mathematics: A Systematic Literature Review

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Abstract

Gamification in teaching and learning mathematics is a current trend. This approach not only creates a fun learning environment, but also shows positive feedback from students. This systematic literature review examines the effectiveness of gamification integration in teaching and learning mathematics. Two major databases, Scopus and World of Science (WoS), were searched for articles published from 2018 to 2023. The searched data were analysed using the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) method, resulting in 22 articles that met the criteria. Before the review was conducted, criteria were set to facilitate the literature review process. The findings improvement and rating gamification in teaching and learning mathematics is effective in terms of engagement, motivation, learning personality, retention, performance, social skill development, cognitive skill improvement, and reducing mathematics anxiety. The results of the analysis of this study are expected to help researchers and educators in implementing appropriate gamification applications aligned with the objectives of the research and mathematics learning.

Keywords: Gamification, Application, Effectiveness Aspects, Mathematics, Systematic Literature.

Introduction

There are various perceptions among students regarding mathematics. Some view it as a challenging and beneficial subject, while others find it boring and difficult. Students' personal experiences and self-beliefs, as well as the teaching methods employed by teachers, are some of the factors that can influence students' perception of mathematics. In mathematics education, the approach used by teachers can significantly impact students' responses during learning sessions. Active learning can be fostered if teachers employ innovative and different approaches to mathematics instruction, departing from conventional methods (Taranto et al., 2021). This statement is supported by Qomario et al (2020), who stated that innovative teaching approaches can enhance students' motivation and academic achievements.

The current development of technology enables teachers to be more innovative in designing engaging learning methods that captivate students' interest. Gamification of learning is one

strategy that can be used to make mathematics education more appealing and encourage student involvement. Research conducted by Oliveira et al (2020) has shown that gamification in education can make teaching activities more interesting, enhance motivation, and increase student engagement and attention.

Gamification is the process of integrating components of game design into situations that are not games, like education (Dustman et al., 2021). Based on past studies, it has been shown that games are widely liked and enjoyed, indirectly making them a popular choice among students. The integration of gamification in mathematics education has gained attention as a potentially effective tool to enhance the effectiveness of learning. As a result, gamification of mathematics has become an approach to transform conventional learning into digital games that can be accessed regardless of time and place. This approach aims to improve students' learning experiences, making it more engaging and interactive.

The teacher has limited time to help students maintain their mathematical skills. In this case, the teacher can use an alternative approach, such as gamification. According to Krause et al (2015), gamification can improve students' knowledge retention by 25%, and the addition of game elements can increase this to 50%. By integrating game elements into the learning process Jung et al (2021), gamification can motivate students, relax their minds, and reinforce their habits. The main advantage of integrating gamification into mathematics education is that it instils curiosity among students. This, in turn leads to a greater interest in mathematics and encourages students to be active learners. Additionally, gamification promotes social development Dash et al (2022) as students engage in collaborative and competitive games. Moreover, gamification provides a way to achieve educational objectives by presenting mathematical concepts interactively and in an enjoyable way.

Combining elements of games such as challenges, stages, and rewards into mathematics education can motivate students to improve their math skills. The potential for gamification in mathematics education may enhance students' problem-solving skills (Abu-Hammad and Hamtini, 2023). Games also require players to think critically, devise strategies, and apply mathematical concepts to progress or succeed. Gamification is believed to assist students in becoming more proficient in solving mathematical problems and actively engaging in gameplay (Marín-Díaz et al., 2020). Moreover, gamification also helps to improve students' cognitive skills; through gamification, students are required to think logically, make decisions, and analyse information to advance in the game (An, 2021). As a result, they develop critical thinking skills and become better problem solvers.

Therefore, the integration of gamification in teaching and learning mathematics can address the diversity of students' learning styles. By providing interactive and visually appealing games, gamification caters to the needs of visual, auditory, and kinaesthetic’ learners (Lopez-Belmonte et al., 2020). Additionally, gamification in mathematics education can help reduce mathematics anxiety among students (Marín-Díaz et al., 2020). According to Mehmet and Hulya (2021), mathematics anxiety can hinder students' learning and performance in mathematics: by combining game elements and creating a more relaxed and enjoyable learning environment, gamification can help alleviate math anxiety.

Research Questions

The purpose of this systematic literature review is to examine the effectiveness of integrating gamification into mathematics education. The research questions in this systematic literature review are as follows

1. What gamification applications are used in teaching and learning mathematics?

2. What are the aspects of the effectiveness of gamification in teaching and learning mathematics?

Methodology

Eligibility Criteria

In this systematic literature review, the research criteria included published in the form of scientific journal articles. According to Cals and Kotz (2013), the latest reference, can assist in ensuring that the conducted studies are relevant and up-to-date, enhancing their credibility and impact. Therefore, the researcher chooses articles published between the years 2018 and 2023. Additionally, the selected articles must be published in the English language. Furthermore, the researcher assessed and identified articles that align with the objectives and research questions by evaluating their titles, abstracts, keywords, and overall content. Through this process, only 22 articles out of 66 were selected for the implementation of the systematic literature review.

Data Sources and Retrieval

To ensure the relevance and reliability of the articles referenced in this systematic literature review, the researcher utilised two well-known databases, namely Scopus and WoS (Web of Science). According to Pranckutė (2021), these are suitable as data sources because they are currently the most comprehensive and influential bibliographic databases. Additionally, to obtain articles that are not openly accessible or unavailable, the researcher used the ResearchGate website and sought assistance from the librarians at the Tun Sri Lanang Library. The preferred search terms for this systematic literature review are integration, gamification, and mathematics education, and pedagogy. The search for synonymous or related terms is conducted to facilitate the search, and these terms were looked up on the Thesaurus.com website. The search terms are in the English language. The four search techniques utilised include Boolean Operators (AND, OR), phrase searching, and truncation. The initial search results can be seen in Table 1.

Table 1
Initial Search Results

Search terms	Database	Exemption Criteria	Findings
TITLE-ABS-KEY ((integrat* OR amalgamat* OR unif* OR merge*) AND ("gamification*" OR "game-based learning*") AND (math* OR "math* education" OR "math* pedagogy"))	SCOPUS	● Article ● Bidang Mathematics/Education Scientific Disciplines ● 2018-2023 ● English	207
TS= (integrat* OR amalgamat* OR unif* OR merge*) AND ("gamification*" OR "game-based learning*") AND (math* OR "math* education" OR "math* pedagogy")	WoS	● Article ● Bidang Education Educational Research /Education Scientific Disciplines/ Mathematics Interdisciplinary Applications /Mathematics /Mathematics Applied ● 2018-2023 ● English	265

Study Selection

Screening

The diagram of the screening process can be seen in Figure 1. A systematic literature review was conducted following the PRISMA guidelines, which help to ensure that the review is accurate, comprehensive, and easy to read (Page et al., 2021). The screening process was performed for all articles obtained from the Scopus and WoS databases. The studies in the literature review should include articles that match the requirements. To ensure these are suitable and relevant, they must have been published between 2018 and 2023 and in the form of journal articles. The selected articles must be empirical studies in English to standardise and facilitate the article analysis. The selected subject areas are Social Science, Mathematics, Education Educational Research, Education Scientific Disciplines, Mathematics Interdisciplinary Application, and Mathematics Applied. Next, the final screening process is conducted by examining titles, abstracts, and keywords that align and correspond with the objectives and research questions. A total 22 articles is included in this systematic literature review as study samples.

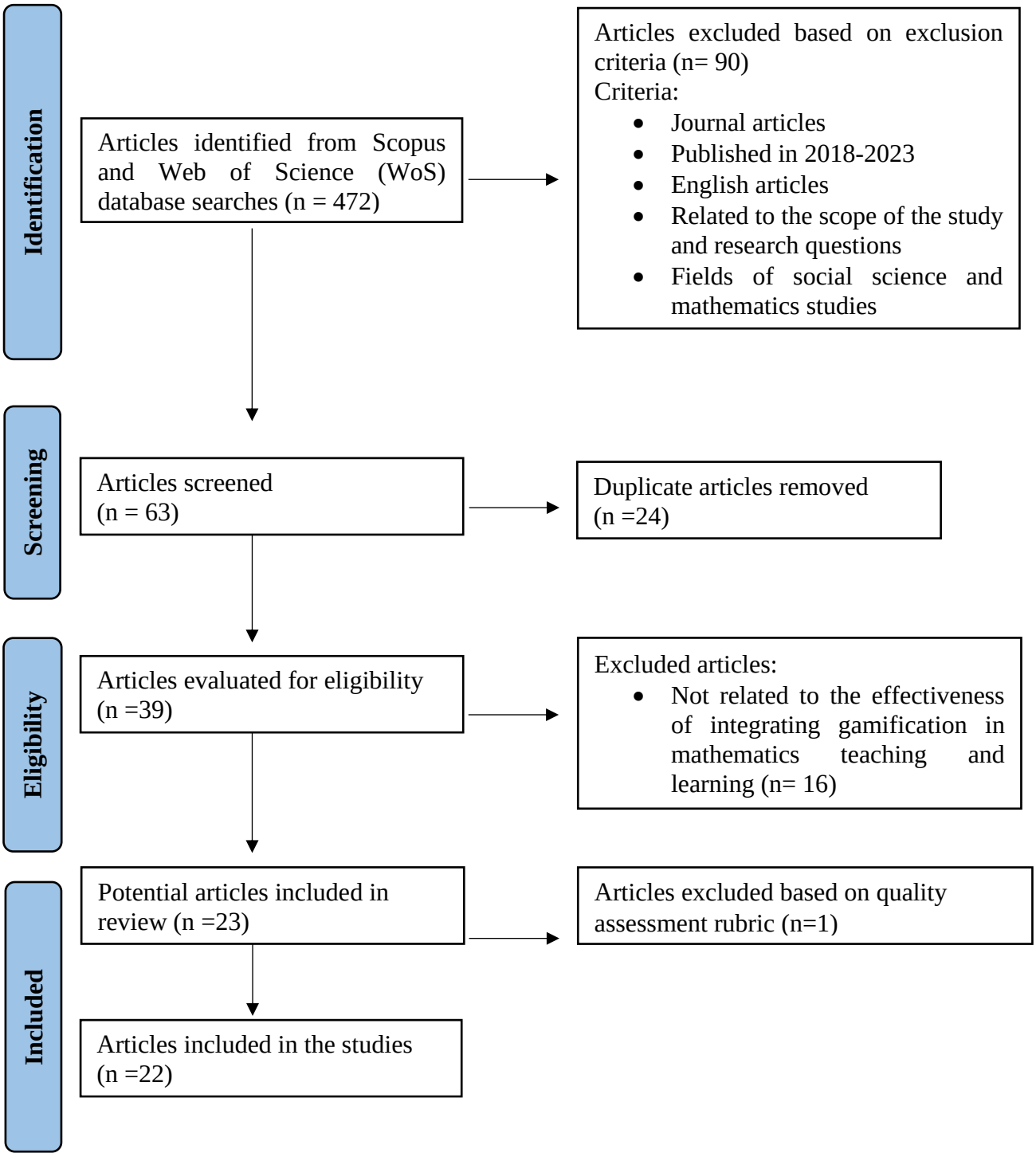

Figure 1 Diagram of the screening process using PRISMA (Page et al., 2021).

Evaluation

To evaluate the quality of each eligible article in the systematic literature review, a rubric examining seven criteria (Objective and Purpose, Literature Review, Theoretical Framework, Participants, Method, Results and Conclusion, and Significance) is used in the full-text content, and each of the seven criteria is measured to determine if it meets the quality reporting standards (Mullet, 2016), as shown in Table 2. Each of the seven sections is scored on a 4-point scale, where 1 = does not meet standards, 2 = nearly meets standards, 3 = meets standards, and 4 = exceeds standards. After this process, the researcher sums up the scores

for all seven criteria, with the possible score range for each article being between 7 and 22. Articles scoring equal to or less than 9 are excluded for not meeting the quality standard. Following the assessment of each article, 16 were excluded, and 22 were retained.
The protocol involved the researcher reading all 22 articles and analysing them. The reliability of the assessment on these articles was calculated using the Quality Assessment Rubric (Mullet, 2016).

Table 2
Quality assessment rubric

Criterion	4—exceeds standard	3—meets standard	2—nearly meets standard	1—does not meet standard
I Objective and Purposes	Clearly articulated problem, objective, rationale, research questions.	Adequately articulated.	Poorly articulated.	Incomplete.
II Review of literature	Critically examines state of the field. Clearly situates the topic within the broader field. Makes compelling connections to past work. Discusses and resolves ambiguities in definitions. Synthesises and evaluates ideas; offers new perspectives.	Discusses what has and has not been done. Situates topic within the broader field. Makes connections to past work. Defines key vocabulary. Synthesises and evaluates ideas.	Minimally discusses what has and has not been done. Vaguely discusses broader field. Makes few connections to past work. Lacks synthesis across literature. Minimal evaluation of ideas.	Fails to discuss what has and has not been done. Topic not situated within broader literature. No connections to past work.
III Theoretical or conceptual frameworks	Clearly articulated and described in detail. Frameworks align with study purposes.	Articulated; aligns with study purposes.	Implied or described in vague terms, or fails to align with purposes.	Absent.
IV Participants	Detailed, contextual description of population, sample and sampling procedures.	Detailed description of population, sample and procedures.	Basic description of sample and procedures.	Incomplete.
V Methods	Instruments and their administration	Instruments and their administration	Instruments described. Incomplete	Incomplete.

	described in detail. Evidence for validity and reliability. Documented best research practices. Potential bias considered.	described. Evidence for validity or reliability. Some evidence of best research practices. Potential bias considered.	evidence of validity or reliability. Questionable research practices.	
VI Results and conclusions	Detailed results. Exceptional use of data displays. Discussion clearly connects findings to past work. Proposes future directions for research. Conclusions clearly address the problem or questions.	Complete results. Sufficient use of data displays. Discussion connects findings to past work. Conclusions address the problems or questions.	Basic results. Insufficient use of data displays. Discussion fails to connect findings to past work. Conclusions summarise findings.	Incomplete.
VII Significance	Clearly and convincingly articulates scholarly and practical significance of the study.	Articulates scholarly and practical significance of the study.	Articulates scholarly or practical significance, but is neither clear nor convincing.	Not articulated.

Results

Table 3 shows the overall selected research based on the author's name, publication year, article title, research approach, and gamification application. Out of 22 analysed articles, 17 articles implemented gamification in digital game applications, while only three articles applied gamification in non-digital game settings. Additionally, two articles focused on the analysis and perspectives of teachers regarding the integration of gamification in teaching and learning mathematics. Each analysed article employed different game-based approaches, some focusing on specific mathematical topics, while others did not elaborate on the games used, instead concentrating on assessing the effectiveness of gamification integration.

Table 3
Applied gamification games

No.	Author(s) (year)	Title	Research methods	Gamification Application
1	Deng L. et al.(2020)	Digital game-based learning in a Shanghai primary-school mathematics class: A case study	Qualitative	Wuzzit Trouble
2	Hershkovitz, A., Tabach, M., and Cohen, A. (2022)	Online Activity and Achievements in Elementary School Mathematics: A Large-Scale Exploration	Quantitative	Applet
3	Hwa S.P. (2018)	Pedagogical change in mathematics learning: Harnessing the power of digital game-based learning	Quantitative	DigiGEms
4	Hung C.-Y., Sun J.C.-Y., and Liu J.-Y. (2019)	Effects of flipped classrooms integrated with MOOCs and game-based learning on the learning motivation and outcomes of students from different backgrounds	Quantitative	Capture the Flag-style game
5	Yang K.H., and Chen H.H. (2021)	What increases learning retention: employing the prediction-observation-explanation learning strategy in digital game-based learning	Quantitative	POE-integrated Digital Game-based Learning
6	Denham, A.R. (2019)	Using the PCaRD digital game-based learning model of instruction in the middle school mathematics classroom: A case study	Qualitative	Model PCaRD: Ration Rumble and DragonBoz Algebra 5+
7	Hossein-Mohand, H. et al. (2021)	Analysis of the use and integration of the flipped learning model, project-based learning, and gamification methodologies by secondary school mathematics teachers	Quantitative	-
8	Chen, M.F. et al. (2023)	Design and evaluation of a remote synchronous gamified mathematics teaching activity that integrates multi-representational scaffolding	Mixed	Multi-Representational Scaffolding: Google Jamboard

		and a mind tool for gamified learning		
9	Zhang, L. et al. (2020)	Supporting primary students' learning of fraction conceptual knowledge through digital games	Quantitative	Tablet-Based Fraction Games: Motion Math and Slice Fractions
10	Denham, A.R. (2018)	Using a digital game as an advance organizer	Quantitative	Algebra DragonBox
11	Ke, F. (2019)	Mathematical problem solving and learning in an architecture-themed epistemic game	Mixed	E-Rebuild
12	Nasir, S. M. M et al.(2023)	Game-Based Learning Kit Method in Isometric Transformations: Usability and Effects on Students' Achievement and Motivation	Quantitative	KitTI Method
13	Jarrah, A.M. et al. (2022)	Assessing the impact of digital games-based learning on students' performance in learning fractions using (ABACUS) software application	Quantitative	ABACUS
14	Hamden Hamid, S., Zulkiply, N., & Mohamad, F. S. (2022)	The Effects of Non-Digital Game-Based Learning and Cognitive Level of Questions on Isometric Transformations	Quantitative	Board, Card and Dice Game Called Transformation Checkers (TC)
15	Bouzid, T. et al. (2021)	Enhancing math-class experience throughout digital game-based learning, the case of Moroccan elementary public schools	Mixed	Edutainment Games
16	Lanuza, M.H. et al. (2020)	A gamification technique through the method of a lesson study in teaching probability	Qualitative	Rock, Paper, and Scissors; Game of Chances and Probability Themed Park.
17	Lanuza, M.H. (2020)	Integrative gamification technique in teaching specialization courses in mathematics	Quantitative	Non-Virtual Filipino Modified Games
18	Hernandez-Nieto, C., and Martinez, P.S. (2019)	Integration of gamification elements in the generation of visual representation of a mathematical function using	Qualitative	The Fish Game

		digital technology: A case study		
19	Jagust, T., Boticki, I., and So, H.J. (2018)	Examining competitive, collaborative and adaptive gamification in young learners' math learning	Quantitative	The Math Widget
20	Mahmud, M. S., & Law, M. L. (2022)	Mathematics Teachers' Perceptions on the Implementation of the Quizizz Application	Quantitative	Quizizz
21	Chen, P.-Z., Chang, T.-C., and Wu, C.-L. (2022)	Class of Oz: role-play gamification integrated into classroom management motivates elementary students to learn	Mixed	Class of Oz
22	Kesicioğlu, O.S. (2021)	Opinions of pre-service pre-school teachers on the use of mathematics activities	Qualitative	-

Table 4 shows the overall selected study based on the author's name, year of publication, article title, and aspects (A: Involvement, B: Motivation, C: Learning Retention, D: Performance, E: Learning Personality, F: Social Skills, G: Cognitive Skills, and H: Reducing Math Anxiety).

Table 4
Aspects of Gamification Effectiveness

No.	Author(s) (year)	Title	Aspects							
			A	**B**	**C**	**D**	**E**	**F**	**G**	**H**
1	Deng L. et al.(2020)	Digital game-based learning in a Shanghai primary-school mathematics class: A case study	/	/	/		/	/	/	
2	Hershkovitz, A., Tabach, M., and Cohen, A. (2022)	Online Activity and Achievements in Elementary School Mathematics: A Large-Scale Exploration	/							
3	Hwa S.P. (2018)	Pedagogical change in mathematics learning: Harnessing the power of digital game-based learning		/		/				
4	Hung C.-Y., Sun J.C.-Y., and Liu J.-Y. (2019)	Effects of flipped classrooms integrated with MOOCs and game-based learning on the learning motivation and outcomes of students from different backgrounds	/	/		/				
5	Yang K.H., and Chen H.H. (2021)	What increases learning retention: employing the prediction-observation-explanation learning strategy in digital game-based learning	/	/	/	/		/	/	

6	Denham, A.R. (2019)	Using the PCaRD digital game-based learning model of instruction in the middle school mathematics classroom: A case study	/	/	/	/			
7	Hossein-Mohand, H. et al. (2021)	Analysis of the use and integration of the flipped learning model, project-based learning, and gamification methodologies by secondary school mathematics teachers	/	/	/	/	/		
8	Chen, M.F. et al. (2023)	Design and evaluation of a remote synchronous gamified mathematics teaching activity that integrates multi-representational scaffolding and a mind tool for gamified learning	/	/	/	/	/	/	/
9	Zhang, L. et al. (2020)	Supporting primary students' learning of fraction conceptual knowledge through digital games	/	/	/	/			
10	Denham, A.R. (2018)	Using a digital game as an advance organizer				/			
11	Ke, F. (2019)	Mathematical problem solving and learning in an architecture-themed epistemic game	/	/				/	
12	Nasir, S. M. M et al.(2023)	Game-Based Learning Kit Method in Isometric Transformations: Usability and Effects on Students' Achievement and Motivation	/	/		/			
13	Jarrah, A.M. et al. (2022)	Assessing the impact of digital games-based learning on students' performance in learning fractions using (ABACUS) software application	/	/	/	/	/		
14	Hamden Hamid, S., Zulkiply, N., & Mohamad, F. S. (2022)	The Effects of Non-Digital Game-Based Learning and Cognitive Level of Questions on Isometric Transformations	/	/	/	/	/	/	
15	Bouzid, T. et al. (2021)	Enhancing math-class experience throughout digital game-based learning, the case of Moroccan elementary public schools	/	/	/	/	/	/	/
16	Lanuza, M.H. et al. (2020)	A gamification technique through the method of a lesson study in teaching probability	/	/	/	/		/	
17	Lanuza, M.H. (2020)	Integrative gamification technique in teaching specialization courses in mathematics	/	/	/	/	/	/	/
18	Hernandez-Nieto, C., and Martinez, P.S. (2019)	Integration of gamification elements in the generation of visual representation of a mathematical function using digital technology: A case study	/	/	/	/	/	/	

19	Jagust, T., Boticki, I., and So, H.J. (2018)	Examining competitive, collaborative and adaptive gamification in young learners' math learning	/	/	/	/	/	/
20	Mahmud, M. S., & Law, M. L. (2022)	Mathematics Teachers' Perceptions on the Implementation of the Quizizz Application	/	/				
21	Chen, P.-Z., Chang, T.-C., and Wu, C.-L. (2022)	Class of Oz: role-play gamification integrated into classroom management motivates elementary students to learn		/		/		
22	Kesicioğlu, O.S. (2021)	Opinions of pre-service pre-school teachers on the use of mathematics activities	/	/		/		

Findings

What gamification applications are used in teaching and learning mathematics?

From the literature review conducted, 17 out of 22 analysed articles focused on gamification and digital games applied in Mathematics Education. The following are the gamification applications used: Wuzzit Trouble (Deng et al. 2020), Applet (Hershkovitz, Tabach, and Cohen, 2022), DigiGEms (Hwa, 2018), Capture the Flag-style game (Hung, Sun, and Liu, 2019), POE-integrated digital game-based learning (Yang and Chen, 2021), Model PCaRD: Ration Rumble and DragonBoz Algebra 5+ (Denham, 2019), Multi-Representational Scaffolding: Google Jamboard (Chen et al. 2023), Tablet-based fraction games (Motion Math and Slice Fractions) Zhang et al (2020), Algebra DragonBox Denham (2018), E-Rebuild Ke (2019), KitTI Method Nasir et al (2023), ABACUS Jarrah et al (2022), Edutainment games Bouzid et al (2021), The Fish Game Hernandez-Nieto and Martinez (2019), The Math Widget Jagust et al (2018), Quizizz Mahmud and Law (2022), and Class of Oz (Chen et al., 2022). Digital games are proven to be effective teaching tools in teaching and learning mathematics. Not only do they enhance aspects of fun and excitement in learning, but they also increase student motivation and improve conceptual understanding. As a result, students will enjoy classroom activities more and, at the same time, improve their mathematical problem-solving skills.

Three out of the 22 involved articles are about gamification and non-digital games, specifically a board, card, and dice game called Transformation Checkers (TC) Hamid et al (2022), Rock, Paper, and Scissors, a game of chance, and Probability Themed Park Lanuza et al (2020), and Non-Virtual Filipino Modified Games (Lanuza, 2020). Non-digital games play a significant role in mathematics education. They help improve concentration, foster collaboration, bring abstract concepts to life, and provide recovery from learning. The use of non-digital games in mathematics classrooms not only enhances students' understanding but also helps them develop social skills and creativity.

Other than that, two articles focused more on teachers' perspectives on the use of gamification in teaching and learning mathematics. In mathematics, the application of gamified digital games is seen as a potential teaching tool that can motivate, capture students' attention, and reinforce their understanding. Meanwhile, the implementation of non-digital gamified applications should be considered an effective learning strategy for delivering enjoyable and meaningful mathematical concepts to students.

What are the aspects of the effectiveness of gamification in teaching and learning mathematics?

Games and gamification can provide unique perspectives on students' learning. Some students demonstrate excellent performance when competing, while others prefer to

improve their scores from the previous day. Additionally, they have different learning approaches when solving problems. Through direct and indirect observation of students playing math games, we can understand and comprehend their behaviours and thought processes, how they go about the processes, and their strengths and struggles during gameplay.

Gamification is an effective approach to enhancing student engagement in learning mathematics. The application of gamification in mathematics can improve the learning experience and support students in staying engaged, motivated, and confident in their skills (Chen et al., 2023; Bouzid et al., 2021; Deng et al., 2020; Denham, 2019; Lanuza, 2020; Yang and Chen, 2021). If students previously felt bored and hesitant to participate in mathematics learning activities, incorporating gaming elements such as leader boards, points, badges, or skill levels that can be improved will challenge them and actively involve them in mathematical activities.

The use of gaming elements in mathematics education can enhance students' motivation. Students' intrinsic motivation and self-confidence in their capacity to learn and excel in mathematics can both be increased by gamification aspects. (Deng et al. 2020). Based on conducted studies, it has been found that gamification can increase students' learning motivation, especially for those with low to moderate self-confidence levels in mathematics. Furthermore, motivating tasks, challenges, competitions, rewards and performance improvements can increase students' motivation to learn mathematics (Bouzid et al., 2021; Jagust et al., 2018; Jarrah et al., 2022; Lanuza, 2020; Lanuza et al., 2020; Nasir et al., 2023; Yang and Chen, 2021).

By allowing students to select their own challenges and rewards, gamification also helps to personalise maths learning by progressing at their own pace and receiving immediate feedback (Bouzid et al., 2021; Hamid et al., 2022; Hernandez-Nieto and Martinez, 2019; Jarrah et al., 2022; Lanuza, 2020). This, in turn, can help meet the individual needs of each student and ensure they stay motivated.

Furthermore, gamification can also help enhance learning retention in mathematics by providing opportunities for students to practise and apply their existing knowledge in a fun and engaging manner. According to a study conducted by Bouzid et al (2021), gamification can improve learning retention by offering students chances for repetition and practise while engaging in game activities. Additionally, gamification can assist students in developing a deeper understanding of mathematical concepts. Through practical experience and frequent repetition, students can visualise abstract mathematical concepts and reinforce their understanding of them.

Gamification can improve students' math performance by offering useful teaching tools and making the learning process more interesting and engaging, especially for those who struggle with math (Denham, 2019; Jarrah et al., 2022). Students also have the opportunity to compete with themselves or their peers in a healthy and positive manner. They will be more focused on their goals and remain motivated when facing challenging activities. However, it is crucial to establish and design the implementation of gamification in mathematics education to make it effective. If gamification is solely implemented for students' amusement, the learning objectives will not be achieved.

In addition, the implementation of gamification through digital game-based learning can enhance interaction, communication, and collaboration among students. It also promotes the growth of social skills in math learning by giving students chances to cooperate, communicate, and participate in constructive gaming competitions (Bouzid et al., 2021; Chen et al., 2023;

Deng et al., 2020; Hamid et al., 2022; Hernandez-Nieto and Martinez, 2019; Jagust et al., 2018; Lanuza, 2020; Lanuza et al., 2020). Through competitive elements in gamification, students can collaborate in teams and foster healthy competition. Cooperation can stimulate discussions among students to solve mathematical problems together, while positive competition can encourage students to strive and improve their own achievements. These skills are crucial to hone not only in learning mathematics but also in other fields.

Furthermore, students' cognitive skills can be enhanced through gamification activities involving problem-solving, critical thinking, and decision-making Bouzid et al (2021); Hamden Hamid et al (2022); Yang and Chen (2021); and spatial ability (Chen et al., 2023; Ke 2019). Students have the opportunity to practise and improve their cognitive skills in a less stressful environment. Through gamification, students are capable of analysing and evaluating information, making logical connections, and drawing conclusions. Gamification can help students build confidence and reduce their anxiety about mathematics, thereby enabling them to develop cognitive skills more effectively and become more proficient in mathematics. Mathematics anxiety is not uncommon among students. In a study by Chen et al (2023), the use of gamification mechanisms was found to reduce students' anxiety during activities. As such, gamification approaches can serve as a tool in learning to alleviate mathematics anxiety by providing an enjoyable learning experience with less pressure (Lanuza, 2020). A comfortable learning environment enables students to focus better on solving mathematical problems with less stress.

However, it should be noted that the implementation of gamification in teaching and learning mathematics may vary depending on the implementation and learning objectives. Factors such as game design, proper integration with the learning material, and the selection of suitable game elements will influence the effectiveness of gamification in achieving the desired learning outcomes.

Discussion

Gamification applications used in teaching and learning mathematics

Analysis of 22 literature reviews indicates that the application of game elements in gamification of mathematics education can have a positive impact on students. The use of games, whether digital or non-digital, in teaching and learning mathematics can enhance students' understanding of math and their desire to learn. Game elements bring students closer to real-world situations, making it easier for them to grasp concepts and see the connections. This study finds that gamification in teaching and learning mathematics receives positive recognition and support. This suggests that a game-centered learning approach can be an effective method for improving students' understanding and performance in mathematics (Peng et al., 2020).

Integrating gamification into teaching and learning mathematics can be an innovative approach to enhancing student engagement and motivation in mathematics (Yiğ and Sezgin, 2021). This approach allows students to actively participate and interact with mathematical concepts, transforming passive learning experiences (Ratnasari et al., 2021). Gamification makes mathematics more easily understandable as it provides a positive learning experience and a fun environment for students. Students can learn mathematics better through gamified activities and strategies. For example, a gamification-based approach like Quizizz has been introduced to increase students' interest in solving percentage-related problems (Setiyani et al. 2020). Through this approach, students who are passive during conventional teaching and learning mathematics can become more active and motivated to participate. Gamification

can also help students tackle various mathematical problems, which is particularly crucial in mathematics subjects, especially for those struggling with complex mathematical concepts and formulas.

The gamification approach provides students with opportunities to learn and apply mathematical skills in a fun and interactive way through games (Attard and Holmes, 2020). Gamification can stimulate problem-solving skills and critical thinking in students when they face challenges and puzzles in mathematical games. It allows students to apply mathematical concepts practically and contextually, bridging the gap between mathematical theory and the real world (Abidin et al., 2019). Besides its impact on students, gamification also benefits teachers by providing them with teaching tools to enhance student engagement and encourage active learning. Teachers can use gamified platforms to make learning interactive with quizzes and activities that capture students' attention and foster their involvement. These platforms can also provide teachers with information to monitor students' progress, allowing them to identify weaknesses and devise appropriate strategies based on students' learning styles.

The aspects of the effectiveness of gamification in teaching and learning mathematics

The analysis of this literature review indicates that the key aspects of gamification's effectiveness in teaching and learning mathematics are increased engagement, motivation, and achievement. By incorporating game elements and challenges, gamification makes the learning environment more enjoyable and less stressful. It also helps improve students' cognitive skills in solving mathematical problems and reduces math anxiety. Additionally, opportunities for collaboration with peers and receiving immediate feedback enhance the social interaction and social skills of students. These findings suggest that the implementation of gamification in mathematics education can be an effective teaching aid to enhance student learning, motivation and achievement.

The impact of integrating gamification into mathematics teaching and learning has been widely recognised. By enhancing students' motivation and engagement in mathematics, gamification can improve their academic achievement. Additionally, gamification has been found to enhance students' self-directed learning and mathematical skills (Rincon-Flores et al. 2018). This not only increases motivation and engagement but also allows for different personalised learning experiences. Furthermore, gamification also assists students in developing crucial abilities like problem-solving, critical thinking and decision-making. Moreover, incorporating gamification into mathematics instruction helps students understand the relevance and importance of mathematical concepts in real-life situations. This contextualisation of mathematics assists students in comprehending the goals and practical applications of mathematical skills, making their learning more meaningful (Sayekti et al., 2022).

Furthermore, the integration of gamification in teaching and learning mathematics aligns with the shift towards student-centred learning. It provides students with opportunities for self-directed learning, as gamification is a flexible and adaptable approach (Abidin et al., 2019). This can encourage a more student-centred approach that fosters collaboration and cooperation among students. Additionally, an effective implementation of this integration can foster the growth of critical 21st-century competencies including digital literacy and problem-solving. Students can enhance their mathematical abilities by developing digital skills and becoming comfortable with using various software and technological resources. In

conclusion, integrating gamification into the teaching and learning mathematics can be highly effective in enhancing the overall educational experience.

Conclusion

Systematic literature reviews on the effectiveness of gamification in teaching and learning mathematics emphasize the significant impact on innovative approaches such as gamification in enhancing student engagement, motivation, and academic achievement. By providing a stimulating and engaging learning environment through game-based activities, gamification helps students in mathematics to understand key concepts, apply newly acquired skills, and make connections between theory and real-world applications. This approach also benefits teachers by providing tools for interactive teaching and monitoring student progress, enabling them to identify areas where students may need additional support. Gamification has the potential to be a valuable tool in enhancing the overall educational experience in mathematics by making learning more enjoyable, relevant, and effective.

Gamification in education aims to make a subject enjoyable. Educators can use this systematic review as a guide to utilise gamified applications that align with the learning objectives, thereby helping to improve math achievement. Understanding the effectiveness of different gamification elements can help teacher tailor their approaches to meet the diverse learning needs of students. Since these 22 findings were discovered across various studies covering different math topics, they can also contribute to future professional development and teacher initiatives aimed at enhancing teaching efficacy through the use of gamification in math. Teachers need training and professional development opportunities to effectively integrate gamification elements into their teaching practices. By equipping teachers with the necessary knowledge and skills, they can create engaging learning experiences that enhance student engagement and motivation in mathematics. If gamification in math education is effectively implemented, learning outcomes can meet the objectives of math education, and students will become more interested in learning mathematics.

The study results indicate that gamification should be implemented in the teaching and learning of mathematics at various educational levels. Teachers can search for and create suitable games aligned with the existing mathematics curriculum to enhance interaction and make mathematics teaching and learning more engaging. Although gamification offers numerous benefits in mathematics education, there are factors that need attention. If too many games are used, they may distract from the actual learning objectives (Caserman et al., 2020). Therefore, teachers need to use games wisely and ensure that learning objectives remain the primary focus. Overall, this systematic literature review provides a strong foundation for the use of gamification in mathematics teaching and learning activities. Teachers can make mathematics learning more enjoyable, interactive and effective by using appropriate gamification applications.

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