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Gamified Instruction in Mathematics: A Meta-Synthesis

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Abstract

Gamified instruction refers to utilizing game design elements for non-game activities and applying them in education. In this study, a meta-synthesis research design was utilized to synthesize findings on gamified instruction. Harzing's Publish or Perish software was used to collect articles on gamified instruction from the Google Scholar and Scopus databases that were published from 2015–2022. A review protocol in the form of inclusion and exclusion criteria was established to screen possible articles for meta-synthesis, and 32 out of 134 articles were selected as part of this systematic review. Preferred Reporting Items for the Systematic Review and a Meta-Analysis flow diagram were used to organize the extracted data. Braun and Clarke's protocol on thematic analysis was used to analyze the collected data from the included studies. Eleven themes emerged that were clustered into three meta-themes, consisting of positive experiences, negative experiences, and addressing these challenges. Students' experiences enabled them to learn mathematics engagingly without trying hard to learn, while enhancing and creating meaningful learning. It is recommended that teachers should test the effectiveness of gamified instruction to assess students' mathematical achievements.

Keywords: *Gamified instruction, mathematics, systematic review, meta-synthesis*

Introduction

Gamified instruction refers to utilizing game design elements for non-game activities and applying them in education (Nah et al., 2014). Several published papers have noted that it has become one of the most notable technological developments for human engagement (Majuri et al., 2018), that it can positively impact learning (Stott & Neustaedter, 2013), and that it increases attendance and participation (Barata et al., 2013 as cited in Dicheva et al., 2015). However, one published systematic review noted that gamified instruction also may have negative impacts (Toda et al., 2017). Several systematic reviews of gamified instruction have been conducted, yet they have not been focused on mathematics instruction alone. An effort to address this research gap was undertaken in the present study.

According to Ming (2020), Minecraft gamification can help low-achieving students understand probability concepts successfully. This is in line with other research findings which have indicated that gamification is useful. This finding is also supported by Zaharin et al. (2021), who showed that gamification is beneficial in teaching and learning since this method arouses student interest in learning, facilitates acquisition of soft skills, stimulates self-improvement, and improves academic performance. A study by Darnasta et al. (2020) indicated that when learning guide media are utilized, student concentration and focus improved, further aiding their academic learning. Furthermore, a gamified learning environment lessens monotony in the learning process because this new setting makes it more engaging and instructive, and encourages individuals to engage in class activities (Ariffin et al., 2022).

Additionally, by adapting gamification concepts to school mathematics, it is possible to show how the activation of cognitive and motivational structures and–in particular–how a probabilistic way of thinking is effectively developed during the process of learning complicated mathematical concepts (Dvoryatkina et al., 2021). In Lanuza's (2020) investigation, respondents generally were able to incorporate gamification techniques and gamification related topics into their repertoires; such matters included increasing academic performance, cooperative behavior, and familiarizing

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customized Filipino games. In another study, it was demonstrated that playing GeoGebra games increased students' drive to learn mathematics and prevented them from giving up too quickly (Lim & Leong, 2017).

The use of gamification in teaching helps teachers to observe students' mathematical comprehension, which in turn enables students to reach greater levels of cognitive function (Zabala-Vargas, 2021). Studies have shown that shifting from traditional learning to gamification of math education has been successful, with many advantages for both students and teachers (StudyPug, 2015). Deng et al. (2020) researched the effect of game-based learning in Shanghai, and found that digital gaming increased student interest and engagement in studying when played every day for six days. Ke (2008) discovered that elementary students' math achievement increased when computer games were employed, particularly when combined with a cooperative learning strategy. Electronic gaming applications help students learn math ideas, retain and apply rules, overcome topic challenges, manage individual disparities with classmates, and develop positive motivation through competition to increase their abilities (Babeer, 2021).

Although gamification has shown great potential as a means of education, it is not a universal remedy for every learning issue. Even those who advocate using games in the classroom recognize the challenges they might create (Sillaots, 2014). Xiao (2022) noted that when gamification is used in a class, the game's flexibility is limited, personalization is complex, and not everyone can be accommodated. According to a study conducted by Kimble (2020), just two of the 10 grade-level competencies were mastered by fourth-grade pupils utilizing gamification. The notion that students master more grade-level math abilities with the application of gamification was not supported by this evidence.

To grasp the idea of conducting gamified instruction in mathematics, a systematic review was conducted to answer the following questions:

1. What are the positive experiences of teachers and students in gamification?
2. What were teachers' and students' negative experiences or challenges in gamification?
3. How do teachers or students address their negative experiences?
4. What can be recommended to teachers before implementing gamified instruction?

Methodology

Research Design

Meta-synthesis is a technique for reinterpreting and altering previous qualitative data on gamified mathematics teaching (McClean & Shaw, 2005). The idea is to advance conceptual knowledge by developing an interpretation of an occurrence or process supported by the evidence. In this approach, qualitative findings from mixed-method studies and isolated findings from qualitative research studies on thematically related topics have been synthesized and presented as gamified instructions.

Search Strategy

Scholarly electronic databases were used to identify published research articles in English language journals related to gamified instruction in mathematics. Google Scholar and Scopus academic databases were utilized in selecting published articles: Studies relevant to gamified instruction in mathematics published from 2015–2022 were downloaded and synthesized. Publish or Perish software (Harzing, 2007) was used to select these published articles. Keywords used to select studies were: (a) gamified instruction, (b) mathematics instruction, and (c) qualitative study. These terms were purposively selected to extract data to aggregate information needed for meta-synthesis. A Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram was used to organize the extracted data.

Inclusion and Exclusion Criteria

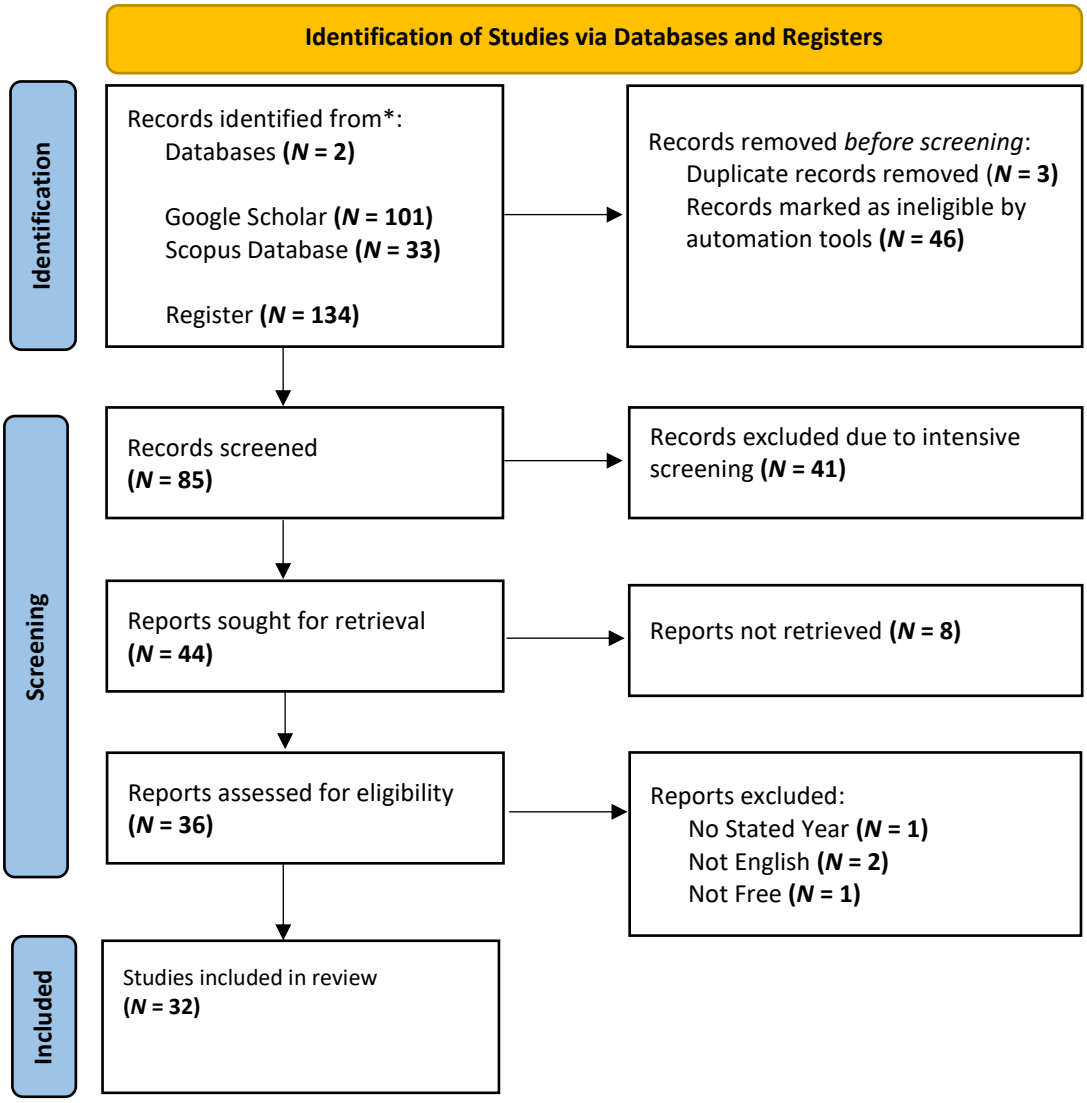
Studies included in this review were selected based on the following criteria: (a) gamified instruction, (b) mathematics instruction, (c) qualitative research output, (d) published articles, (e) peer-reviewed, (f) 2015–2022 studies, (g) written in the English language, and (h) cited at least once.

Results and Discussion

Search Results

Figure 1 shows the search result in identifying themes included in the meta-synthesis and organized using the PRISMA 2020 Flow Diagram.

Figure 1 *PRISMA Flow Diagram in the Inclusion of Studies*



Articles were collected from two academic databases: Google Scholar and Scopus. From the Google Scholar database, 101 studies were identified, while 33 studies came from the Scopus database, yielding a total of 134 studies collected. A total of 102 studies were removed due to the following reasons: duplication; ineligibility by using automation tool; intensive screening; not retrieved; no year stated; not English; and not free. Thirty-two (32) studies were included in the meta-synthesis after thoroughly checking the available relevant studies.

Included Studies

The definitive collection of 32 studies utilized various games in their instruction, is as indicated in Table 1. The authors were affiliated with institutes located in Asia (18 studies), Europe (10 studies), North America (2 studies), and South America (2 studies). From the studies selected, 11 themes and three meta-themes were identified. Table 1 below provides the overview and characterization of the final collection of studies included in the meta-synthesis.

Table 1 *Overview of the 32 Studies Included in the Meta-Synthesis*

No.	Authors	Year	Setting	Games
1	Udjaja et al.	2018	Indonesia	Game-Based Instruction
2	Lo & Hew	2020	Hong Kong	Game-Based Instruction
3	Gurjanow et al.	2019	Germany	MathCityMap
4	Su	2017	Taiwan	Adaptive learning system
5	Cunha et al.	2018	Brazil	Game-Based Instruction
6	Hosseind-Mohand et al.	2021	Spain	Moodle, etc.
7	Türkmen & Soybaş	2018	Turkey	EBA Games
8	Lameras & Moumoutzis	2015	UK	GamifyMaths
9	Stoyanova et al.	2017	Bulgaria	Kahoot
10	Putra & Yasin	2021	Indonesia	Game using the MDA Framework
11	Chu & Fowler	2020	Canada	Game-based formative feedback system
12	Sakai & Shiota	2016	Japan	Football
13	Malvasi et al.	2022	Italy	Chess
14	Saleh & Sulaiman	2019	Malaysia	Quizizz
15	Dvoryatkina et al.	2021	Russia	Game-Based Instruction
16	Lanuza	2020	Philippines	Filipino Game
17	Jablonka	2017	Germany	Surveillance Gamification
18	Karamert & Vardar	2021	Turkey	Progress Map
19	Lim & Leong	2017	Malaysia	Geogebra
20	Lantarón et al.	2018	Spain	Gamification and manipulative tools
21	Zaharin et al.	2021	Malaysia	Game-Based Instruction
22	Ariffin et al.	2022	Malaysia	Game-Based Instruction
23	Ming	2020	Malaysia	Minecraft Gamification
24	Darnanta, et al.	2020	Indonesia	Game-Based Instruction
25	Zsoldos-Marchis	2019	Romania	Gamification system
26	García-Hernández & González-Ramírez	2021	Spain	Discrete mathematics through gamification
27	Maulidya et al.	2022	Indonesia	Quizzis
28	Yung et al.	2020	Malaysia	1 Slash 100%
29	Ortiz et al.	2022	Peru	MathyFight

No.	Authors	Year	Setting	Games
30	Lai	2017	USA	Eyewire
31	Nebril et al	2020	Spain	Augmented Reality (Break-Out)
32	Vitabar et al.	2019	Uruguay	Teacher Training Program

Data Analysis

The fundamental or recurring topics in the gamified mathematics training were found using thematic data analysis. The results were condensed into a number of themes. Thematic analysis utilizing Clarke and Braune's (2013) procedure was chosen to examine the data. According to Windle et al. (2020), thematic analysis is a technique for locating, examining, and deciphering themes within qualitative data. The six steps of thematic analysis include familiarization, creation of preliminary codes, topic search, theme review, definition and naming of themes, and report creation.

Ninety-five codes were determined based on the significant findings of the studies that were thematically analyzed. These codes were clustered into three categories: four themes involved positive experiences, four themes dealt with negative experiences, and three themes addressed the challenges. The themes and meta-themes are discussed below.

Meta-theme 1: Positive Experiences in Gamified Instruction in Mathematics

Gamification as a teaching tool gives benefits and positive experiences to learners (Lai, 2016). It fosters and integrates students into a collaborative environment of teamwork, promotes learning on one's own initiative, encourages creative conjecture-making, fosters learning beyond the book, recognizes the strengths of the team, and aids in understanding how each individual fits into the whole. Students employ a variety of forms of learning media as learning guides, which can boost their focus and levels of concentration, which in turn helps them learn more efficiently in the classroom (Darnanta. et al., 2020). Students also reportedly attended more classes and participated more actively in problem-solving processes when gamification was used (Zsoldos-Marchis, 2015). Gamification techniques, in general, were well received by the students who were allowed to experience them (Lanuza, 2020).

Furthermore, the positive experiences of students and teachers were described in the utilization of gamified instruction in mathematics. Twenty-three out of 32 studies from Bulgaria, Canada, Germany, Hong Kong, Indonesia, Italy, Japan, Malaysia, Peru, the Philippines, Russia, Spain, Taiwan, and Turkey showed that students enjoyed positive experiences with gamified instruction. Four themes emerged from the students' positive experiences as shown below.

Theme 1: Interactive and Enjoyable Instruction

Gamified instruction provides interactive and fun instruction, which allows learning to be more productive, enjoyable, and engaging (Saleem et al., 2021). These features help students to learn mathematics interactively and the teacher to explain concepts, which also boosts mutual relationships among teachers and students in a fun and enjoyable way (Udjaja, 2018; Yung et al., 2020). Gamified mathematics instruction enhances the learning process, which motivates and helps students understand concepts better and attain higher performance levels while enjoying a non-serious learning process.

Theme 2: Better Cognitive Engagement

Gamification made the lessons in mathematics more interesting and exciting, promoting participation in in-class learning activities (Ng & Lo, 2022). Students were able to understand mathematical concepts, which affected their mathematics achievement (Ming, 2020; Karamert & Vardar, 2021). Activation of cognitive structures in the development of thinking in mastering complex

mathematical knowledge was evident on account of gamification (Dvoryatkina, 2021). Student performance improvement was positive and showed that they understood mathematical concepts.

Theme 3: Increased Students' Motivation

Using game-based learning strategies in the classroom can boost students' enthusiasm and interest in the subject (Sakai & Siota, 2016; Gurjanow et al., 2019; Nebril, 2020; Malvasi et al., 2022). Students' confidence levels may increase, allowing them to ask and answer questions more easily. Students are given the opportunity to participate in real-world investigations thanks to gamification, which helps them develop investigative abilities and encourages critical thinking and problem-solving. Students enjoy studying mathematics, even if the subject was unrelated to other things that interest them.

Theme 4: Teamwork and Collaboration

Gamification encourages a collaborative environment and teamwork, recognizing an individual's strengths in a team setting (Lai, 2017; Hossein-Mohand, 2021). Collaboration allows students to participate and share the knowledge they master (Sanjaya & Wijaya, 2007). Collaborative learning helps students develop higher-level thinking skills, which boosts their confidence and self-esteem. Team effort in gamified instruction maximizes the educational experience by demonstrating the application of the material while improving social and interpersonal skills.

Meta-theme 2: Challenges in the Utilization of Gamified Instruction in Mathematics

If gamified learning is not carried out with an effective method of instruction, students and teachers may be subjected to various unpleasant experiences (Zaharin et al., 2019). Lai (2017) mentioned the drawbacks of using gamified instruction in mathematics. According to him, gamification only generates a focus on gaining individual achievements rather than learning the subject, which leads to addiction and a lack of grasp of how the material is learned. Vitabar et al. (2019) enumerated several factors contributing to students and teachers negative experiences with gamification. These factors involved a lack of resources, time, feedback, and confidence. It would be easier for the teachers to read and understand student performances with effective technology. On the other hand, improper structuring of educational processes or insufficient competence of a majority of mathematics teachers to actually implement gamification techniques are issues that render gamification non-beneficial to students and teachers (Dvoryatkina et al., 2021). Another factor that has contributed to adverse student and teacher experiences with gamification is their lack of motivation. Students needing remediation sometimes lack confidence in their abilities, leading to little interest in mathematics and boredom with school (Sakai & Shiota, 2016). Lastly, there has been a lack of research into creating synergy between gaming and didactic technologies to facilitate the mastering of complicated mathematical knowledge. Effective technologies are needed to enhance student development and construction of a modern style of thinking (Dvoryatkina et al., 2021)

Under this heading, negative experiences were described that emerged during the utilization of gamified instruction in mathematics. The 17 studies considered were from Canada, Germany, Italy, Japan, Malaysia, Peru, the Philippines, Russia, Spain, Taiwan, Turkey, the United States, and Uruguay. Four themes emerged using gamification and negative effects on teachers and students.

Theme 5: Lack of Teacher Preparation

For educators tasked with gamifying instruction, there are specific requirements for in-game integration of knowledge. They must learn the procedures used in class (Hossein-Mohand et al. 2021), and students must understand how games may help them learn math (Malvasi et al., 2022). There needs to be more study on the symbiosis of gaming and didactic technologies in learning complicated mathematical concepts, and the necessity of looking for efficient technologies to determine how they impact student progress (Dvoryatkina et al. 2021). In gamification research, it may have taken longer to find statistically significant improvements in boosting grades given the practice of using students'

improved game-based feedback, rather than examining the whole gamified system (Lim & Leong, 2017; Chu & Fowler, 2020). The duration of the whole process affects the learning of mathematics. If games were taught to students more regularly, they might have a greater appreciation for their potential.

Theme 6: Unmotivated Teachers and Learners

Students may be introduced to learning mathematics using gamification by poorly motivated or less than enthusiastic teachers. Teachers may ask appropriate questions, but need more motivation on aspects of applicability. Remedial pupils may also lack the motivation to learn mathematics (Lim & Leong, 2017). Perceived drawbacks of gamification as a teaching tool are that its focus is on obtaining individual achievements rather than understanding the material and its applicability (Lai, 2016). Connecting arithmetic principles to real-world situations is a challenge in classroom instruction. It is challenging for professors to create pertinent questions for pupils, which is one reason that this problem arises (Sakai & Shiota, 2016). Questions raised by teachers need to be more clearly connected with real-world situations, and how the game may help to provide answers.

Theme 7: Insufficient Teacher Qualification

Teachers may feel uncomfortable because they are working in an unfamiliar situation. They need to become more accustomed to using games to teach math. Insufficient qualifications may be a problem for some mathematics teachers, interfering with their ability to suggest practical ways to implement gamification (Dvoryatkina et al., 2021). A lack of resources, time, feedback, or confidence in the teacher also can contribute to poor performance in gamification (Vitabar et al., 2019). Solving mathematical problems necessitates knowledge, skills, creativity, and resilience (Lameras & Moumoutzis, 2015). It is evident that before gamification is used in a classroom, teacher qualifications must be considered. They must receive sufficient training to become accustomed to using the games properly.

Theme 8: Lack of Resources and Feedback

Due to varied working methods, a lack of materials, and other factors, teachers need help in implementing gamification in the classroom; if this is not done, it can lead to misunderstanding or failure (Lanuza, 2020). One issue identified is that teachers cannot easily monitor or interpret student performance without the aid of specialized equipment or software (Jablonka, 2017). A lack of teacher feedback, time, and resources provided to students may also pose problems (Vitabar et al., 2019); in the process of teaching and learning, resources and feedback on the use of gamification are essential.

Meta-Theme 3: Addressing the Challenges on the Utilization of Gamified Instruction in Mathematics

Incorporating gamification into math instruction and learning presents several challenges. Some of the most pressing concerns have been discussed above. In order to address these challenges, there is a need to establish pedagogical links between the subject matter and technological advancements employing "instrumental genesis." Mathematics teachers are encouraged to participate in ongoing training and education on the appropriate applications of mathematics-specific tools and resources. There is also a need to improve the quality of education and spark students' interest in mathematics by conducting more research on how gamification and serious games may help students learn (Malvasi et al., 2022). To spark students' interest, it is essential to consider their views regarding the use of gamification–particularly regarding acceptability, interest, and soft skills. There is a need to provide students with opportunities to compete, explore, and excel in the classroom setting and make the educational experience more pleasurable. Giving students more extended interventions, perhaps over a five-month semester, would be beneficial. Ensuring a more positive experience could also be provided by considering how game-based formative feedback could be provided to improve student's learning in all of their classes (Chu & Fowler, 2020). Lastly, it would be advisable to conduct future studies on whether using game assessment activities in the classroom improves academic

performance and engagement with discrete mathematics learning more than when traditional evaluation is used (Garcia-Hernandez & Gonzalez-Ramirez, 2021).

Under this meta-theme heading, opportunity is taken to describe how issues identified in the studies were dealt with. Out of the 44 studies, 22 are from Canada, Germany, Italy, Japan, Malaysia, Peru, the Philippines, Russia, Spain, Taiwan, Turkey, the United States, and Uruguay. Three themes were identified in this group, namely, gamification as an intervention, gamification as a pedagogical tool, and the importance of student feedback.

Theme 9: Gamification as an Intervention

Gamification is potentially able to give math professors more energy or effective tools. It can help them encourage pupils to study and be passionate about learning mathematics. This approach is designed to use the advantages of game-based learning settings. Gamification of math classes for kids emphasizes the connection between math education and its uses in society (Shiota & Sakai, 2016; Chu & Fowler, 2020). The creation of systems for planning and selecting information is a vital undertaking to establish a sound program of scientific and methodological assistance for instructors (Dvoryatkina et al., 2021). The first-grade math teacher especially needs to be trained and kept up-to-date on how to use resources and technologies for math education. This includes making pedagogical connections between different subjects (Hossein-Mohand et al., 2021) and examining how to give students constructive feedback through games (Chu & Fowler, 2020). An investigative structural model serves as the foundation for the context of a learning style (Su, 2019); it is an effective method for motivating kids to study arithmetic.

Theme 10: Gamification as Pedagogy

Gamification has been shown in some studies to lead to good outcomes or at least to be an adequate methodology for use in math education. Since teachers are fundamental to the learning process, they must be trained and updated on the use of tools and resources prior to using gamification to teach mathematics (Hossein-Mohand, 2021). The guidelines for using gamification techniques need to be redefined. The responses to using gamification techniques in mathematics education differ significantly depending on the demographic profile of learners (gender, age, educational experience). This means that different approaches need to be used with various groups (Lanuza, 2020). It has been proposed that gamification could be introduced as an integral part of other learning approaches to promote learning, enhance motivation and participation, and establish connections between mathematics and other disciplines (Lameras & Moumoutzis, 2015). Furthermore, when gamification is introduced as part of a teacher training course, it can motivate teachers and give them confidence. Gamification can also simplify assessment and provide opportunities for adapting content (Vitabar et al., 2019). It is a suitable method to practice teaching math in the modern world to hold students' interest and encourage them to appreciate math through enjoyable learning.

Theme 11: Importance of Students' Feedback

Gamification is a powerful and sometimes beneficial method that can be applied when the motivation to learn math is at risk. Remedial students introduced to these learning device have often responded enthusiastically to them and were not inclined to give up, which resulted in a satisfactory and improved learning experience (Lim & Leong, 2017). The use of computer games to teach mathematics is a form of seduction to control the child player's emotions so as to regulate their involvement in an allegedly unpleasant mathematical activity (Jablonka, 2017). In order to develop mechanisms for organizing and determining the content and methodological support, teachers should be assisted so as to become confident and efficient as quickly as possible, because this means essential improvement in their skills (Vitabar et al., 2019). An analysis of students' learning through feedback must be conducted to reassure teachers that the gamification method is more effective in delivering results in contrast to classical teaching methods (Chu & Fowler, 2020; Ming, 2020).

Conclusion and Recommendation

Implementing gamified instruction in teaching mathematics has multifaceted effects on students. The positive experiences of students enable them to learn mathematics engagingly without actually trying hard to learn, which enhances and creates meaningful learning experiences for them. Teachers may be challenged in the task of implementing gamified instruction; however, various strategies can be adopted to address these challenges. At the completion of a learning session, it is recommended that teachers should test the effectiveness of their gamified instructions to assess students' mathematics achievements. As a consequence of the challenges and difficulties identified, the training of teachers in gamification techniques is essential to optimize the impact of these approaches on the learning of mathematics.

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