

The Use of Gamification in Teaching and Learning Mathematics: A Meta-Synthesis

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Abstract: The Use of Gamification in Teaching and Learning Mathematics: A Meta-Synthesis.

Objectives: This study aimed to explore and synthesize the use of gamification in teaching and learning mathematics. **Methods:** A meta-synthesis was used in this systematic review to focus on the use of gamification in teaching and learning mathematics. The final 13 articles in this study were developed using the Critical Appraisal Skills Programme (CASP) checklist and structured using the PRISMA 2020 flow diagram. **Findings:** Four themes emerged from the thematic analysis, namely: time element, positive attitude, collaboration and engagement, and feedback and assessment. A meta-theme emerged as Futures Thinking: Gamifying Mathematics Education for Engaged Learning. **Conclusion:** The findings provide significant insights for educators and curriculum designers looking for novel techniques to improve mathematics teaching and learning. It should be noted that the effectiveness of gamification in mathematics teaching and learning is dependent on the careful design and implementation of the gamified features.

Keywords: gamification, meta-synthesis, systematic review, teaching mathematics.

Abstrak: Penggunaan Gamifikasi dalam Pengajaran dan Pembelajaran Matematika: Sebuah Meta-Sintesis. Tujuan: Penelitian ini bertujuan untuk mengeksplorasi dan mensintesis penggunaan gamifikasi dalam pengajaran dan pembelajaran matematika. **Metode:** Meta-sintesis digunakan dalam tinjauan sistematis ini untuk fokus pada penggunaan gamifikasi dalam pengajaran dan pembelajaran matematika. 13 artikel terakhir dalam penelitian ini dikembangkan menggunakan checklist Critical Appraisal Skills Program (CASP) dan disusun menggunakan diagram alir PRISMA 2020. **Temuan:** Empat tema muncul dari analisis tematik, yaitu: elemen waktu, sikap positif, kolaborasi dan keterlibatan, serta umpan balik dan penilaian. Sebuah meta-tema muncul sebagai Pemikiran Masa Depan: Gamifying Mathematics Education for Engaged Learning. **Kesimpulan:** Temuan ini memberikan wawasan yang signifikan bagi para pendidik dan perancang kurikulum yang mencari teknik baru untuk meningkatkan pengajaran dan pembelajaran matematika. Perlu dicatat bahwa efektivitas gamifikasi dalam pengajaran dan pembelajaran matematika bergantung pada desain dan implementasi fitur gamifikasi yang cermat.

Kata kunci: gamifikasi, meta-sintesis, review sistematis, pengajaran matematika.

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■ INTRODUCTION

Gamification has as its overarching objective the creation of educational settings that combine learning with the fun and joy provided by a well-designed game (Antonopoulou, et. al, 2022). Gamification is the use of game components outside the game to raise the student's motivation, performance and lecture involvement to the highest level. Gamification is based on motivation and it aims to internalize the external motivation provided by game components (Türkmen, 2019). Gamification has emerged as one of the most significant technological developments for human engagement. It is not surprising, then, that gamification has been addressed and implemented specifically in the realm of education, where supporting and retaining engagement is a constant challenge (Majuri et. al, 2018). Researchers in several countries have demonstrated the educational contributions of games and game-like formations, particularly for primary and secondary school students (Karamert & Vardar, 2021; Asan & Çeliktürk-Sezgin, 2020; Eltem & Berber, 2020; Uđurel & Moralý, 2008; Yařar, 2018). Several studies on the effects of gamification elements on primary and secondary students' motivation and learning discovered that students demonstrated increased motivation and engagement as well as improved knowledge at both the primary and secondary levels (Papp, 2017; Chen 2019; Hasan et. al, 2019; Smith, 2017). Furthermore, according to a Deakin University study, when math was gamified, students developed a more positive attitude toward it. Additionally, students were more engaged and motivated because the gamification process alleviated the monotony of practicing question after question.

In the research of Lister (2015), games have been shown to be effective in promoting learning and are more motivational for students than non-gaming teaching methods. The gamification of

education can enhance levels of students' engagement similar to what games can do, to improve their particular skills and optimize their learning (Smiderle et. Al, 2020). The use of games will encourage students actively participate in the learning process which promote adverse impact to their experiential learning in the classroom. This is also evident in the study of Martí-Parreño et. al (2016) that the use of games or games elements in the classroom can also enhance the classroom atmosphere.

Gamification is being used in business to engage staff in attaining corporate goals and to incentivize customers to use their products. Gamification has lately emerged as an effective educational tool in K-12 education, as well as elite colleges and universities (Brull & Finlayson, 2016). As technology evolves, so does the desire for fresh teaching materials. As a result, the Department of Education in the Philippines recommends that teachers provide instructional materials with the goal of developing gamified instructional materials in genetics to aid in the teaching and learning process of grade 12 STEM students (Funa & Ricafort, 2019).

Learners in the twenty-first century are known to be technologically savvy and to be involved in a variety of multi-media platforms. As a result, technology has become ingrained in human life. According to Funa and Ricafort (2019), technology has become a necessity, and integrating it into their daily school activities is critical. The advancement of technology has increased the demand for innovative instructional materials. As technology advances, new types of games are being developed to pique students' interest and motivation. Aside from using technology, some offline applications for teaching mathematics exist. This could also refer to math teaching strategies that include games to make learning more enjoyable. As a result, a growing number of contemporary experts are looking into the educational implications of its use. Nobody

denies that video games are educational. They are attracting educators, academics, and game designers from around the world. (Antonopoulou, et. al, 2022; Clark et.al, 2016).

Mathematics has been recognized as a significant factor in development that contributes to many fields and emphasizes in the national agenda (Angco, 2021). Learning mathematics is not just about calculations, memorizing formulas, or theories; even mathematical learning involves research, testing, and problem-solving (Angco, 2023; Patena & Dinglasan, 2013). It has also been said to be difficult and of little interest to certain people especially students (Ariffin et.al, 2022). In this case, teacher knowledge influences student performance and achievement, becoming one of the most influential factors in student learning. As a result, teachers are expected to be effective educators. The teacher must not only be an expert on the subject matter, but also be able to explain it in a variety of ways (Angco, 2023; Kutub & Wijayanti, 2019). Thus, the use of gamification is a good learning approach in mathematics.

Despite the potential benefits of gamification in math education, there has been little research into how to effectively implement gamification in a math classroom. While studies on the impact of gamification on student engagement and motivation have been conducted, there has been little research on the long-term effects of gamification on student learning outcomes. More research is needed to better understand the best practices for incorporating gamification in math classrooms, as well as the impact of gamification on student math achievement.

Existing reviews on gamification literature have indicated that education and learning are the most common contexts for empirical research of gamification (Majuri, et.al, 2018; Koivisto & Hamari, 2017; Hamari, Koivisto & Sarsa, 2014; Seaborn & Fels, 2015). Though many qualitative studies were conducted, no systematic synthesis

was conducted in summarizing the experiences of the students. The dearth on the meta-synthesis aspect has driven the researcher to conduct this study.

Hence, this study aimed to explore and synthesize the use of gamification in teaching and learning mathematics employing a meta-synthesis method using available literatures which conducted qualitative studies across the different journals.

■ METHODS

Research design

This study employed a meta-synthesis research strategy that aims to interpretatively synthesize findings from many connected studies (Walsh & Downe 2005). Systematic review and integration of information from qualitative studies (Lachal et al., 2017).

Search Strategy

Through the use of Publish or Perish software, Google Scholar, Crossref, Semantic Scholar and some academic publications connected to the use of gamification in teaching and learning mathematics were found in an electronic database for scholarly research. All research published between 2017-2023 that are pertinent to the use of gamification in teaching and learning mathematics have been downloaded and examined. Further, the descriptors or keywords entered in the software were as follows: qualitative, basic education, gamification, and mathematics teaching. The keywords mentioned were selected to draw out articles. A flow diagram using PRISMA 2020 was then utilized to sort out the screened data.

There were three (3) stages of the research paper selection using the PRISMA Flow Diagram 2020. The three stages are the following: Identification, Screening, and Included. On the identification stage, Two Hundred (200) studies were registered in Google Scholar, Six Hundred

Seventeen (617) studies were registered in the Crossref database, and Four Hundred Forty-One (441) were registered in Semantic Scholar

database totaling to One Thousand Two Hundred Fifty-Eight (1258) studies on the initial screening using the Publish or Perish software.

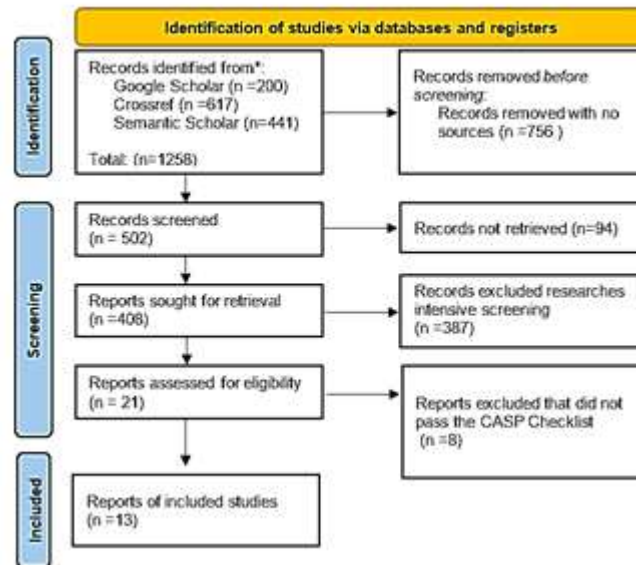


Figure1. Search strategy using PRISMA

Inclusion and Exclusion Criteria

Inclusion and exclusion criteria provide a basis on which the reviewer draws valid and reliable conclusions (Meline, 2006). Included studies were selected on the basis of inclusion criteria protocol: (a) must include studies related to the use of gamification; (b) must utilize qualitative design; (c) must be written in English; (d) must published from 2017-2023; and (e) must qualify using the Critical Appraisal Skills Programme (CASP). Selected papers were screened with the set inclusion criteria.

Data Analysis

The emerging themes were determined using the thematic analysis procedure described by Clarke and Braune (2013). It is a qualitative data analysis technique that entails reviewing a data collection and looking for themes that run across the data.

RESULTS AND DISCUSSION

The teaching and learning experiences in using gamification in teaching and learning mathematics were used to generate initial codes highlighting the 13 studies considered in the meta-synthesis.

As shown in table 1, the initial codes on the use of the gamification in teaching mathematics were generated to search for themes. The general codes were analyzed using the thematic analysis approach, which emerged with four (4) themes and one (1) meta-theme. The themes generated are the following: (1) time element; (2) positive attitude; (3) collaboration and engagement; and (4) feedback and assessment.

Theme 1: Time element

Addressing the challenges in gamified math instruction is important because it can help students engage with the subject more effectively

Table 1. Studies highlighting the use of gamification in teaching mathematics

Article	Author/s & Year Published	Setting	Generated Initial Codes on the Use of Gamification in Teaching and Learning Mathematics
1	Smith, N. (2018)	Denver, Colorado	<ul style="list-style-type: none"> • Negative to positive attitude on gamification among students • Allowed teachers to be more flexible • Rewarding and effective tool • Better connection to the content and retention • Develop life-long skills • More motivated in class participation
2	Brigham, J. (2019)	United States of America	<ul style="list-style-type: none"> • Games have a wonderful place in the classroom • Became more involved • Some games may not be geared for some levels (the same effect in another grade level) • Teachers should play and plan the game • Games should be familiar to students
3	Kristiani, T., Sudiyanto, & Usodo, B. . (2022)	Indonesia	<ul style="list-style-type: none"> • Exciting and fun learning • Some games need compatible devices • Online games affected by network difficulties • Teachers need to be have knowledge on the game • Gamification creates a friendly competition
4	Vitabar, F., Lavicza, Z., & Hohenwarter, M. (2019, February)	Uruguay	<ul style="list-style-type: none"> • Lack of time • Technical issues • Importance of Collaboration
5	Gillo, M. (2019)	Philippines	<ul style="list-style-type: none"> • Gamification is fun • Motivating and engaging • Provide fun and diverse learning experiences
6	Zabala-Vargas, S. A. et.al (2022)	Philippines	<ul style="list-style-type: none"> • Importance of interaction of the teacher • Satisfaction • Time element • Motivating than traditional • Teamwork and competetiveness
7	Jedel, I., & Palmquist, A. (2021)	Sweden	<ul style="list-style-type: none"> • Positive impact on students • Unclear indication of the progress of the students • Compatability with needs • A walkthrough of the different gamification parts

			<ul style="list-style-type: none"> • Technological support • Doubt about effectiveness • Collaboration
8	Folgieri, R. et.al., (2019)	Italy	<ul style="list-style-type: none"> • Developed self-awareness and learning • Integration of real problems • Reduce stress and fear of math
9	W. Ortiz, D. Castillo and L. Wong (2022)	Peru	<ul style="list-style-type: none"> • Effective in motivating learning • User-friendly • Satisfied with the game
10	Papp, T. A., & Theresa, A. (2017)	Canada	<ul style="list-style-type: none"> • Putting theory into practice • Enjoyable and fresh approach to learning • Exciting and competitive • Build team skills and problem-solve together • Engaging, motivating, and a preferred method
11	Rahayu, F. S., Nugroho, L. E., Ferdiana, R., & Setyohadi, D. B. (2022)	Indonesia	<ul style="list-style-type: none"> • Excitement, curiosity, interest, and challenging • Negative to positive reaction • Students tend to get bored easily • Tend to be competitive based on the leading scores
12	May, A. (2021)	Winona, Minnesota	<ul style="list-style-type: none"> • Competition against classmates • The use of different game elements to stimulate excitement • Behavior decreases once loses in the game • Time management is difficult • Excessive competition and time management become challenges when implementing game-based learning in the classroom
13	An, Y. (2021)	Texas	<ul style="list-style-type: none"> • gamified learning experience should be relevant to the students

and improve their math skills. Some of these challenges include, time management, technical issues, and the kind of games embedded to suit the needs of the students. Xezonaki (2022) highlighted that one of the most significant issues of gamification in education should be considered, which is the creation of competition between students and the elimination of internal motivation.

The use of e-learning gamification, which has no significant effect on improving students' cognitive motivation when used only once

(Prasetyo & Napitupulu, 2018). The use of e-learning gamification must be done on a regular basis. Students can exchange opinions, knowledge, and ideas when they are used on a regular basis. Furthermore, materials related to daily life can stimulate aspects of students' cognitive motivation.

One of the challenges in gamification is creating a competitive environment through gamification in education. This challenge stems from a lack of appropriate methods and/or frameworks for the design and development of

gamification in the context of learning, and it should be taken seriously by teachers when implementing gamification in their classrooms. To avoid such issues and limitations, teachers should exercise caution when developing gamification teaching tools and consider their students' needs as well as their educational goals. Gamification can thus improve educational processes in preschool science teaching, with promising results in terms of student motivation (Xezonaki, 2022). In contrast, the study of Competitive aspects, such as leaderboards or challenges, are frequently used in gamification. Healthy competition can encourage student collaboration as they strive to attain common goals or exceed their peers (Hamari & Koivisto, 2015).

Further, it is argued that it is common for students to be discriminated against based on their skill levels and grades, which they achieve during gamification activities. This can lead to a gradual loss of motivation and commitment of participants (Xezonaki, 2022; Toda et al., 2017). At the same time, loss of productivity can be detected when game elements distract users from the activity's primary purpose (Xezonaki, 2022; Thiebes et al., 2014).

Theme 2: Positive attitude

Gamification in math lessons can help to promote this mindset by rewarding students for engaging with the material and completing tasks. This can help them see math as a fun challenge rather than a chore, and it can motivate them to keep trying even if they make mistakes or encounter difficulties. It can also help to foster a collaborative and learning environment by allowing students to work together to earn rewards and expand their knowledge. Gamification has been shown to provide benefits in a variety of areas, teachers should consider using gamification in the classroom to help students understand mathematical concepts better and more clearly (Yan & Matore, 2023).

Gamification in instruction, as well as the development of basic numeracy skills, can improve students' attitudes toward problem-solving skills, thereby improving their overall performance in mathematics (Smith, 2018).

Gamification in mathematics instruction displayed similar attitudes among the students. There were some who were initially adaptable, whereas others were nervous, skeptical, timid, or fearful. These negative attitudes and perceptions gradually faded, and they developed a more positive attitude and outlook over time (Smith, 2018).

Another effect of gamification to the students are the motivational factor. To implement active learning, teachers must use a variety of teaching methods and approaches that allow students to be active participants with strong motivation and engagement in their own learning, as well as new approaches and techniques. One of these trends is gamification (Furdu et.al, 2017). This is also supported by Kusuma et. al (2017) that gamification is now one of the techniques that can increase motivation and encourage user involvement, particularly in the education domain, where teaching and learning activities must be more fun and interesting.

Lawrance, et.al (2021) also highlighted in their study's findings that gamification tools significantly increased students' motivation in learning and understanding mathematical concepts, as well as their engagement in gamification activities, which increased their critical thinking and problem-solving skills. On the other hand, to stimulate cognitive motivation from students, the material provided should also support real application in everyday life (Prasetyo and Napitupulu, 2018; Hashim et. al, 2011).

One manifestation of the effect of gamification on mindset and attitude was highlighted in the study of Türkmen and Soyba^o (2019), in which students expressed that they are normally bored in mathematics classes, but when

digital games are used, the lessons are fun. During the lessons, students have stated that they have lost track of time. Furthermore, students stated that they are bored in mathematics classes. The mathematics course, which is quite abstract for the students in the concrete operational stage, is perceived as boring and monotonous by the students. Games created in this manner will positively influence students' attitudes and interests in mathematics lessons.

Theme 3: Collaboration and engagement

Collaboration and engagement are essential for gamified math instruction to be successful. Students learn best when they actively engage with one another and discuss their ideas in a safe and supportive environment. Working together allows students to gain confidence and improve their problem-solving abilities. This confirms in the study of Xezonaki (2022) that students are more confident to participate in the learning process, while the collaboration between peers is enhanced, creating appropriate fields for the implementation of collaborative learning.

Gamification uses components such as prizes, points, and achievements to tap into students' innate motivation. These game-like characteristics provide instant feedback and a sense of accomplishment, which can increase students' willingness to participate actively in learning activities. Students become more involved and invested in the collaborative process as a result (Hamari et. al, 2014).

Gamification in a pedagogical context gives some relief for many students who are alienated by traditional methods of learning. Gamification could provide a partial answer to the school system's current reduction in learner motivation and engagement. Gamifying not only graduate recruitment techniques, but also college course material and curricula, could help the college atmosphere greatly (Alsawaier, 2018).

Further, Wouters et al. (2013) discovered that collaborative gameplay is more effective than

solitary gameplay in the setting of games. Clark et al. (2016) included competition in their meta-analysis of digital games and discovered that games with a combination of competition and cooperation, as well as single-player games without competitive aspects, outperform games with only competition.

Theme 4: Feedback and Assessment

Teachers must understand the math concepts underlying the games and how to use them to help students learn those concepts. They should also have to be familiar with the game rules and have a variety of activities available to help students practice and should be able to assess students' progress and modify game activities as necessary. One of the most powerful mechanisms of video games is the ability to provide feedback in real time, not only as evaluation, but more often as guidance to facilitate and correct performance. This is largely in line with the idea of formative assessment in education (Figueroa-Flores, 2016).

Teachers must assess their students to determine where they are currently functioning and devise a plan to meet students' educational needs. Assessment (whether formal or informal) can provide teachers with an opportunity to learn more about their students. During the implementation of each game, participants discovered a way to assess the level of their students. Assessments included ensuring that each student had paper to write on, providing feedback on solutions given after a math problem, and listening in on student discussions during gameplay (Bragham, 2019 & William, 2011). As cited by Bragham (2019), immediate feedback is ultimately necessary for students when engaging in gameplay that involves learning or reviewing a skill (Stott & Neustaedter, 2013).

Feedback should center on assisting the student in understanding how their emotions affect their performance and how to develop the skills required to effectively manage their emotions.

Teachers should provide positive reinforcement for students' progress as well as suggestions for how to improve. They should also provide strategies for dealing with difficult emotions and resources to assist the student's emotional development. This is one of the highlights in the study of Prasetyo and Napitupulu (2018) that for the emotional side of the students, teachers also have an important role. Example when a student has difficulty in understanding a lesson, a teacher can help or guide the student. The absence of a teacher's role in self-paced e-learning will make the students feel difficult and confused in understanding the lesson. Students tend to hate lessons that he finds difficult. In addition to impact on emotional students, it also affects student achievement.

In addition, Sanmugam (2017) mentioned that with the use of gamification, teachers are able to identify the types of assessment that motivates a certain group of students, and at the same time by identifying the player motivation types, the teacher can create a higher level of assessment for those students. In a way, a teacher can use the gamified system for easier assessment. In addition, the feedback provides can give teachers direct information about the learning level of their students (Xezonaki, 2022).

Gamification gives students with rapid feedback on their accomplishments, allowing them to track their development and make required adjustments. The continuous comments and progress tracking foster a sense of transparency, assisting students in identifying areas for development and collaborating to solve obstacles (Hamari, J., and Koivisto, J., 2015).

Meta-Theme: Futures Thinking: Gamifying Mathematics Education for Engaged Learning

Changes in our world necessitate reforms in the educational system as a whole and in teaching methods. When a teacher employs outdated methods, it is easy to lose interest and

motivation. Some of the students find mathematics difficult and dull. Teachers must adapt to new technologies and seek out new educational methods. Gamification trends began to develop rapidly and were widely used in Mathematics beginning with the Covid-19 pandemic in the year 2020. The situation necessitates desperate measures, particularly in the gamification approach, after its necessity and impact were determined to be critical for the learning process (Yan & Matore, 2023). Gamification will remain a hot topic as more teachers look for new ways to engage their students. In the classroom, there are several ways to connect with students. Gamification implementation that works teachers must understand how game mechanics work and have a comprehensive list of elements that can be incorporated.

Since the twenty-first century, the use of emerging technologies in education has grown dramatically. For many educators, this has become a difficult task, especially as 21st century learners flood the classrooms. However, these digital natives are vastly different from those who began the millennium. These students want to be challenged, engaged, and motivated by a learning process that connects them to the world. Although, in order to achieve the learning outcomes required for the twenty-first century, educators are adapting approaches tailored to these students, such as game theory, video games, and gamifying instruction (Figueroa-Flores, 2016).

CONCLUSIONS

Gamification in teaching and learning mathematics has resulted to various impacts to the curriculum. The findings provide significant insights for educators and curriculum designers looking for novel techniques to improve mathematics teaching and learning. It should be noted that the effectiveness of gamification in mathematics teaching and learning is dependent on the careful design and implementation of the

gamified features. Clear learning objectives, adequate feedback methods, and a balance of challenge and support are all critical considerations. Gamification should also be supplemented by good pedagogical methods and appropriate instructional methodologies to guarantee meaningful learning experiences. Based on the findings of the study, it is recommended to tailor fit the games in the curriculum to address the needs of the students, this will enable students to choose challenges or themes that resonate with their interests. It is also recommended that educators may integrate gamified elements thoughtfully considering all of its effects. This way, educators can use gamification to improve mathematics teaching and learning by encouraging students' enthusiasm, engagement, problem-solving skills, and collaborative learning. Finally, the use of gamification is recommended to be incorporated in the curriculum and with this, it is necessary that educators as well shall go through professional developments to make them more familiar with the games and learn the proper techniques and strategies in the teaching process.

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