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Implementation of Gamification Techniques in Mathematics Education: A Study on Student Engagement and Learning Outcomes

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Abstract: This study represents a systematic literature review aimed at investigating the utilization of gamification techniques in mathematics learning from 2013 to 2023. Through literature sources indexed by Google Scholar, PubMed, and IEEE Xplore, this study highlights that gamification techniques in mathematics learning have yielded positive impacts on student motivation, engagement in learning, and academic achievement. However, there is a need for further research to deepen the understanding of how appropriate gamification designs can enhance the effectiveness of mathematics learning, particularly in adapting to diverse student needs and preferences. Therefore, further research in this regard is considered crucial to identify best practices and the most effective strategies in implementing gamification techniques in the context of mathematics learning.

Keywords: Gamification techniques, Student engagement, Learning outcomes, Student preferences, Learning strategies.

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A. INTRODUCTION

Introduction to the concept of gamification in the context of mathematics education requires a profound understanding of the nature and application of the concept. Simply put, gamification refers to the use of game elements in non-game situations with the aim of enhancing motivation, engagement, and learning outcomes (Sri Legowo 2022).The incorporation of elements such as points, levels, challenges, and rewards in the learning environment is expected to boost students' interest and involvement in the mathematics learning process. The implementation of gamification techniques in the context of mathematics education has been a primary focus in efforts to enhance learning effectiveness. Various research and practices indicate that the use of gamification can influence students' intrinsic motivation and improve their learning outcomes in various mathematical situations. For instance, the utilization of student competitions, virtual rewards, and progress assessments has proven to increase

students' interest in mathematics learning. Recent developments in the implementation of gamification techniques in the context of mathematics education show an intriguing trend, with growing interest in this approach coinciding with awareness of challenges in teaching mathematics, particularly in sustaining student interest and enhancing their learning outcomes. Therefore, the implementation of gamification techniques remains relevant in the context of modern mathematics education. This research aims to further explore student engagement and learning outcomes achievable through the application of gamification techniques in the context of mathematics education. It is hoped that this research will provide valuable insights for educators and policymakers in enhancing innovative and effective mathematics learning approaches (Yulian et al. 2023).

Enhancing the effectiveness of mathematics education poses a significant challenge for educators, particularly considering various factors influencing this process (Etistika Y W, Dwi A S, and Amat N 2016). One of the primary issues is maintaining students' interest in mathematics, which is often perceived as complex or tedious by some students. Furthermore, educators are required to improve students' academic achievement in mathematics, given the importance of a solid understanding in this field for future academic success and careers.Within this framework, the use of gamification techniques in mathematics education holds promise as an approach that may help address these challenges. By leveraging game elements such as points, levels, and challenges, gamification can stimulate students' interest and enhance their engagement in mathematics learning (Sri Legowo 2022). This has the potential to create a more dynamic and interactive learning environment, ultimately expected to enhance students' learning achievements.Therefore, research investigating the implementation of gamification techniques in the context of mathematics education has significant potential to contribute to addressing these issues and improving the overall effectiveness of mathematics learning (Rukmana, Supriandi and Wirawan 2023).

In mathematics education, there are several typical challenges, such as negative perceptions of the subject and the need for creative problem-solving skills (Shofia Rohmah et al. 2023). Negative perceptions of mathematics often arise because students perceive it as a complex or boring subject, which can reduce their motivation and interest in learning. Additionally, mathematics also requires the ability to solve problems creatively, where students are expected to apply mathematical concepts in real-world situations to find appropriate solutions (Muhammad et al. 2018). In addressing these challenges, the use of gamification techniques demonstrates significant relevance. By incorporating game elements such as points, levels, and challenges, gamification can help transform negative perceptions of mathematics into a more engaging and enjoyable learning experience for students. Moreover,

gamification techniques can also stimulate students' creative thinking by providing challenges that require mathematical problem-solving in an interesting and interactive context (Syuhada, Mulyati, and Persada 2024). Thus, the utilization of gamification techniques in mathematics education holds strong relevance in addressing these specific challenges to enhance the effectiveness of mathematics learning (Nggego 2023).

Previous research has investigated the implementation of gamification techniques in mathematics education, yielding intriguing findings. For instance, studies have shown that the use of a gamified learning platform (CALP) with features such as problem repetition after suboptimal attempts can enhance student engagement and learning outcomes, particularly in algebraic concepts (Hui and Mahmud 2023) .Digital game-based interventions have also proven effective in enhancing students' learning potential in school mathematics, especially for those experiencing difficulties in understanding the material (Tepho and Srisawasdi 2023). Furthermore, the utilization of online learning environments incorporating gamification has significantly increased motivation and engagement among students in learning computer concepts at the university level (Syafitri 2023). The implementation of gamification techniques, whether simple or complex, in computational thinking (CT) education has also shown improvements in CT skills and learning motivation, both intrinsically and extrinsically, particularly among second-grade students (del Olmo-Muñoz et al. 2023). Additionally, the use of the Kahoot gaming platform in the learning process has been found to ADDIN CSL_CITATION {"citationItems":[{"id":"ITEM-1","itemData":{"DOI":"10.1007/s10639-023-11708-6","ISBN":"0123456789","ISSN":"15737608","abstract":"Gamified learning is an instructional strategy that motivates students to learn, and the use of multiple representations assists learning by promoting students’ thinking and advanced mathematical problem-solving skills. In particular, emergency distance learning caused by the COVID-19 pandemic may result in a lack of motivation and effectiveness in learning. This study designed an online gamified learning activity incorporating multi-representational scaffolding and compared the differences in the learning achievement and motivation for the gamified activity and general synchronous distance learning. In addition, for the group that conducted the gamified learning activity, we measured the participants’ flow, anxiety, and emotion during the activity. A total of 36 high school students participated in the experiment. The results indicated that the gamified learning activity was not significantly effective in terms of enhancing learning achievement. In terms of learning motivation, a significant decrease in motivation was found for the group using general synchronous learning, while a significant increase in motivation was found for the group using synchronous gamified learning. This indicates that despite the negative impact of the pandemic on learning, gamified learning still enhances students’ learning motivation. The results of

flow, anxiety, and emotion showed that the participants had a positive and engaged experience. Participants provided feedback that the multi-representational scaffolding facilitates learning.","author":[{"dropping-particle":"","family":"Chen","given":"Mei Fen","non-dropping-particle":"","parse-names":false,"suffix":""},{"dropping-particle":"","family":"Chen","given":"Yu Chi","non-dropping-particle":"","parse-names":false,"suffix":""},{"dropping-particle":"","family":"Zuo","given":"Pei Ying","non-dropping-particle":"","parse-names":false,"suffix":""},{"dropping-particle":"","family":"Hou","given":"Huei Tse","non-dropping-particle":"","parse-names":false,"suffix":""}],"container-title":"Education and Information Technologies","id":"ITEM-1","issue":"10","issued":{"date-parts":[["2023"]]},"page":"13207-13233","publisher":"Springer US","title":"Design and evaluation of a remote synchronous gamified mathematics teaching activity that integrates multi-representational scaffolding and a mind tool for gamified learning","type":"article-journal","volume":"28"},"uris":["http://www.mendeley.com/documents/?uuid=decc3991-c688-4c3f-8e95-9ca0ab6bef15","http://www.mendeley.com/documents/?uuid=0775d490-5548-4e4e-83be-ae9e7ea6b811"]}],"mendeley":{"formattedCitation":"(Chen et al. 2023)","plainTextFormattedCitation":"(Chen et al. 2023)","previouslyFormattedCitation":"(Chen et al. 2023)"},"properties":{"noteIndex":0},"schema":"https://github.com/citation-style-

Further research is urgently needed to fill knowledge gaps and provide a deeper understanding of the implementation of gamification in the mathematics learning process. As indicated by the literature, gamification has shown positive results in enhancing students' learning skills in the field of science education (Peltenburg et al. 2023). However, further research is still required to better understand how gamification can be effectively applied in the context of mathematics education. Future research is expected to focus on identifying specific areas where previous studies have not fully explored the benefits and challenges associated with the use of gamification in mathematics education (Ajemba and Arene 2022). By addressing these knowledge gaps, future research is expected to provide valuable insights into the design and implementation of gamification strategies capable of enhancing mathematics learning outcomes for students (Ulhusna, Diana Putri, and Zakirman 2020).

Previous research has shown intriguing results regarding the application of gamification techniques in mathematics education. (Hui and Mahmud 2023) Some studies highlight the effectiveness of using gamified learning platforms, such as CALP, in enhancing student engagement and learning outcomes, especially in algebraic concepts.(Tepho and Srisawasdi 2023) Additionally, digital game-based interventions

have proven effective in enhancing students' learning potential in mathematics, particularly for those experiencing difficulties in understanding the material. Other studies indicate that the use of online learning environments adopting gamification can significantly increase motivation and engagement among students in learning computer concepts. Furthermore, the implementation of gamification techniques in computational thinking education has led to improvements in CT skills and student learning motivation. These studies demonstrate the significant potential of gamification in enhancing mathematics learning. However, there is still a gap in understanding how gamification can be effectively applied in the context of mathematics education, particularly concerning the identification of specific benefits and challenges. Therefore, this research aims to address this gap through a systematic literature review approach, focusing on recent studies exploring the implementation of gamification techniques in mathematics learning .(del Olmo-Muñoz et al. 2023)Thus, this research will provide deeper insights into how gamification can be used to enhance student engagement and learning outcomes in the mathematics education domain.

The primary objective of this research is to investigate the impact of gamification techniques on student engagement and mathematics learning outcomes. This aligns with previous studies that have explored various innovative teaching methods to enhance mathematics education, finding that the use of music-based techniques, aimed at balancing the functions of the left and right brain, is effective in improving students' mathematical understanding. Similarly, highlighting the importance of problem-solving skills in mathematics education and proposing problem-based learning as an effective approach. Identifying common difficulties in understanding mathematical concepts among elementary school students and providing suggestions to address these challenges. Finally, emphasizing the significant role of mathematics education in raising awareness of the environment and proposing the concept of "green mathematics" as an effort to integrate environmental education into mathematics learning. These studies collectively underscore the necessity of employing innovative teaching methods, such as gamification, to enhance student engagement and learning outcomes in mathematics.

B. METHODE

This research aims to investigate the implementation of gamification techniques in the context of mathematics education, focusing on student engagement and learning outcomes. The primary objective is to understand how gamification techniques have been applied in mathematics learning and how this influences student engagement and learning outcomes. This research is conducted through a Systematic Literature Review approach, aimed at systematically investigating and analyzing relevant

literature in this domain. Literature searches were conducted through academic databases such as Google Scholar, PubMed, and IEEE Xplore. Keywords used include "gamification," "mathematics education," "student engagement," and "learning outcomes." This search was limited to studies published within the last 10 years, encompassing both journal articles and conference papers, with a preference for publications in the English language.

The inclusion criteria used encompass studies specifically addressing the implementation of gamification techniques in mathematics learning while investigating student engagement and learning outcomes. The primary language used is English. The exclusion criteria encompass studies that do not focus on the use of gamification techniques in the context of mathematics education, as well as studies that do not include relevant data on student engagement and learning outcomes. The article selection process involves initially examining titles and abstracts, followed by thorough readings to determine conformity with the inclusion and exclusion criteria. Relevant data, including information on gamification implementation, student engagement, and learning outcomes, are extracted from each selected article. This information is then analyzed to identify key findings and emerging patterns in the related literature. By following this approach, it is expected that this research will provide a comprehensive understanding of the use of gamification techniques in mathematics education and their impact on student engagement and learning outcomes.

C. RESULTS AND DISCUSSION

1. The implementation of gamification techniques in mathematics education

The implementation of gamification techniques in mathematics education has proven effective in enhancing student participation, learning motivation, and comprehension of the material. Research indicates that integrating game elements into non-traditional academic environments can improve students' ability to work independently or in teams, as well as increase their satisfaction and motivation towards mathematics (Alvarado Rodriguez and Rosado Cusme 2023). The integration of gamification techniques with computational thinking instruction has also been explored, revealing that both shallow and deep implementations of gamification can enhance computational thinking skills in young students, with deeper implementation showing a stronger motivational impact (del Olmo-Muñoz et al. 2023). Furthermore, game-based mathematics learning approaches, whether using traditional or modern games, have been shown to improve learning quality, teacher skills, and student participation, leading to enhanced student competencies (Himmawan and Juandi 2023). The use of gamification strategies in online learning also shows potential in boosting motivation and student participation (Sarkar and Sur Roy 2023). However, it

should be noted that the success of gamification implementation in mathematics learning heavily depends on underlying pedagogical considerations (Sri Legowo 2022).

(Ramlah and Hanifah 2018)The use of gamification techniques in mathematics education has proven effective in enhancing students' understanding of mathematics and their learning satisfaction. (Putri et al. 2016)This is further reinforced by the application of the Concrete-Pictorial-Abstract (CPA) approach, which helps students establish connections between mathematical concepts and real-life situations. (Prayitno and Masduki 2017) However, despite the potential benefits of this approach, many students still encounter difficulties in understanding mathematics. (Andi Asrafiani Arafah, Sukriadi, and Auliaul Fitrah Samsuddin 2023) To address this issue, constructivist learning theory can be applied in mathematics education, emphasizing student-centered learning and the importance of students' personal experiences in the learning process.

The results of these studies indicate that the use of gamification techniques in mathematics education has a significant positive impact. The integration of game elements enhances student engagement, learning motivation, and understanding of the material. Additionally, combining gamification techniques with computational thinking instruction provides additional benefits in enhancing computational thinking skills. Game-based mathematics learning approaches have also been proven effective in enhancing overall learning quality. Although the research findings demonstrate success in implementing gamification techniques in mathematics education, it is important to note that this success heavily depends on underlying pedagogical considerations, This emphasizes the importance of appropriate approaches and careful integration of gamification techniques in the context of mathematics learning.

2. The influence of using gamification techniques on student engagement in mathematics learning

The implementation of gamification techniques has been proven to have a positive impact on student engagement in the mathematics learning process. The use of digital games as classroom interventions has been effective in enhancing students' learning potential and cognitive engagement in the context of mathematics content (Andi Asrafiani Arafah, Sukriadi, and Auliaul Fitrah Samsuddin 2023).Aligning gamification techniques with computational thinking (CT) instruction has shown to enhance CT skills and motivation, with deeper gamification techniques yielding stronger motivational effects (Saeputri, Sutriyono, and Pratama 2019). Gamification-infused online learning environments have been proven to enhance motivation and engagement among students in understanding essential computer concepts (Alsadoon 2023). The incorporation of game design elements in mathematics learning activities, particularly through problem-based gamification approaches, can enhance the gaming

experience and motivation of students in engaging with learning activities (Alt 2023). Game-based learning (GBL) in the context of mathematics has had a positive impact on students' cognitive aspects, involving an increase in mathematical knowledge and skills, as well as affective aspects, including achievement, attitudes, motivation, interest, and student engagement (Hui and Mahmud 2023).

(Putri et al. 2016) The utilization of gamification techniques in mathematics education has been proven to enhance student engagement. (Prayitno and Masduki 2017)However, despite the potential for enjoyable learning experiences in mathematics, many students still face difficulties in mastering the subject. (Ananda and Wandini 2022) These difficulties are often related to a lack of understanding of basic mathematical concepts, which can hinder further learning development. (YULIYAWATI 2020)Therefore, while the use of gamification can enhance engagement, it is necessary to address these fundamental issues in order to fully reap its benefits in the context of mathematics education.

The research findings indicate that the consistent use of gamification techniques consistently has a positive impact on student engagement in mathematics learning. The integration of game elements, whether through digital games, computational thinking instruction, or problem-based gamification approaches, enhances student motivation and enriches their learning experiences. Despite the positive findings, it is important to consider that research results may be influenced by factors such as instructional design, student characteristics, and learning environments. Additionally, the sustainability and long-term effectiveness of gamification techniques need to be considered to understand their overall impact thoroughly.

3. Specific factors that influence the success or failure of gamification implementation in the context of mathematics learning.

Several factors influencing the success or failure of gamification implementation in mathematics learning involve pedagogical considerations regarding gamification activities (Alt 2023).Design aspects, such as focusing on pedagogical goals and simulation interactions, also play a crucial role in determining the effectiveness of gamification (Lee Yan and Mohd Matore 2023).Additionally, the level of students' knowledge in relevant technical areas is a factor influencing gamification (Chamorro-Atalaya et al. 2023). It should be noted that the use of gamification alone may not provide sufficient motivation for students to actively participate in learning unless based on strong pedagogical grounds (Sallik, Hipiny, and Ujir 20). Furthermore, the impact of gamification approaches on student learning can be measured through affective, cognitive, and psychomotor dimensions (Sallik, Hipiny, and Ujir 2022). All these factors must be carefully considered when implementing gamification in the context of mathematics learning to ensure its success.

The success or failure of gamification implementation in mathematics education is influenced by various factors. According to (Dharmayanti and Munadi 2014) key factors in student institution selection involve student interest, campus image, and student activity units. (Mangera 2020) highlights the importance of teacher performance and student achievement in the implementation of contextual teaching. Both (Notoatmodjo 2022) and (Mangera 2020) emphasize the significant impact of environmental, behavioral, healthcare services, and genetic factors on public health, which may also be relevant in the context of gamification use in mathematics education. The findings of these studies collectively indicate that the success of gamification in mathematics education may be influenced by a combination of student, teacher, and environmental factors.

The research findings indicate that the success or failure of gamification in mathematics learning depends not only on pedagogical aspects related to gamification activities but also on design, students' knowledge, and motivation based on solid pedagogical reasons. It is important to understand that gamification implementation cannot rely solely on gaming elements but must also consider these complex factors. While these factors are relevant, it is important to remember that evaluating gamification implementation should also take into account contextual factors, such as learning environment and student characteristics. Comprehensive evaluations considering all these aspects can provide a deeper understanding of the success or failure of gamification in the context of mathematics learning.

4. Patterns or specific trends in research findings related to the implementation of gamification in mathematics education

The implementation of gamification in the context of mathematics education has yielded specific findings and trends in research results. The use of gamification techniques, whether through traditional or modern games, has proven effective in enhancing the quality of mathematics learning (del Olmo-Muñoz et al. 2023). Reward systems employing gamification with badges, leaderboards, and avatars have successfully transformed the learning environment and student attitudes, leading to improved attitudes towards mathematics and reduced anxiety levels (Vankúš 2021). Deeper gamification techniques, involving more complex and challenging experiences, have shown to have a stronger motivational impact compared to shallow gamification (Rincon-Flores et al. 2023). The implementation of problem-based gamification activities has been found to be more effective in enhancing gameplay experience and student motivation compared to non-problem-based masalah (Lee Yan and Mohd Matore 2023)The literature on the application of gamification in mathematics education continues to grow, with Spain standing out as the most researched country in this field (Alt 2023). These findings and trends significantly contribute to the

development of knowledge in the literature regarding the implementation of gamification in mathematics learning.

(Antarsari 2020) The implementation of gamification in mathematics education has shown positive results in several studies. Antarsari notes that using patterns in mathematical and language analysis can significantly improve children's skills in both areas. Meanwhile, , (Mataheru, Huwaa, and Matitaputty 2021)found that gamification can help identify and correct errors in understanding basic mathematical topics among students. However, (Hariyono and Nur Widhi 2021) and (Prayitno and Masduki 2017) did not present specific findings related to the implementation of gamification in mathematics education.

The findings of the research indicate that the use of gamification in mathematics education has a positive impact on the quality of learning. Gamification techniques involving badges, leaderboards, and avatars have shown significant changes in students' attitudes, enhancing positive views towards mathematics, and reducing anxiety. Deeper gamification techniques demonstrate that more complex learning experiences tend to provide higher motivation compared to shallower approaches. Additionally, problem-based gamification activities have proven to be more effective in enhancing gameplay experiences and student motivation. The success of implementing gamification in mathematics education is reflected in the improvement of students' attitudes and motivation. Reward systems implemented using gamification elements, such as badges and leaderboards, have demonstrated positive changes in the learning environment. However, it is important to note that some studies did not provide specific findings related to the implementation of gamification in mathematics education.

D. CONCLUSIONS AND SUGGESTIONS

Overall, this research emphasizes that the implementation of gamification techniques in mathematics education has great potential to enhance student participation, learning motivation, and understanding of the material. While the positive impact on student engagement has been proven, the success of gamification implementation requires careful pedagogical considerations and appropriate integration into the design of mathematics instruction. Evaluations indicate that the use of gamification techniques positively contributes to student attitudes and motivation, and integrating gamification across various learning contexts provides opportunities for improved learning outcomes. However, to achieve optimal success, a thorough understanding of pedagogical aspects, instructional design, student knowledge, and motivation needs to be the primary focus. Although these findings provide a positive outlook, there are still research gaps that need to be addressed, including exploring long-term impacts, potential side effects, and the adaptability of

gamification in diverse mathematics learning contexts. Therefore, future research can delve deeper into understanding the potential and limitations of gamification in enhancing mathematics learning and develop more specific and focused strategies.

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