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Gamification using Board Game Approach in Science Education - A Systematic Review

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ABSTRACT

Gamification acceptance in learning is seen as a mass appeal for motivation, learning participation, and social influence, which is also considered a digital realm. However, non-digital gamification is just as valuable in education as in the digital world. This research aimed to present the empirical findings from the most recent literature on gamification in science subjects using a board game approach. It reveals the most recent scientific evidence on emerging learning science trends using board games and gamification plugins. Other than that, it expands the possibilities for future research directions in rioting learning and instruction through gamification. The systematic literature review examined 11 empirical research papers published between 2018 and 2022 in the Web of Science (WoS) and Scopus databases. The review critically appraised and evaluated the various contradictions found in the literature and established the importance of future research studies to re-examine the theoretical foundations of board games, their game mechanics, and learning outcomes. The findings not only attempt to analyse the novelty of gamified learning using board games perceived as a critical enabler of achievement, motivation, enjoyment, and engagement in science education but also seek to outline recommendations for future research on this topic comprehensively.

1. Introduction

According to Deterding *et al.,* [1], gamification is defined broadly as applying game design elements to non-game contexts. Since the term "gamification" was coined in 2011, researchers have focused on studies in education that employ gamified learning. Following the gamification concept's rapid growth, it has also been applied to other formal human activities, such as economy, tourism, and health, to achieve specific goals within their respective fields. Nevertheless, most gamification research focuses on education [2,3]. Gamification is a popular approach for promoting learning through game elements. There is evidence that gamification gains increased acceptance as an effective learning strategy for creating highly engaging learning experiences. Most previous studies

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have demonstrated the positive impacts of gamification on both teachers and students in education. Students' performance and attitudes significantly improve when teaching methods incorporate game activities [4]. In addition, the elements of games can intrinsically motivate students during a lesson [5]. Therefore, students will repeatedly play the game, unaware they are also learning during the session.

Gamification is frequently associated with and closely related to digital gaming. Digital gamification is becoming more attractive in education as interactive materials become more prevalent in the digital technology age. However, the concept of gamification should be broader than the use of technology alone [6]. Non-digital gamification methods, such as board games and cards, are also critical in helping students and teachers with teaching and learning. It also provides an effective gamification strategy platform that includes chance, challenge, and consequence elements. Board games are familiar in education, and widespread use is expected in the classroom. Board games are unique in their approach towards learning and cognition because they allow students to interact with the learning material. Although board games do not have the same digitally designed aesthetic as video games, they provide a unique and engaging pedagogy through student-centred play activities.

Previous studies have shown that board games are a great way to learn about various topics in learning. It can build inclusive learning environments conducive to multiple students' learning styles. Board games allow kinesthetic, visual, and auditory learners to interact while communicating through the game's mechanics [7]. Complex concepts (e.g., engineering, economics, and science) are easily grasped through board games, as the human mind is more receptive to a fun environment, resulting in a significant increase in conceptual understanding and attitudes towards science learning [8-11]. Additionally, board games help students develop their self-esteem [12]. When they are drawn to games, their goal is winning rather than focusing on the learning materials. Students will alleviate their fear of being judged by others.

Besides that, board games are an excellent way to teach students to focus and concentrate better while studying [13]. Most board games can keep students seated for more than an hour to complete a game without being interrupted by the internet's problems. Students' attention spans may be shortened due to technological and multimedia flaws. A teaching methodology that uses board games can also help students improve their problem-solving skills [14]. Students will be given various problems to solve while playing, and they must select and try multiple strategies to win. Board games can indirectly help students develop the critical thinking skills they need to succeed [15].

Moreover, it is undeniable that using a board game can promote teamwork among students. A board game can unite students and allow them to collaborate to achieve a common goal [16,17]. Students can brainstorm, develop ideas, and solve problems more effectively when they work in teams rather than alone. A mix of student motivation and engagement can lead to good teamwork performance [18].

Additionally, board games can help students who are not native English speakers improve their ability to communicate in English [19]. Social interaction makes playing board games with others more pleasurable. Other than that, eye contact and the ability to communicate without using a microphone or voice chat differentiate the experience from users who rely on digital gamification and cannot engage in active peer discussion. While listening skills may appear to be simple skills, they can be enhanced through the use of board games [20]. Students must listen attentively to everybody else's answers and respond to ideas proposed in discussions. Listening to others gives more insight into who they are and facilitates communication. Math skills also can be improved through board games [21]. The board game's immersed nature enables students to connect and grasp new concepts

quickly. Furthermore, it is a perfect way to demonstrate to children that math is all around them, whether they notice it or not.

Although many kinds of research have focused on using board games in the school teaching and learning process, there still needs to be more researchers who have examined the available studies in a systematic literature review. For example, Kalogiannakis *et al.,* [22] have conducted a comprehensive review of 24 empirical research studies to describe the empirical findings of current research on the use of gamification in digital form in science education. In addition, Zainuddin *et al.,* [23] stated that it is necessary to conduct further empirical studies on the research gaps in non-digital gamification settings because it is also a best practice for student learning.

This study aims to include the current body of knowledge by conducting a systematic literature review on the patterns of board games used in the teaching and learning of science from the studies that have been implemented. The following questions were set up and used to examine current literature: a) What are the target users and content areas? b) What targeted learning theories or models are used in board games? c) What are the game mechanics used and affected learning outcomes? Other than that, the purpose of this investigation also suggests future studies on what else needs to be conducted in the field.

2. Methodology

This study systematically reviewed the literature, aggregating, reviewing, and evaluating it using pre-specified and standard techniques to implement a concrete and comprehensive understanding of gamification in science education using the board games approach. The Preferred Reporting Items guided the review for Systematic Reviews and Meta-Analyses (PRISMA) statement used by Moher *et al.,* [24]. This technique is appropriate for systematic research assessment and evaluation since it outlines guidelines for examining publications' transparency, accuracy, and selection criteria. Furthermore, this systematic investigation is an appropriate research strategy for contributing to accurate scientific synthesis [25].

2.1 Article Selection and Screening

Identification is the process of identifying variants of the study's primary keywords, related phrases, or synonyms: board games, scientific education, and education. Its objective is to provide a database with an additional means of locating related papers for evaluation. This systematic study enabled a comprehensive search across two electronic database search engines. WoS and Scopus were employed as databases, and each database has a diverse collection of high-quality and high-impact items. Only peer-reviewed publications and journal papers were included.

The researchers expanded the existing terms and generated a complete search string using field code functions, wild card, truncation, phrase searching, and Boolean operators utilising the databases. The search string was used narrowed into keywords as follows: ("board game" OR "tabletop game" OR "non-digital game" OR "physical board game") AND ("science education" OR "science teaching" OR "teaching of science" OR "biology" OR "chemistry" OR "physic" OR "astronomy" OR "geology") AND ("education" OR "primary education" OR "elementary education" OR "K-12 education" OR "high school" OR "junior high school" OR "secondary school" OR "middle school" OR "intermediate school" OR "university" OR "graduate school" OR "tertiary level education"). In most cases, the search string that included all core concepts and their synonyms was utilised. During the search, these two databases, Scopus and WoS, returned a total of 149 articles.

2.2 Inclusion and Exclusion Criteria

The inclusion and exclusion criteria for the review are part of the screening method. To conduct our study, we set precise criteria that would assist us in sorting through the numerous studies, selecting and including those that were relevant to our research subject and excluding those that did not fulfil specific criteria. The criteria for article selection were determined by screening all 149 articles using the database's sorting function. According to Kraus *et al.,* [26] a mature study may have a faster time frame for publishing than a less mature one in which numerous papers can be tracked. To correlate gamification methods using board games with new trends in science education, we combed through published research from the last five years. As a result, one of the inclusion criteria was chosen for 2018 and 2022. Only papers that encompass empirical data and are issued in a publication are incorporated in the review to ensure their quality. Furthermore, to avoid ambiguity, the review only contains publications that have been published in English. Ninety-one items were excluded due to this procedure because they could not meet the inclusion criteria. Thus, the remaining 58 articles were used for the third process eligibility. The following criteria were used to determine inclusion and exclusion (Table 1):

Table 1
The inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
Publication timeline	2018 to 2022	2017 and before
Document type	Articles with empirical data and review	Book, chapter in a book, conference proceedings
Source type	Journal	Non-journal
Nature of the study	Focus on an educational environment	Not focus on an educational environment

The second screening process, known as eligibility screening, requires authors to review the collected articles to ensure that all other papers (after screening) comply with the standards. Reading the title and paper abstract is how the achievement screening process is conducted. As a result, 36 articles put more emphasis on topics unrelated to learning and teaching in science education. In addition, the focus is on physical board games rather than virtual or hybrid board games that combine physical and digital elements. In this study, using traditional board games combined with interactive digital features such as augmented reality, video games, and quick response (QR) code scanning was not an option. In addition, 5 articles were not written in English, and another 6 were duplicates, of which 11 were finally selected as Figure 1.

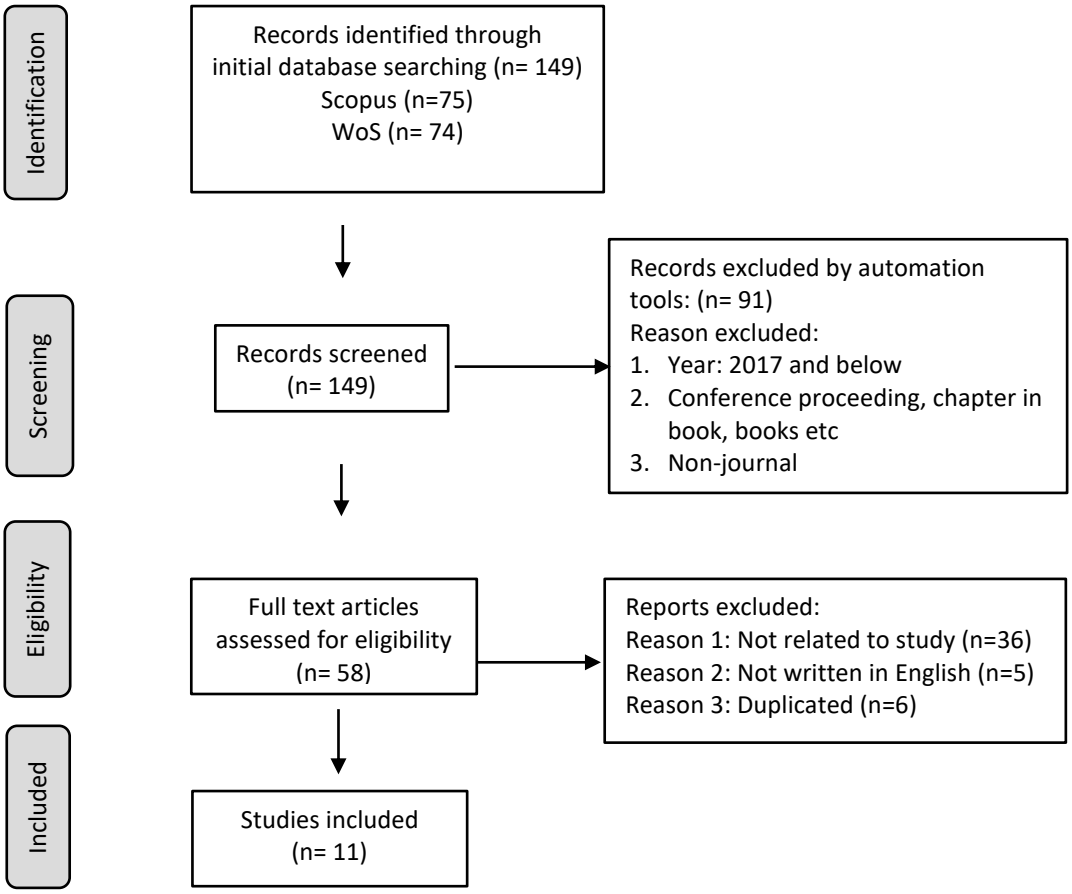

Fig. 1. Flow diagram detailing the application of PRISMA 2020 to studies published between 2018 and 2022 [27]

3. Results

Table 2 lists the study results on the selected documents and a brief discussion of the findings.

Table 2
List of recent articles related to the educational board game in science learning from 2018 to 2022

Authors	Target	Content Area	Theories Underpinning	Game Mechanics	Affected Learning Outcomes
Bernardo and González [28]	Primary school, undergraduate	Chemistry	Not mentioned	• Collaboration • Challenges • Achievement badges	• Motivation • Communication • Critical thinking • Achievement
Cardinot and Fairfield [29]	Primary school	Physics	Not mentioned	• Dice rolling • Challenges • Progression level	• Achievement • Attitude • Communication
Cavalho *et al.,* [30]	Secondary school	Biology	Constructivism	• Challenges	• Communication • Achievement
Tsai *et al.,* [31]	Secondary school	Chemistry	Not mentioned	• Points • Collaboration • Challenges • Countdown	• Achievement • Engagement • Attitude • Motivation
Triboni and Weber [32]	Secondary school, undergraduate	Chemistry	Not mentioned	• Dice rolling • Challenges	• Critical thinking • Enjoyment • Engagement

Kucukkal and Kahveci [33]	Undergraduate	Chemistry	Not mentioned	• Challenges • Dice rolling • Feedback • Achievement/badges • Progression level	• Motivation • Engagement • Enjoyment
Dziob [34]	Secondary school	Physics	Not mentioned	• Points • Challenges • Feedback • Countdown • Epic meaning	• Attitude • Motivation • Achievement
Lin *et al.,* [35]	Secondary school	Marine science	Keller's ARCS motivational theory	• Points	• Motivation • Achievement • Attitude
Thammavongsy *et al.,* [36]	Undergraduate	Chemistry	Not mentioned	• Points • Collaboration	• Achievement
Arboleya-García and Miralles [37]	Primary and secondary school	Marine science	Not mentioned	• Dice rolling • Challenges • Feedback • Countdown	• Achievement
Tabek and Önder [38]	Undergraduate	Physics	Not mentioned	• Dice rolling • Challenges	• Achievement

3.1 Target Users and Content Area

Based on the collected data, most studies involved secondary education students (6 articles). Other than that, 5 articles involved undergraduate students. Although the number of articles focusing on primary education was lower, it remained significant. This study found that only three studies were conducted at the primary school level. Primary school students are less likely to play board games than secondary and tertiary school students. The difficulty of finding the most significant board games, the high cost of board games, time constraints, teachers' lack of knowledge, and pedagogical competence in board games all contribute to the lack of board games in the classroom [39]. Due to the relatively broad and compact science education syllabus, teachers are more comfortable using a simplified teaching approach to ensure that all learning objectives are met within the allotted time. Additionally, it was found that some researchers used the same board game to assess target users at two different levels [28,32]. The board games were designed with students in primary and secondary education in mind and first-year undergraduates. Depending on their educational level, it could help them interact with various materials and other learning content. For example, primary school students used *'Chemical Battleship'* to raise their interest and awe in science, while graduates improved their academic study results in chemical concepts [28].

The analysis revealed that chemistry was the premium content used in science education by board games for most gamification, followed by physics with three articles, Marine science with two articles, and biology with one (see Table 2). There were articles on the chemistry topic for each target user level. Additionally, 2 articles were on organic chemistry, 1 each on physical chemistry, periodic table, and chemical element concept [28,31-33,36]. On the other hand, Cardinot and Fairfield [29] and Zsoldos-Marchis and Juhász [39] chose astronomy as the focus topic for physics board games, whereas Dziob [34] emphasised general physics knowledge. On the other hand, Lin *et al.,* [35] and Arboleya-García and Miralles [37] designed board games for Marine science to help players acquire a broad knowledge of science, the marine environment, and its importance and literature. In contrast, Cavalho *et al.,* [30] designed a biology board game exclusively to help students better understand protein synthesis.

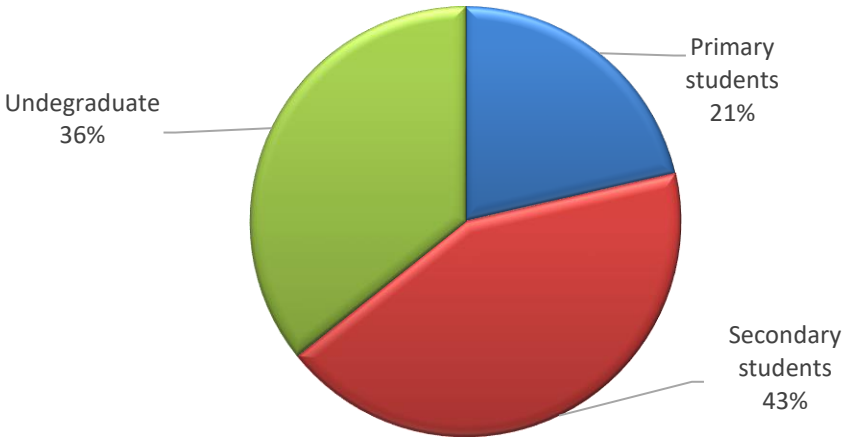

Fig. 2. Percentage of target users

3.2 Theories or Models Underpinning

Theoretical models that underpin the design of educational board games are critical. The theoretical model's current state in gamification was analysed using research on board games in science education. As shown in Table 2, most articles reviewed did not elaborate on the theoretical content or theory upon which they were based. Furthermore, only 2 articles explicitly mentioned their learning theory or model. Meanwhile, the remaining 9 lacked a theoretical foundation for their research. This finding corroborated previous research by Ramesh and Sadashiv [9], who found that most prior studies on gamification in education research lacked theoretical concepts.

An article by Cavalho *et al.,* [30] used constructivism as a theoretical framework as one of the most relevant approaches to educational gamification [40,41]. The constructivist theory emphasises that students actively construct and collect new information while playing. Teachers will act as facilitators to ensure that the information provided is accurate with the science concepts learned. Moreover, Ong and Linaugo [42] asserted that students learn to correctly answer questions and achieve goals through social interaction and peer collaboration. Individual games can assist students in actively gaining experience and knowledge by providing feedback.

The reviewed article by Lin *et al.,* [35] also incorporated Keller's ARCS (Attention, Relevance, Confidence, and Satisfaction) motivational theory. It stated that ARCS could help students achieve their marine science goals by capturing their attention through experiences. Hence, students can understand their learnings and then apply them personally, developing cheerful learning readiness. They may also gain insight into and confidence in the teaching content materials due to their efforts. They could experience the joy of learning and a sense of accomplishment.

3.3 Game Mechanics and Affected Learning Outcomes

The term game mechanics has been frequently used in gamification research. Game mechanics are the rules and procedures that guide players through a game and define how the game reacts to their actions. We believe that reviewing the main game components used in gamified learning and instruction is crucial. This analysis can help researchers determine the types of game elements that they can and should use in their research. According to the analysis, all board games use more than one game mechanic. In general, the board games examined used easy-to-grasp game mechanics that have become popular among students. These standard game rules can prevent students from concentrating on game mechanics rather than content learning [29]. Typically, game-based learning includes problem-solving activities and rewards learners for completing challenges. Many modern

board games have been designed with new mechanics, not just dice throwing and pawns moving in the squares. We discovered that challenges, dice rolling, feedback, points, and progression level were the most frequently utilised game mechanics in gamification using board games in science learning (Figure 3). These mechanics emphasise gameplay as the basis of game design and mechanics as tools a player must use to complete gameplay activities. The challenges used vary depending on the board game's rules. Moreover, Tsai *et al.,* [31] as well as Triboni and Weber [32] reported that the challenge of elements incorporated in gamified questions or problems encouraged participation and increased their focus in class.

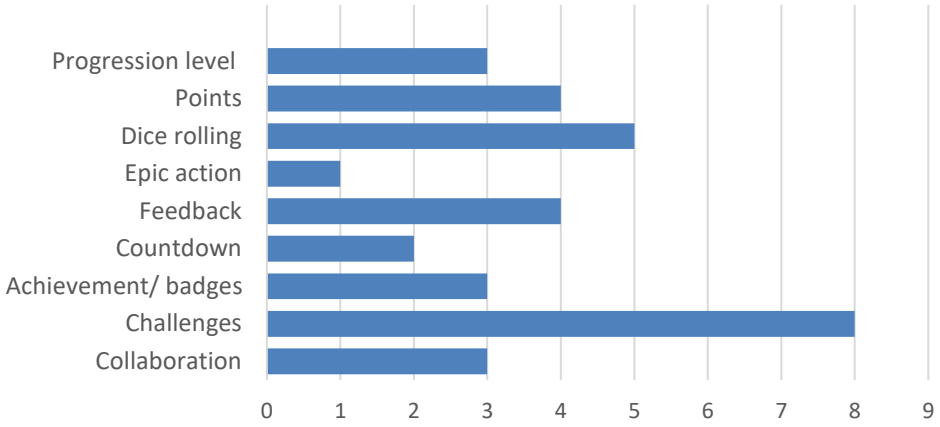

Fig. 3. Frequency of game mechanics

Furthermore, they propose a game obstacle that encourages competition and increases motivation to learn [34,36]. This point is demonstrated by a board game created by Bernado and González [28], in which students must answer questions about the periodic table. The first team to correctly answer the question begins the game as the attacker. The attacking team must solve the problem by launching "shots" at the periodic table elements on the opposing team. If the attack is successful, the student will keep shooting until the opposing team's 'ship' is destroyed. If they fail, the opposing team will become the attackers. *Chemical Battleship* has proven to be a handy and exciting tool for increasing student motivation. In other studies, using the element of challenge to gamify a course resulted in significantly better learning performance. For example, Cardinot and Fairfield [29] improved students' knowledge of astronomy concepts by having them complete questions based on Bloom's Taxonomy, which divides learning into six levels of thinking. Each card requires the players to use different cognitive skills, such as recalling physics facts and comprehending concepts previously learned in the classroom. Gamification requires challenging elements and competitions to encourage students to compete with their peers and win. Every level of the game, as well as the goals and challenges presented in the board game, aroused their interest and strengthened their resolve [39]. Moving a variable space based on a pair of dice's probability distribution is a mechanical example commonly used for board games. The game's result would be predictable and tedious if a fixed number of moves dictates movements. However, this game mechanic did not limit students' knowledge because each space on the board encouraged students to explain, carefully reflect on physics, concepts and engage in active discussion with their peers [30]. Table 3 summarises the game mechanics used in board games as outlined by Taspinar *et al.,* [43] in her article.

Table 3
Summary of game mechanics in articles examined

Game Mechanics	How is it implemented in the game
Quest, challenges, and task	The players must solve a question
Countdown	There is a time limit for completing a challenge
Feedback	Players receive instant feedback on the outcome of a question (e.g., true or false)
Points	For actions such as completing a quest, numerical values are assigned
Progression level	Players can see how far they have progressed on the board(s)
Collaboration	Solving a problem together brings people, perhaps an entire group, together and in touch with one another
Achievement/badges	Achievements are a physical representation of completing a task
Epic meaning	Players will be highly motivated if they believe they are working towards a great goal

As a teaching and learning tool in science, board games aim to improve students' learning abilities. The bar chart in Figure 4 shows that most board games can help improve academic performance in science learning. We found that most of the activities designed in the board games were according to the content of the science curriculum by the respective ministries of education [28,29,32,34,37]. In addition, using board games in science learning can increase understanding of science concepts and broaden students' view of science and its applications in daily life [28,29,37].

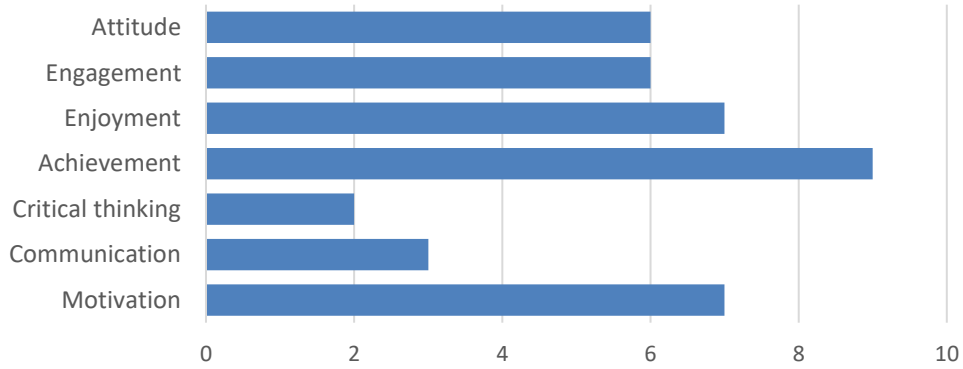

Fig. 4. Frequency of games affected learning outcomes

A good improvement in student achievement may be due to the play environment, which increases their motivation and interest in learning the content. Students easily acquire knowledge in a relaxed atmosphere, and information is absorbed efficiently and effectively [10]. The relaxed atmosphere can help them quickly understand and memorise science concepts, reactions and mechanisms. In addition, the use of board games can reduce anxiety about the exam [34]. Even the game implementation before each exam is also suggested because it can help them identify which concepts to focus on for the final exam [33]. Active self and peer assessment involvement can increase students' self-confidence, increasing knowledge retention [29,33,34].

Many studies suggest that board games can increase motivation and interest in learning [28,31,33,34]. Nevertheless, Lin's *et al.,* [35] study found that students with medium and low achievement levels are less interested in learning activities than students with high achievements. For some students, different teaching methods will affect their interest in learning, while others may not be affected by utilising different teaching methods. She points out that many board games, which are for research or teaching, often emphasise the teaching of knowledge and ignore the game, turning "board games" into "teaching tools" will not arouse students' interest [35].

Students' misconceptions about science education are high due to various factors, including incorrect initial perceptions of students, teaching materials used, and models not relevant to science learning [44]. Through games, misconceptions in science teaching can be identified and addressed without stress and fun for students [45]. Nevertheless, although gamified concepts embedded in gamified environments improve student learning performance, they are often characterised by short-term and immediate effects [29].

4. Conclusions

The purpose of this systematic review was to present an overview of the empirical research literature on gamification in science education using a board game. This review found encouraging support for gamified learning using various forms of board games for science education across various countries, subjects, and targets of students' education. Based on the findings, the use of board games in science education is limited. However, various exciting and informative board game designs have been created to improve students' achievement, engagement, motivation, enjoyment, and thinking skills while learning science. This study contributes to filling the research mentioned above gaps and provides practical insights and direction for future gamification research.

Most gamification studies that use board game instruction have been conducted at the secondary and tertiary education levels. Research at the primary and kindergarten levels is strongly recommended. There needs to be more research on gamified learning in science learning, especially on applying gamification using board games to biology. Next, most prior studies on gamification in education research needed more theoretical concepts. Therefore, researchers are recommended to expand on the theoretical foundation for gamification design in future teaching and learning, focusing on board games.

A systematic literature review identified several benefits of using gamified learning. Improved student achievement, motivation, engagement, and enjoyment are the most significant benefits of using gamification-based learning applications using board games. These successful learning outcomes make a strong case for the application of gamification using board games in science learning. However, the review revealed a need for more research examining the potential for using board games that improve students' critical thinking skills in learning science. Developing conceptual and practical thinking abilities is crucial for students' success in science education [46]. Students collaborate to plan their strategies, solve problems, and achieve their goals efficiently as possible when gamification incorporates collaborative elements. Indirectly, formulating strategy and problem-solving will encourage high-level thinking skills among students. This development of thinking abilities further enhances one's ability to understand a topic more deeply.

This review also identified the game mechanics of challenges, dice rolling, feedback, points, and progression level as the most frequently used and appropriate elements to implement in board games for science learning. The selection of game mechanics is a crucial step in designing a game. Therefore, readers and researchers can use this study's findings to determine which game mechanics to use in their research. It is critical to analyse gamified board game learning and teaching mechanics. Action points, role-playing, simultaneous action selection, trading, and tile placement are all exciting game mechanics that could be used in gamified learning using board games.

Since the use of board games in learning and education is familiar, information on its current state of play as a science teaching method can be gathered, resulting in possible guidelines and directions for future research on this topic. The interested parties, science experts, researchers, and the general public, may form long and short-term complications from the approach outlined as a result of the review. Rather than waiting for technology to advance further, researchers and instructors interested

in gamifying their classes are encouraged to take action immediately. Game mechanics can be used to engage and motivate students at any level and subject, regardless of the digital devices available. They can still implement innovative learning instructions without using technological devices. Students worldwide, particularly rural students, can benefit from innovative pedagogical concepts even when no high-tech equipment is used.

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