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# Game-Based Learning Application in Chemistry Learning: A Systematic Literature Review

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**Abstract:** Game-based learning attention to the design of learning and game that can help the learning process be fun, creative, innovative, and not boring. This research aimed to review empirical research articles in chemistry learning using the Systematic Literature Review (SLR) method is to identify, analyze, and interpret the findings on the research topic published from 2017 to 2021. Twelve articles were identified through a search engine providing international and national journal pages that could be accessed using ERIC and Scopus databases. The articles studied in terms of objectives, learning design, and game implementation in learning. The results review focuses on increasing knowledge, understanding concepts, learning outcomes, critical thinking, motivation, emotions, literacy, and student independence. Using digital games is more widely applied in chemistry learning because of interest in educational technology having a better evaluation of the subject matter studied and the achievement of a deeper understanding.

**Keywords:** game-based learning, chemistry learning, literature review.

***Abstrak:*** *Pembelajaran berbasis game memperhatikan rancangan pembelajaran dan permainan yang dapat membantu proses pembelajaran yang menyenangkan, kreatif, inovatif, dan tidak membosankan. Penelitian ini bertujuan untuk meninjau artikel penelitian empiris tentang pembelajaran kimia berbasis permainan menggunakan metode Systematic Literature Review (SLR) yaitu mengidentifikasi, menganalisis dan menginterpretasi temuan-temuan pada topik penelitian tersebut yang diterbitkan dari tahun 2017 hingga 2021. Dua belas artikel diidentifikasi melalui mesin pencari penyedia laman jurnal Internasional dan nasional yang dapat diakses menggunakan database ERIC dan Scopus. Artikel dikaji dari segi tujuan, desain pembelajaran, dan implementasi game pada pembelajaran. Hasil review berfokus pada meningkatkan pengetahuan, pemahaman konsep, hasil belajar, berpikir kritis, motivasi, emosi, literasi, dan kemandirian siswa. Penggunaan permainan digital lebih banyak diterapkan dalam pembelajaran kimia karena minat teknologi pendidikan yang lebih besar dan memiliki evaluasi yang lebih baik mengenai materi pelajaran yang dipelajari dan ketercapaian pemahaman yang lebih mendalam.*

***Kata kunci:*** *pembelajaran berbasis game, pembelajaran kimia, reviu literatur.*

## ▪ INTRODUCTION

Game-based learning often involves students in game-playing activities, game content, and ways to solve problems in games to improve students' knowledge and skills to pose challenges or emotions to students. The expected emotions are positive emotions generated by students so that they can increase their enthusiasm for learning to take part in learning. The potential of game content is well designed to be able to improve the

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teaching and learning process (Wang & Zheng, 2020). Games in learning are also very motivating and increase the effect of positive emotions for learning on students (Sari et al., 2017). Game-based learning is not only designing a game so that students only play but also designing learning activities that can gradually introduce a material concept and can guide students to guide until the end of the learning process (Pho & Dinscore, 2015).

The active role of students in the learning process has direct involvement with the learning model applied by educators. This is often found because students often experience an atmosphere and enthusiasm for learning that is lacking in absorbing and accepting the material presented by the teacher. High school chemistry learning materials have many concepts that are quite difficult for students to understand, making many students less confident in understanding the material because it is abstract, simplified from the actual situation, sequentially, and tiered (Lutfi & Hidayah, 2021).

Learning science, especially chemistry in schools using a game-based learning model is an effective method to support students' learning of science knowledge (Wang & Zheng, 2020). The use of appropriate learning methods and strategies by educators will determine a good and effective chemistry learning process (Sari et al., 2017). Previous research has shown that game-based learning has a positive effect on student learning and can increase their self-efficacy so that more and more researchers and educators are starting to integrate game-based learning into science classrooms on both digital and non-digital types of games (Wang & Zheng, 2020).

Efforts can be made so that students can understand the material presented by educators by creating digital and non-digital game-based learning methods and media that are fun, challenging, motivate students, and even stimulate good memory. Games can integrate learning with fun that can motivate students to have a passion for learning science. Games can give a distinct impression on students' memories and provide a pleasant learning atmosphere without leaving the learning objectives and student learning outcomes can be achieved as expected (Lutfi & Hidayah, 2021).

Game-based learning is very important for teachers because it not only emphasizes problems on cognitive but also effective psychomotor processes. That is, students' motivation will greatly determine the success of their learning, namely intrinsic and extrinsic motivation. Intrinsic motivation is related to a love for learning and an interest in mastering a subject. While extrinsic motivation is related to motivation that comes from outside ourselves, such as values, parental pressure, work or school, friends around, and so on (Valls-bautista, 2021).

Based on research conducted by Cahyana et al, (2017), the effectiveness of learning by implementing mobile device-based learning which is an alternative learning med that can design learning to create a pleasant atmosphere, easy to understand, and students can access easily. Research on android-based educational games conducted by Sari et al, (2017), on chemical-oriented colloidal material through the analysis and design stages with the characteristics presented in the form of questions that are integrated with games equipped with interesting pictures and animations that can improve students' chemical literacy.

Various game designs are designed in chemistry learning, such as the use of technology-based learning tools, this game aims to help students interact in the organizational experience by learning skills and knowledge to improve literacy (Kargbo, 2017). Literacy in reading is very important so that students explore a lot of reading sources that support the subject matter given by the teacher. By increasing cross-

disciplinary literacy, teachers can use game-based tools to motivate and engage students more in their learning.

Game-based learning research is widely studied by researchers to be developed and has different variations and characteristics. The study conducted by Chen et al, (2020) in the results of their research shows that game-based learning does not only discuss learning outcomes and motivation, but the positive and negative emotions of students in participating in the learning process are also very influential. Teachers as facilitators must be able to create innovative learning designs such as collaborative games to maintain positive emotions in students and facilitate conceptual learning for students with low achievement abilities. This study shows that conventional practice impairs the learning emotions of middle and high-achieving students, even though their concepts improve (Chen et al., 2020).

A literature review conducted by Li & Tsai (2013) with the research topic Game-Based Learning in Science Education, mostly digital games are used to promote knowledge or scientific learning concepts and are applied to facilitate students' problem-solving skills. only a few studies explore the outcomes of aspects of the scientific process, influence, engagement, and socio-contextual learning. In contrast, research has a wider scope of analysis focus including increasing knowledge, understanding concepts, learning outcomes, critical thinking, motivation, emotions, literacy, and student independence.

The latest findings contained in this study provide a strong understanding of game-based learning, especially in chemistry learning which emphasizes that the implementation of the use of games used is adjusted to the needs and objectives of learning as well as other learning methods by developing and improving game design systematically by adopting research methods by paying close attention to game design and design in learning. Each learning method and strategy has its strengths and weaknesses. Therefore, the use of the characteristics of an effective method is based on the design and mastery skills of the teacher to apply games in chemistry learning.

This research can be done so that it becomes the latest research trend regarding games-based learning that can be applied to chemistry learning materials. Therefore, the research objectives and appropriate learning methods will provide an overview of the current interest in game-based learning research. Two important aspects that have not been reviewed in the research discussion are how games are designed and implemented. Second, the science of pedagogy or instructional design embedded in the game must play an important role to make learning effective. The learning outcomes emphasized by games-based learning researchers are the focus of the current review.

### *Research Question*

The following three main research questions that the study seeks to answer: (1) How is the effectiveness of the game-based learning method used in chemistry learning? (2) What types of games are there in learning chemistry through games-based learning? (3) What are the characteristics of games-based learning that are effective in teaching chemistry to students?

## ▪ METHOD

The method of writing review journals in a systematic search for literature data uses the Systematic Literature Review (SLR) method was a method that has stages of identifying, evaluating, and interpreting the findings and findings of the literature study used to answer research questions that have been determined (Kitchenham & Charters,

2007). In this review, the Eric and Scopus databases were used to obtain games-based learning research articles obtained from providers of international and national journal pages that can be accessed freely. Searching for literature data using the Eric database (Education Resources Information Center) is an online digital library for research and educational information. we can explore and search for the latest, updated, and quality educational articles. Searching for literature data also uses the Scopus database which is a library database that indexes abstracts and citations of scientific journal articles owned by Elsevier, a major journal publisher in the world. The collection of literature data that was studied was then analyzed from October 1 to November 19, 2021.

In this study, data used included the keywords games-based learning in chemistry, games-based learning, and application games-based learning. After searching for keywords, the researcher reads the title and abstract of the article to select articles that meet the following inclusion criteria: (1) Articles about games-based learning in chemistry learning; (2) The range of the year the journal was published is from 2017-2021 (last 5 years); (3) Publication of reputable, accredited, and full-text articles. This study had exclusion criteria, namely research journals with problem topics that were not related to game-based learning in chemistry learning as well as journals published before 2017. After the screening process, the results of data extraction will be known with certainty the initial amount of data that meets the requirements to be analyzed and studied more deeply. Furthermore, the data obtained was paraphrased again the results from the articles that have been obtained and presented in this article.

The search results found 4120 articles related to the topic under study. Then re-selection based on the inclusion criteria obtained 608 articles. Furthermore, the data were sorted by assessing and considering the suitability of research topics, abstracts, and research content so that 12 articles were obtained consisting of 6 articles obtained from the Eric database and 6 articles obtained from the Scopus database which have met all requirements. Inclusion criteria can be seen in Table 1.

**Table 1.** Selection of Articles and Journals

| Author | Selected Journal | Database |
|---|---|---|
| Chen et al., (2020) | International Journal Of Science Education (Q1) | Eric |
| Cahyana et al., (2017) | Eurasia Journal of Mathematics Science and Technology Education (Q2) | Eric |
| Hilliard & Karbgo (2017) | International Journal of Education and Practice (Q4) | Eric |
| Tsai et al., (2020) | Education Sciences (Q2) | Eric |
| Karbgo et al., (2021) | European Journal of Science and Mathematics Education | Eric |
| Fitriyana et al., (2020) | Cakrawala Pendidikan (Q3) | Scopus |
| Gupta (2019) | American Chemical Society (Q1) | Scopus |
| Clapson et al., (2020) | Journal Of Chemical Education (Q2) | Scopus |
| Luthfi et al., (2021) | Journal of Physics: Conference Series (Q4) | Scopus |
| Wang & Zheng (2020) | Springer Nature Switzerland AG (Q2) | Eric |
| Sari et al., (2017) | Journal of Physics: Conference Series (Q4) | Scopus |
| Wardani et al., (2017) | Jurnal Pendidikan IPA Indonesia (JPII) (Q2) | Scopus |

The article search process described above can be seen in the flow chart in Figure 1 below.

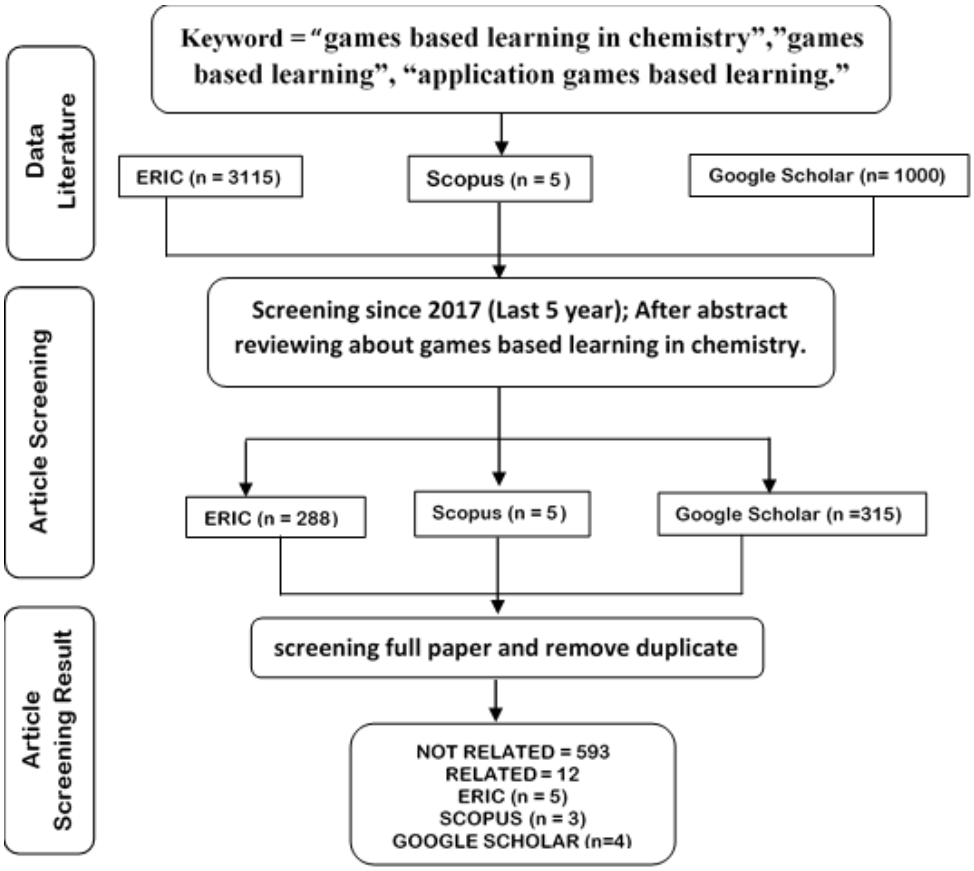


**Figure 1**. Search Flowchart and Article Search

## ▪ RESULT AND DISCUSSION

The results of the analysis of the literature study research using a learning perspective focused on learning knowledge, learning outcomes, motivation, student literacy, understanding concepts, emotions, and students' critical thinking.

First, the effectiveness of using game-based learning in chemistry learning, the types of games reviewed, and the characteristics of effective methods in learning chemistry.

### The Effectiveness of Game-Based Learning in Chemistry Learning

Information on the literature study in terms of abstracts, background, research questions, objectives, methods, and research results is presented in the following table. Among the 12 articles reviewed, 4 were published in 2017, 1 article was published in 2019, 5 articles were published in 2020 with 2 articles were published in 2021. The following games-based learning methods in chemistry learning can be seen in Table 2.

**Table 1.** Game-Based Learning Method in Chemistry Learning

| Author | Method | Result |
|---|---|---|
| Wardani et al., (2017) | The use of interactive learning media Chemistry Board Game or also called Al Chemist Knight. | Improve students' critical thinking skills and understanding of concepts in the effective category. |

| | | |
|---|---|---|
| Cahyana et al., (2017) | Use of Mobile Game-Based Learning (M-GBL) media | M-GBL media has a positive effect on student chemistry learning outcomes. |
| Hilliard & Karbgo (2017) | The use of games through the application of video game-based technology. | Can increase students' motivation and literacy across disciplines. |
| Sari et al., (2017) | The use of android-based educational game media on colloidal material. | Can improve students' chemical literacy. |
| Gupta (2019) | Use of Molebots games or first-person-shooter games. | Students find games effective in learning chemical nomenclature. |
| Fitriyana et al., (2020) | Android-based games in face-to-face learning (ABG-FTFL). | There is a positive influence of technology-based games on self-efficacy and learning achievement |
| Clapson et al., (2020) | Card games, board games, and bioplastic synthesis activities. | Can improve understanding of chemical concepts in polymer chemistry |
| Chen et al., (2020) | Use of cards, board games, and puzzles, and use of conventional paper and pencil exercises. | Can increase students' positive emotions and facilitate conceptual learning for low achievers. |
| Tsai et al., (2020) | Element Enterprise Tycoon (EET) scientific board game design implementation | Empirical data shows that it can improve students' understanding of chemical concepts and better performance. |
| Wang & Zheng (2020) | Digital and non-digital game-based learning. | Can improve content knowledge assessments and report higher self-efficacy than the traditional lecture group. |
| Karbgo et al., (2021) | Use of project-based learning media and WebQuest | The pedagogical approach to students can be improved. |
| Luthfi et al., (2021) | Use of smartphone-based games. | Able to eliminate boredom when studying chemistry and make the retention power of learning outcomes high. |

Based on Table 2, the results of research in learning chemistry using games-based learning models can be said to be effective because in research conducted by Cahyana et al, (2017) learning chemistry using mobile-based game media (M-GBL) can support learning practical, fun, interesting, can be used anywhere, and by the facilities owned by students. M-GBL media had a positive effect on student chemistry learning outcomes when applied to groups of students who have high learning independence. The use of digital games as well as the Chemistry Board Games (CBG) improved students' critical thinking skills and understanding of concepts in the effective category (Wardani et al., 2017). The use of cards in games was also able to maintain positive emotions of students in learning Chen et al, (2020) and improved engineering concepts related to chemistry (J. Tsai et al., 2020).

The effectiveness of game-based learning on chemistry learning by Gupta (2019) shows the results of research that students found games effective in learning chemical nomenclature and had a preference for visual learning compared to textbooks as a medium. The use of android-based educational games by Sari et al, (2017) which were visualized with games equipped with pictures and animations so that it improved students' chemical literacy can make learning more effective and increase students' self-efficacy

and learning achievement (Fitriyana et al., 2020). Not only android-based games or digital or non-digital game combination technology also increases student self-efficacy, mastery of student knowledge, and skills (Wang & Zheng, 2021). This was different from Sousa & Costa (2018) who said the same thing that the potential of video games in learning was increasingly studied, documented, and maintained will make learning more lively, and fun. The relevance of video games in the learning process and cognitive enrichment was increasingly being studied, although it is a relatively new field.

Lutfi & Hidayah (2021) effectively used game-based learning using smartphone-based games can eliminate boredom when studying chemistry and increase learning motivation to make the retention power of learning outcomes high. Using smartphones in learning in the form of mobile applications that can help students evaluate their learning abilities was an important need in education. Today, smartphones were the most frequently encountered and used platform in interesting and attractive e-learning (Akour et al., 2020).

The game method was a way of presenting learning materials in the form of games or games that vary. The various methods used have potential as media that were very possible to be used as motivational and innovative learning media for students. The ability of students to complete game content can affect student learning outcomes in the cognitive and emotional aspects of users simultaneously. It can be a strength as a learning medium (Wibawa et al., 2021).

Game-based learning was learning that was carried out directly using a learning-by-doing pattern. This learning challenges the players who were directly involved in the game to be able to pay attention to the consequences of the player to get past every obstacle to solving the problems that exist in the game content. The pattern of the game is designed to avoid the failure factors experienced by the players to encourage other players not to repeat failures in the next stage (Wibawa et al., 2021).

The use of games in learning, especially in chemistry, had enormous potential in building student motivation while studying. The role of capable and skilled teachers in classroom management in the learning process was needed to motivate students to follow conventional learning. Students who learned to use game-based learning methods were more successful than students who were taught using conventional methods.

**Types of Games in Games-Based Learning**

The focus of learning in literature studies is identified through research objectives, research questions, and research results. Although various results are usually collected and analyzed in the studies under review, the main learning focus of these studies is on the study of chemistry. The identified learning focuses are then classified into three categories taken from the chemistry learning literature, namely the use of digital games, non-digital games, and a combination of digital and non-digital games in a learning process. Digital games that emphasized the development and use of game types using applications and technology. Digital game-based games used such as Chemistry Board Game or Al Chemist Knight, Mobile Game-Based Learning (M-GBL), educational games based on android and smartphones, Molebots games, and WebQuest. The non-digital games used include the use of cards, boards, puzzles, and a scientific board game called Element Enterprise Tycoon (EET). The following types of games used in learning chemistry can be seen in Figure 2.

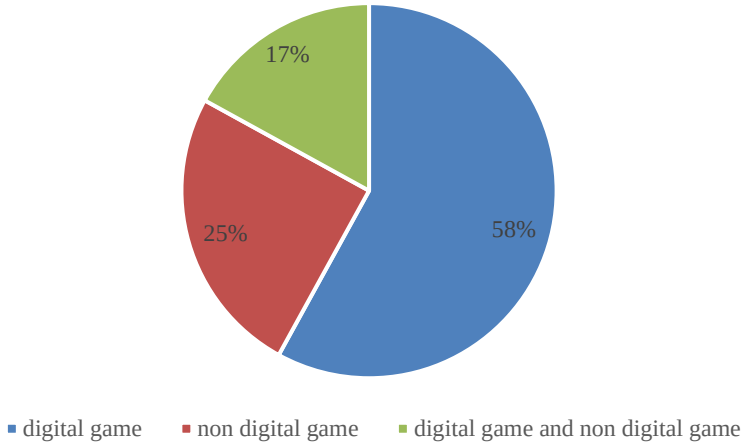


**Figure 2.** Graphics of Game Types in Chemistry Learning

Digital technology in today's rapidly developing scientific developments has enabled a large immersion process so that there was more and more hope for utilizing and developing digital games for the learning process since the beginning of technology development. Based on Figure 2 above, digital game users were the most widely utilized and developed than non-digital games (Hidayat, 2018). This was due to greater interest in educational technology and had a better evaluation of the subject matter studied and the achievement of a deeper understanding.

The potential use of digital games in the form of educational games by Fitriyana et al, (2020) teaches science learning, especially chemistry as an innovative medium in the chemistry learning process. This educational game increases student attention, provides an interactive learning process, and provides an innovative learning environment. Students can follow rules and strive to achieve challenging goals that encourage student self-efficacy. In addition, the presence of Android-based games increases the use of mobile learning as a source of independent learning. This independent learning resource made students more confident in their abilities. Learning motivation and efficiency can be increased through educational games and the introduction of recently enriched game elements that made games increasingly popular to develop (Liu & Chen, 2013).

Research by Clapson et al, (2020) said innovative learning can be designed using card games, board games, and bioplastic synthesis activities. Student learning outcomes can be evaluated by applying a unique molecular group formation quiz that students like. Innovative learning can also be done by applying educational games and experiential learning experiences were integral alternative learning tools, which were becoming increasingly popular in post-secondary classrooms. As the introduction of green chemistry concepts, and with the expansion of polymer chemistry, continues to grow, the need for alternative learning tools that explained the synthesis, function, and design of polymers is increasing and can assist students in understanding polymer chemistry concepts and materials.

Molebots game first-person-shooter focused on chemical nomenclature by Gupta (2019) said learning was not always memorizing terms and definitions. Skills and thought processes to respond appropriately become challenges and problems so that they became pressure in various situations that usually occurred in the learning process. Effective and interactive games provided experiences for students to be actively motivated and involved in the learning process. In contrast to teaching carried out by lecture methods and other

traditional approaches which were more boring for students, well-designed games directly engage and capture their interest to achieve the expected learning objectives. In addition, Game-Based Learning can save costs compared to teaching in the laboratory, because it required active learning media, tools, and materials that were quite expensive and must meet individual learning needs. After all, the speed of teaching in educational games can be adjusted to the needs of students.

In contrast to the research conducted by Tsai et al, (2020) in chemistry learning using element cards containing elements in the periodic table, technical cards such as food and beverage processing techniques, semiconductor fabrication techniques, synthesis reactions, extraction/purification techniques, and nuclear power plants. The product card covers a total of 55 products, such as food, electronic products, cooking utensils, batteries, medicine, energy, transportation, chemical raw materials, and power generation. Product card information must include the product name, product description, and application method. Chance cards consist of money cards, sales cards, and action cards. The game was designed to motivate students not only to pick up information about chemical elements but also to be proficient in chemistry. In addition, games created opportunities for group interaction and competition to engage students in studying the elements of chemistry as they would in a regular science curriculum.

Many studies provide reviews regarding the use of digital games as a team both virtually and in the real world. However, several studies had also used non-digital games as a means to apply game content in learning. Some combine digital and non-digital games in one chemistry lesson conducted by Valls-bautista (2021) where combining digital and non-digital games was a unique and powerful way of combining student work project-based learning and applying WebQuests to teach the contents of the periodic table to high school students.

**Characteristics of Effective Games Based Learning**

Based on the research results of Wibawa et al, (2021) showed that the percentage of 95.8% is the implementation of game-based learning with quizzes learning media. Students are expected to be able to achieve the highest score to become winners so that they can inspire students' enthusiasm in the learning process. Most of them agree with the holding of Game-Based Learning because it can streamline learning.

Game-Based Learning was an appropriate learning method because it had the characteristics of using teaching materials assisted by technology and achievements in completing learning evaluations. Learning evaluation was specially designed using game applications that can help the learning process be creative, innovative, fun, and not boring. This can increase students' enthusiasm for learning through a gameplay approach to hone students' thinking skills in solving problems that exist in in-game content on chemistry. The problems created in the game can be taken from real everyday life and integrated into the fantasy side to make the flow of conflicts or problems more interesting to solve.

The game method was a way of presenting teaching materials or subject matter with various forms of games as done by Cahyana et al, (2017) using M-GBL media as a practical, fun, interesting chemistry learning medium, can be used anytime and anywhere, and many students have this digital facility that makes it easy for students to access. The results showed that the M-GBL media had a positive effect on student chemistry learning outcomes in the group of students who had high learning independence. In the group of students who had low learning independence, the learning achievement of students who

are taught using M-GBL media was lower than students who were taught using traditional media because of the independent learning factor.

Research conducted by Wardani et al, (2017) developed a digital game based on the Android Chemistry Board Game (CBG) or Al Chemist Knight. This media is used to improve cognitive learning and critical thinking. In addition, it also aimed to evaluate the response of students in learning chemistry through the topic of alkane derivative compounds. This game development was adapted from the game development process procedure in a mobile 3D presentation. The collection of evaluation data models that were applied was pre-test and post-test in the test class. The results showed that in the pretest the average learning outcome was 34.35 with a classical target of 5%. While the average posttest learning outcomes were 80.51 with a classical target of 85%.

Non-digital game methods in the form of student projects and digital games using a research WebQuest conducted by Valls-Bautista (2021) to evaluate students using an active methodology to teach the contents of the periodic table of high school can improve the pedagogical approach.

However, this literature review found a gap between students' possible learning experiences in games and the learning outcomes or learning focuses they assessed. For example, searches conducted on virtual or digital games ask students to use their scientific knowledge and concepts, identify problems and draw conclusions with solid evidence. This game process can provide opportunities for students to improve literacy, critical thinking, conceptual understanding, and motivation. However, their ability to evaluate learning outcomes is still limited to knowledge. In addition, games that involve many players can provide opportunities for collaborative learning among students. Students were only asked to explore the game world individually and participate in group or class discussions during learning (Li & Tsai, 2013).

## ▪ CONCLUSION

The effectiveness of a learning method and strategy has its strengths, and weaknesses, so decisions regarding the use of the characteristics of an effective method are based on the design, design, and mastery skills of the teacher to apply games in learning. There are types of games that can be applied in chemistry learning through game-based learning such as digital games, Chemistry Board Game or Al Chemist Knight, Mobile Game-Based Learning (M-GBL), educational games based on Android and smartphones, Molebots games, and WebQuests. Non-digital games using a scientific card, board, puzzle, and board game called Element Enterprise Tycoon (EET). The characteristics of games-based learning that are appropriate are by using teaching materials or subject matter assisted by technology or with traditional media, and displaying several evaluation achievements using applications that are creative, innovative, fun, and not boring so that they can teach chemistry to students well and effectively.

The literature review reviewed in this study was limited to articles according to the inclusion criteria described previously. Although the sample articles are reviewed in this study have several relatively small research focuses, processes, and criteria Sampling was applied carefully to reduce biased sample selection. Moreover, since the current review is not trying to be inclusive but to provide a systematic review Game-Based Learning, the analysis in this review can provide a framework for the integration of future research exploring the literature Game-Based Learning. Suggestions for further research in the reviewed studies, digital games can be developed and utilized independently or combined

with other learning activities such as class discussions or group discussions interesting and innovative way. Digital games also have the potential to connect the world real and game world by adopting AR technology or Kinect or through in-game or world practice communities real. How do students perceive and what can they take advantage of this different Game-Based Learning experience must explore further.

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