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# Systematic Literature Review on The Use of Gamification Approaches in Mastering the Periodic Table of Elements (Chemistry)

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**ABSTRACT**

**Background**: Gamification applications serve as tools for students to independently construct knowledge about lesson content, potentially surpassing achievements gained through conventional methods. The study of gamification is especially important for learning the Periodic Table of Elements, a fundamental topic in chemistry.
**Purpose**: This article aims to explore the application of gamification in learning the Periodic Table of Elements between 2019 and 2023.
**Methods**: A systematic literature review was conducted using online databases such as Scopus and Web of Science to gather relevant information on the subject. Keywords like "Periodic Table," "Teaching Approach," and "Gamification" were used to search for studies related to the topic. The review included literature from 14 countries: Pakistan, Indonesia, Japan, Spain, the United States, Macedonia, Israel, Morocco, Brazil, Portugal, Croatia, Mexico, and Malaysia.
**Results**: The review focused on identifying commonly used gamification methods and assessing the impact of gamification on motivation, academic achievement, and usability. The findings revealed that board games, digital cards, puzzles, and Virtual Labs were the main gamification approaches used. A comprehensive analysis of 18 literature review articles showed that motivation was the primary impact studied in mastering the periodic table using gamification.
**Conclusions**: This study has significant implications for Chemistry teachers, STEM researchers, and the Teacher Education Division in Malaysia's Education Ministry. By understanding learners' preferences, educators can tailor their instructional methods to better meet students' specific needs.

**KEYWORDS**

Teaching Approach, Gamification, Periodic Table

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## INTRODUCTION

Presently, there is a notable decline in the number of students opting for Science, Technology, Engineering, and Mathematics (STEM) subjects in both schools and higher education institutions (HEIs), as reported by the Ministry of Energy, Science, Technology, Environment and Climate Change (MESTECC, 2019). This decline poses a potential shortage of skilled individuals for STEM-related industries. Given Malaysia's aspirations to become a developed country by 2020 and the significance of STEM outlined in the TN50 plan, the importance of these subjects cannot be overstated (Phang and Sipon, 2017). The STEM field encompasses various subjects, including Science,

Physics, Mathematics, Chemistry, Biology, Computer Science, Design, and Technology.

According to the TIMSS International Benchmarking Science Achievement Report (2019), a significant proportion of fourth and eighth-grade students, 92% and 85% respectively, perform at a low benchmark (400), indicating limited comprehension of scientific concepts and restricted access to fundamental scientific knowledge. Many countries provide students with a minimum level of science education, and Malaysia ranks among the lowest with an average grade of 460 for eighth graders. The PISA 2018 report reveals that 78% of students attain at least level 2 in Science, enabling them to identify and explain scientific phenomena and draw conclusions.

Science Education concentrates on process-oriented learning, emphasising scientific skills that encompass critical thinking and science process skills. Science process skills are essential for students to learn and master through the application of strategic activities that facilitate meaningful learning and practical application in everyday life. These skills also prove vital during the research process, enabling the creation of scientific products encompassing concepts, principles, laws, and theories (Prayitno et al., 2017). Acquiring the appropriate skills and attitudes can enhance students' effectiveness in thinking. Malaysia's performance in this aspect is relatively low. However, there has been significant improvement in science literacy based on the PISA 2018 report, with an average score of 438 compared to 420 in PISA 2012. The report indicates that students primarily employ basic scientific knowledge to identify scientific information, formulate research questions, design experiments, interpret data, and draw conclusions based on the data obtained. Consequently, various modifications have been introduced in the national education system to enhance students' mastery of chemistry, particularly the Periodic Table, and one such approach is gamification.

Chemistry is a scientific discipline that utilises models or graphics to understand the phenomena observed in everyday life (Lee, 2013). However, it is often considered a challenging subject for some students, as highlighted in Osman's study (2015). Othman and Talib (2019) attribute this difficulty to the tendency of students to rely on rote methods without grasping the abstract concepts. Moreover, the lack of mastery in teaching chemistry among teachers creates a monotonous and inflexible learning environment. Consequently, it is crucial for educators to adopt an engaging and student-centered approach that is carefully planned.

The implementation of gamification in the PAK21 approach has shown positive effects on the learning process (Qian & Clark, 2016). Additionally, Nurfarhana Rosly et al. (2016) note that technology has become deeply ingrained in students' lives and aligning gamification elements with technology fulfills their inherent desires for fun, competition, and achieving success as in a game. The goal of gamification aligns with the objectives of teachers, who aim to create a better learning environment where students actively participate, comprehend the content, and retain the knowledge, thereby enhancing performance (Pretty M., 2018).

The periodic table holds significant importance in science education across all levels as it provides information about the fundamental physical and chemical properties of different elements that constitute matter. The periodic table (PT) is the most commonly used tool for information about chemical characteristics, including their names, symbols, states of aggregation, metallicity, atomic numbers, oxidation states, electronegativity, and electronic configurations (Adam & Mark, 2018). Traditionally, the periodic table is introduced historically, highlighting the properties of elements and the gradual development of the table over time. This tool serves as a fundamental cornerstone in chemistry and all branches of Science, making it essential in teaching and learning science at all educational levels.

Research and studies indicate that teaching chemistry often follows a traditional approach, focusing primarily on memorising names and formulas. This approach alienates students from real-

world applications, making the subject difficult and uninteresting. Among the challenging topics in chemistry, the periodic table stands out as many students struggle to comprehend its properties and the arrangement of elements. Games have emerged as an alternative to address this difficulty, providing teachers with didactic and pedagogical tools to engage students interestingly and dynamically. In this context, this study aimed to examine the acceptance and impact of the Periodic Domino game on understanding the periodic table in a classroom setting. Field research was conducted with 19 ninth-grade students at Centro Educacional Espaço Criativo School in Quiterianópolis-CE. Data was collected through an evaluation questionnaire, and a graphical presentation of the results revealed that the game piqued the students' interest, with 64% of them assigning the highest score, significantly contributing to their better understanding of the content according to 95% of the students.

However, the process of learning the periodic table is often perceived as dull, mechanical, and lacking engagement for students. Familiarising oneself with the facts related to the periodic table, such as element names, symbols, metallic properties, electronegativity, and so on, can appear tedious and monotonous depending on the teaching approach employed. One method to invigorate students is through gamification, where learning occurs almost unconsciously due to playing games.

With the rapid advancements in mobile technology, new opportunities have emerged to incorporate the latest digital innovations into teaching and learning practices. While studies utilising computer-based educational software and simulations have been conducted, mobile applications in education are still relatively new. However, specific educational applications have shown promise in enhancing teaching effectiveness and shaping student characteristics (L S Ang et al., 2018). Mobile applications can be utilised to captivate science students by providing a flexible platform for learning topics of interest. They are an alternative means to supplement traditional teaching methods and can dedicate more time to the subject matter.

If students lack motivation to learn the periodic table, their understanding of chemistry can be adversely affected. To enhance student motivation, interest, and attention, teachers should provide interactive and engaging learning materials that incorporate elements such as sound, background voices, animations, videos, and other captivating features (Anuar Ahmad, 2020). When students possess motivation and interest in the subject they are studying, they are more likely to achieve positive outcomes as they concentrate and exert effort in their learning (Lee, 1991). Therefore, an intriguing and captivating approach to learning is necessary to boost students' motivation and understanding of chemistry. Consequently, the researcher recognised the need for a study to evaluate the effectiveness of the gamification approach in enhancing student motivation and knowledge of the periodic table, developing a modified model based on the conceptual framework of Digital Game-Based Learning in science education adapted from Wong & Osman (2018) as the foundation for this study. Furthermore, it is worth noting that previous studies have predominantly focused on assessing students' levels of motivation and understanding in chemistry without thoroughly examining the integration and effectiveness of gamification. Thus, this study will also determine how much the gamification approach effectively enhances student motivation and understanding in mastering the periodic table.

## RESEARCH METHODOLOGY

This chapter outlines the procedures followed in conducting the study. A literature review involves collecting, identifying, analysing, formulating, and critically evaluating the relevant issues to be examined (Hazari et al., 2017). According to Siddiqi et al. (2016), a systematic literature review

(SLR) is used to understand the phenomenon surrounding the topic. This study used the keywords "gamification" and "periodic table of elements" to obtain research data.

**Search Strategy:**

Researchers employ detailed and comprehensive search techniques to locate articles and journals related to gamification in the periodic table of elements. Data sources are obtained through electronically searchable databases. Two electronic databases, namely Scopus, and World of Science (WoS), are selected for the search. The selection of Scopus databases begins on June 4, 2023, as they provide access to all Social Science Citation Indexed (SSCI) and Science Citation Indexed (SCI) journals. The search string: ( ("Learn* model" OR "guidelines") AND ("mobile" OR game* OR gamification*) AND ("periodic table" OR "periodic table of elements")

**Acceptance Criteria:**

The criteria for accepting articles include empirical studies relevant to gamification in the periodic table of elements. The publication year for the selected papers falls between 2019 and 2023. Accepted articles include those published in journals or conference materials. The accepted language for the articles is English or Malay.

**Rejection Criteria:**

Studies lacking empirical evidence or unrelated to the investigation topic are rejected. Articles published before 2019 are not considered for selection. Book chapter reviews and reports without full-text availability are also excluded. Non-English and Malay articles are not considered for inclusion.

**Data Extraction**:

Selected articles must meet the criteria mentioned above to ensure accuracy. Each relevant and applicable theme is coded using parameters such as study design, findings, and measurement methods.

**Article Selection Process:**

This systematic review follows the methodology that Khan, Kunz, Kleijnen & Antes (2003) proposed. The article selection process consists of five stages:

Step 1: Formulate survey questions:
Clear and organised questions are formulated before the study. The two questions in this review are to identify the commonly used gamification methods in mastering the periodic table (chemistry) and to determine the impact of gamification on motivation, academic achievement, and student attitude.

Step 2: Identify relevant articles:
A comprehensive search is conducted, encompassing various sources (both computerised and printed) without language restrictions. The selection criteria align with the research questions, with exceptions mentioned above.

Step 3: Assess study quality:

The quality assessment of the systematic review includes three inclusive criteria: research questions, research methodology, and research findings. This evaluation aims to ensure that the systematic review can address the research questions by analysing the articles and their results to facilitate further discussions.

Step 4: Summarise the evidence:
Data synthesis involves tabulating study characteristics, quality, and effects. Statistical methods are employed to explore differences between studies and combine their results, potentially through meta-analysis. Plans are made to explore heterogeneity and its sources (as mentioned in Step 3). A subgroup meta-analysis may be considered if an overall meta-analysis is not feasible.

Step 5: Interpret the findings:
The issues highlighted in each of the previous four steps are addressed. An exploration of publication bias and related biases should be conducted. The examination of heterogeneity should help determine the reliability of overall summaries. If not possible, effects observed in high-quality studies can be used to conclude. Any recommendations made should be evaluated based on the strengths and weaknesses of the evidence obtained.

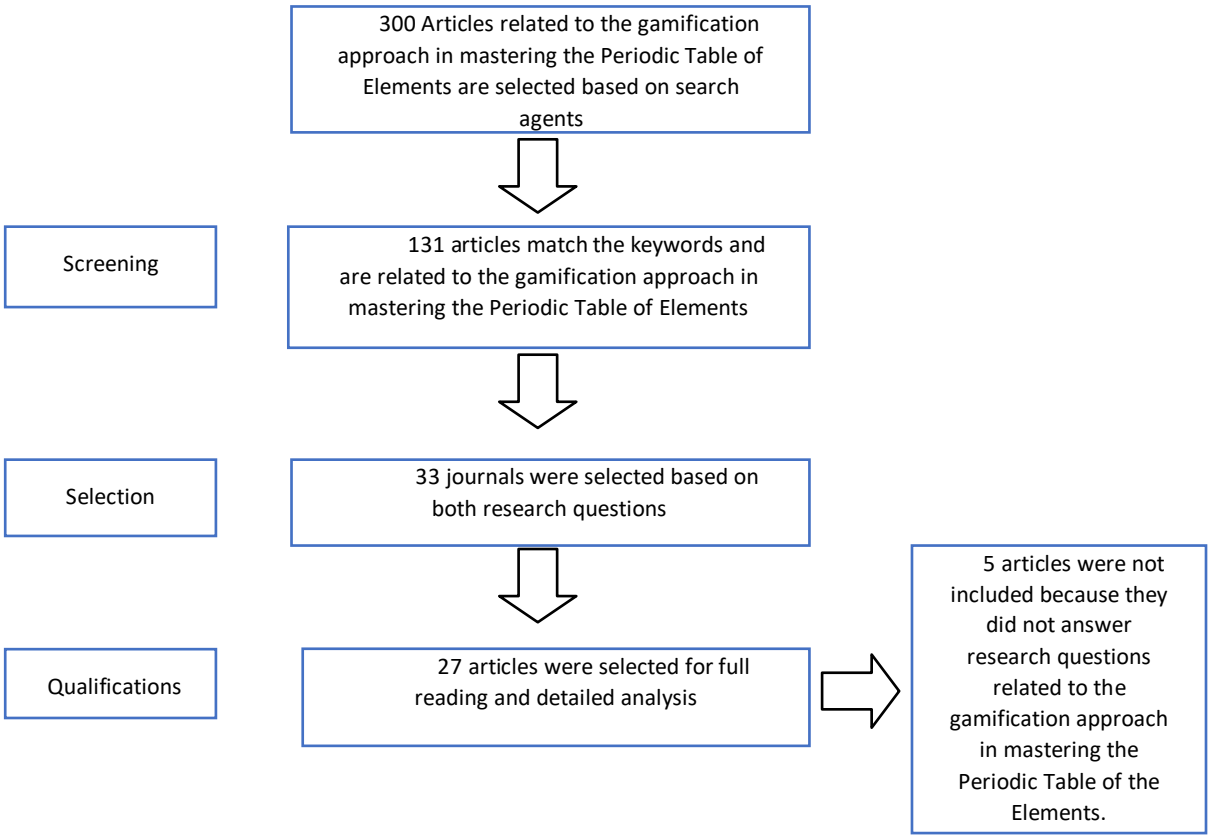


Figure 1. Collection And Analysis Data

Table 1. List of articles published in 2019, 2020, 2021, 2022 and 2023.

| No | Authors | Title | Location | Aim | Methodology | Finding |
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| 1 | (Carabelli et al., 2023) | Historical and philosophical foundations of a game-based learning strategy for | Brazil | to propose an approach that prioritises chemical theories and models over physical ones without forgetting | An analysis was carried out from the epistemological and ontological dimensions that allowed us to define | The aesthetic sense of the idea underlying the different representations was defined as a selection criterion for the periodic tables to be used as game |

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| | | teaching periodic law | | the contributions of this discipline that could facilitate the definitions and understanding of the concepts. | the periodic properties used in the game. | boards. Concerning the development of the new game mechanics, it was modified so that learning occurs during the game and not only at a later stage. |
| 2 | (Canbek et al., 2023) | PToPI: A Comprehensive Review, Analysis, and Knowledge Representation of Binary Classification Performance Measures/Metrics | Singapore | to identify characteristics, similarities, and differences of instruments categorised into 'performance measures' and 'performance metrics' in the classification context for the first time. The concepts reflecting the intrinsic properties of devices, such as canonical form, geometry, duality, complementation, dependency, and levelling, aim to reveal similarities and differences of numerous tools, such as three redundancy and ground-truth versus prediction focuses. | The study first highlights the issues in performance evaluation via a survey of 78 mobile-malware classification studies and reviews terminology. | As an application of knowledge representation, we introduced a new exploratory table called PToPI (Periodic Table of Performance Instruments) for 29 measures and 28 metrics (69 instruments, including variant and parametric ones). Visualising proposed concepts, PToPI provides a new relational structure for the instruments, including graphical, probabilistic, and entropic ones to see their properties and dependencies all in one place. Applications of the exploratory table in six examples from different domains in the literature have shown that PToPI aids overall instrument analysis and selection of the proper performance metrics according to the specific requirements of a classification problem. |
| 3 | (Sundaram & Ramesh, 2022) | Effectiveness of joyful game-based blended learning method in learning chemistry during COVID-19 | India | to help secondary school students learn science concepts using educational card games and digital media. Specifically, it focuses on teaching tenth-grade students chemistry and the periodic table elements (1 to 30). The research will assess the effectiveness of a game-based blended learning approach | A quasi-experimental sample comprises 240 students studying the tenth standard in 4 different private CBSE schools in Palakkad district, Kerala, India. The pre-test, post-test, gain scores, and retention scores were compared. | The study's findings revealed significant differences in the mean scores of students' learning in chemistry (precisely elements) when comparing the experimental and control groups' pre-test, post-test, and retention tests. The use of educational cards in learning chemistry was associated with positive attitudes among students. Implementing a game-based joyful blended learning method fostered reflective thinking and encouraged self-regulated learning among students. |
| 4 | (Haimovich et al., 2022) | "The Masked Scientist": Designing a Virtual Chemical Escape Room | United States | To design (VChEsRm) that operates entirely in the digital realm and principles of the VChEsRm and explores the perspectives of both students and teachers on how it differs from the traditional Chemical Engineering | 256 students completed a questionnaire after participating in the VChEsRm; it referred to their experience in the VChEsRm, what parts were more important to them | (VChEsRms) offer numerous advantages such as cost-effectiveness, accessibility, and ease of use. These virtual rooms have been successfully integrated into Jewish and Arab schools in Israel, even after students and teachers returned to physical classrooms following the pandemic. The VChEsRm's content |

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| | | | | Simulation Room (ChEsRm). | | seamlessly connects to subjects like history, human rights, sustainability, and everyday chemical facts. Despite being initially developed to address remote teaching needs during the pandemic, teachers continue implementing the VChEsRm in face-to-face settings, with groups of 3−4 students sharing one computer. The VChEsRm has become a permanent and valuable addition to the educational landscape. |
| 5 | (Ali et al., 2022) | Interactive Cube for Effective Demonstration of Virtual Periodic Table | Pakistan | To Increase student motivation by presenting a Cube-based Interface in Virtual Periodic Table (CIVPT) to demonstrate detailed information on chemical elements: chemical elements, chemical properties, physical properties, electronic configuration, usage of a component in daily life and chemical bonding, respectively. | Ninety-four (94) students participated and were divided into two groups for the assessment. | It is revealed that CIVPT enhances students' learning and motivation to gain knowledge about chemical elements. |
| 6 | (Da Silveira et al., 2021) | E-Guess: Usability Evaluation for Educational Games | Brazil | to evaluate educational games created from Game User Experience Satisfaction (GUESS) and Nielsen's assessment tools. | Applied research using a quantitative-qualitative approach with the participation of 3 specialised users and four potential users in an educational game used as a case study. The choice of GUESS as a starting point was due to a systematic review of the usability literature. Based on the model, users were invited to operate the educational game and present their impressions | a new use assessment tool, E-GUESS, was formulated. With Educational-GUESS, we introduced changes aimed at pedagogical issues and educational content that also seeks to elucidate essential points in the development of an educational game by allowing insights that are easily ignored during the design phase to overcome the alleged bipolarity between "fun" and "educational" in educational software games. Another research contribution was the usability analysis performed for the educational game used in data collection. This game, which deals with the theme Periodic Table of Chemistry and is in the validation phase, received valuable contributions for adjustments in its gameplay. |
| 7 | (Ewais et al., 2021) | Mobile Learning | Palestine | to investigate the possible use of | The article also presents a | The findings of this research show that mobile |

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| | | Application for Helping Pupils in Learning Chemistry | | educational mobile apps to teach chemistry courses in elementary schools. | qualitative research methodology implemented by including seven pupils. (interview) | learning technology can be adopted for learning chemistry courses to enable pupils to understand the periodic table, chemical elements' properties and their chemical interaction. Also, this study has shown that the proposed mobile application can be integrated into learning chemistry courses for elementary school pupils. |
| 8 | (Balasundram & Karpudewan, 2021) | Exploring The Use of a Writing-To-Learn Activity Embedded with Multiple Modes Using ': Popplet ' On Pre-University Students' Alternative Conceptions on Transition Metals | Malaysia | To explore the effect of embedding multiple modes of representation within a writing-to-learn activity using 'Popplet' in reducing the alternative conceptions of transition metals. | 81 pre-university students responded to a diagnostic test administered as a pre-test before the writing-to-learn activity and a post-test after the exercise. | The post-test results showed fewer students with the alternative conceptions identified in the pre-test. The paired sample t-test shows a significant difference between the pre and post-test means. The qualitative interview responses provided insights into how embedding the modes within the writing activity using 'Popplet' reduces the alternative conceptions. The study's findings inform the teachers of an alternative student-centred approach to teaching lessons on transition metals. |
| 9 | (Horikoshi, 2021) | Teaching Chemistry With LEGO® Bricks | Japan | To explain, LEGO-based teaching aid in chemistry is a simple-to-build tool that has the potential to benefit educators by inspiring the creation of additional innovative teaching aids. | LEGO bricks' diverse shapes and colours allow for creation of numerous teaching aids in chemistry, such as periodic tables, molecular models, polymer structures, and handmade measuring instrument frameworks. Unlike traditional ball-and-stick molecular models, LEGO bricks make building polymeric structure models easy and accessible. | LEGO bricks are ideal for crafting handmade measuring instruments due to their versatility, computer interface compatibility, and the absence of a need for specialised tools. |
| 10 | (Álvarez-Herrero & Valls-Bautista, 2021) | The Game as A Strategy of Learning Chemistry Among High School Students | Spain | to examine the relationship between periodic table learning and the types of strategies students choose to achieve learning outcomes related to it. | 260 students (during five years of investigation) in constructing instructional materials which helped them learn the periodic table, 195 of them chose to develop a game as a tool. | There was no significant difference between genders, showing that students prefer to learn in a playful, motivating and exciting way since they felt a greater interest and better evaluated what they had learned about, reaching a more profound and lasting understanding, hence, significant learning. Gamification |

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| | | | | | | and learning-based games are acquiring a relevant role in education centres, and teachers who apply these methodologies in pedagogical approaches have increased. |
| 11 | (Traver et al., 2021) | Educational Video Game to Learn the Periodic Table: Design Rationale and Lessons Learned | United States | to compare the effects of playing through increasing levels of difficulty versus starting with all elements at once and investigate the impact of displaying groups and periodic numbers of chemical elements along with their symbols versus showing only the element symbols. | E-CHEMMEND is a digital version of a game designed to assist in memorising the group and period numbers of chemical elements, serving as an alternative to the traditional physical card game. | Preliminary findings reveal that E-CHEMMEND is perceived as more enjoyable when displaying group and period numbers, but it enhances learning when this information is hidden, and levels are shown. The study indicates that the game's settings can be adjusted to cater to different educational purposes. The insights from testing E-CHEMMEND will be valuable for chemistry instructors and researchers. For those interested, a desktop-based Windows executable version of the game is accessible at http://www.chemmend.uji.es/game. |
| 12 | (Watson et al., 2021) | Introducing Students to The Periodic Table Using a Descriptive Approach of Superheroes, Meats, And Fruits and Nuts | United States | introduces students to the periodic table of chemistry using a variety of pseudo "periodic tables", including iPad Apps Periodic Table, Fruits and Nuts, Meat and Superheroes. | We have adopted a novel nonhistorical approach as a pre-introduction to the formal periodic table to our first-year chemistry students. | This introduction focuses on key characteristic aspects of the table construction, such as grouping objects using columns, rows, blocks, and colour; numbering of things; use of abbreviations for objects; combining individual objects; and transitioning across and down the table, e.g., size changes across and down the table. These features are demonstrated using a variety of pseudo. |
| 13 | (Siquiere, 2021) | A Proposal for The Periodic Table Teaching in Science Teacher Training Courses and the High School Based on The Theme of Metals | Brazil | to explore the construction and organisation of the Periodic Table from the metal theme in a playful way, thereby allowing the content to be relevant for these students and understood by them. | It consists of two group dynamics that allow to contextualise the presence of metallic chemical elements in objects/products, being the majority present in the students' daily lives, and to explore the construction and organisation of the Periodic Table playfully, thus allowing the contents to become relevant for these students and be understood by them. | - |
| 14 | (Montejo | Chemical | Mexico | To introduce | Chemical Battleship | The game's |

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| | Bernardo & Fernández González, 2021) | Battleship: Discovering and Learning the Periodic Table Playing a Didactic and Strategic Board Game | | Chemical Battleship as a chemical adaptation of the traditional board game Battleship. Its purpose is to facilitate learning about critical topics in the periodic table and the identification of standard laboratory glassware. | was evaluated with primary school and third-year students in the Primary Education Teacher Degree program. | implementation was well-received by both groups of students, generating interest and curiosity among primary school students and enhancing knowledge among third-year students in the Primary Education Teacher Degree program. Notably, the game positively impacted students' subjective perception of their expertise and demonstrated tangible improvements in their understanding of the periodic table, as evidenced by higher scores. |
| 15 | (Stojanovska, 2021) | Celebrating The International Year of Periodic Table with Chemistry Educational Games and Puzzles | Spain | To emphasise the need for teachers to be creative in finding ways to implement game-based learning and design custom puzzles that suit their specific needs and classroom settings. | By embracing this approach, teachers can create a dynamic and immersive learning environment, fostering student engagement, critical thinking, and a deeper understanding of the subject matter. | The games provided are adaptable for creating an escape room-style classroom experience and for independent use. We strongly believe that incorporating educational games into learning will significantly benefit students. |
| 16 | (Zhou et al., 2020) | Periodic Domino Game: A Possibility for Teaching and Learning One of The Periodic Table | Brazil | to verify acceptance and influence in applying the Periodic Domino game in the classroom on the periodic table. | It was carried out with 19 students of the 9th grade of Elementary School II of the Centro Educacional Espaço Criativo School in Quiterianópolis-CE. The data were collected through an evaluative questionnaire. | The results graphically presented showed that the game aroused the students' interest since 64% of them attributed a maximum score and had an excellent influence since 95% of the students stated that the match contributes significantly to a better understanding of the content addressed. |
| 17 | (Rychkova et al., 2020) | Orbital Battleship: A Multiplayer Guessing Game in Immersive Virtual Reality | Rusia | to reinforce the knowledge of the atomic structure. | A futuristic version called VR Orbital Battleship has been developed to offer a fully immersive and collaborative experience. Unlike the pen-and-paper version, this game ensures students cannot input incorrect electron configurations due to its unique control elements. This feature motivates students to accurately apply Madelung's and Hund's rules to participate in the game. | The headset used in the game provides a fully immersive experience, reducing distractions compared to the traditional version. The user-friendly and intuitive design enhances the overall immersive experience for players. The game is recommended as an interactive supplement for school and university classes focusing on atomic structure. VR Orbital Battleship is free worldwide and can be accessed on portable mobile platforms like Oculus Go and PCs by downloading the game. |
| 18 | (Estudante & Dietrich, n.d.)) | Using Augmented | Portuguese | To introduce the original paper-based version explicitly | Participants engage in a mysterious journey where they | AR escape games offer a convenient way to engage large classroom audiences |

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| | | Reality to Stimulate Students and Diffuse Escape Game Activities to Larger Audiences | | designed for a high school/college audience, centred around the Solvay process. The scenario involves students following the journey of a young Belgian physicist, Ernest Solvay. Through this interactive experience, students are encouraged to explore and learn about the Solvay process and its significance in chemistry. | unravel the secrets of Solvay in Brussels by solving enigmas. The puzzles revolve around various aspects of chemistry, such as the periodic table of elements, the CPK colour code, chemical reaction balancing, molar mass, the Solvay process, and the philanthropic conferences Solvay and other scientists organised. These elements serve to illustrate the fascinating chemical processes discovered throughout the game. | without needing a teacher's physical presence or extensive preparation. The advantages and limitations of these tools are examined, considering their potential benefits and drawbacks. Feedback from students who participated in a test exercise using the device supports the notion that such activities can enhance student motivation. |
| 19 | (Setiawan et al., 2019) | Augmented reality application for chemical bonding based on android | Indonesia | To use Augmented Reality to be able to see a 3D model of each chemical element and also to be able to see animations of combinations between elements | to bring up 3D objects of chemical elements and then make a card that will be used as a marker/tracker. In addition, there can be a combination of several chemical elements based on several cards detected by the camera. The test is performed for chemical elements with periodic tables such as H, Ca, Na, K, C, Cl, Br, O, S, SO2, CO2, and OH. Testing the application by performing several merge elements such as HCl, NaCl, H20, CO2, MgS, SO2, O2, CaCl2, HCN, N2, and others. | The results of this study will be tested on several students to see the benefits of student learning. |
| 20 | (De Oliveira et al., 2019) | QUIMIVOX MOBILE 2.0: Application for Helping Visually Impaired People in Learning Periodic Table and Electron Configuration | Brazil | The Quimivox Mobile 2.0 application is being introduced as a new version designed for Android devices. It aims to provide accessible information about the periodic table and electronic configuration of chemical elements for visually impaired individuals, | The interaction in the application is based on vocal commands and simple gestures, providing information through both graphical and voice synthesis means. Comparative assessments were conducted between two versions of the application. The second version included typical | The application was found to be an effective and enjoyable tool that promotes inclusive education. |

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| | | | | including those who are blind or have limited vision and those facing challenges related to colour vision. | information access tools for non-disabled individuals and automated tests to assess its compatibility with colour blindness. | |
| 21 | (Daaif et al., 2019) | Progress Of Digital Learning Resources: Development and Pedagogical Integration of a Virtual Environment Laboratory for The Practical Experiments in Chemistry | Morocco | To implement a laboratory for simulation that helps carry out various practical chemistry work. Next is to demonstrate the pedagogical impact of the use of virtual learning environments on the teaching-learning process in the university curriculum. | Case study the exploitation of the periodic table in descriptive chemistry and the practical works of chemical kinetics. A qualitative study on a sample of students from the Physical Chemistry of Materials Laboratory at the Ben M'sik Faculty of Science to identify the didactical factors influencing the progress of the practical work using our computer solution. | |
| 22 | (Domjanić Drozdek et al., 2019) | The Role of the iPad Tablet in Higher Education Science Teaching | Croatia | Provides four applications within the framework of the unit entitled "Preparing Solutions", "Periodic Table", "Molarity", "Chemist", and "Beaker". | Undergraduate professional study programs Environmental Health Engineering and Laboratory Medical Diagnostics as part of the practical classes in Biology and Chemistry. | Within the class on Biology, tablet computer applications are used to cover subject matter dealing with Genetics and Cell Structure (applications "Cytogenetics", "Diseases and disorders", "Gene Screen", "Population Genetics", and "Cell World"). Though e-teaching certainly cannot replace classic course teaching, it is incredibly beneficial for easier acquiring the course subject matter. |
| 23 | (Guerra et al., 2019) | Constructing A Periodic Table: A Proposed Practice Activity for High School Chemistry Classes | Brazil | to describe a playful classroom activity in which high school students from a public school participate in constructing a periodic table. | The descriptive study applied a qualitative approach to a case study. To achieve this, a practical activity to construct a periodic table with accessible materials was proposed to promote students' understanding of the periodic table and relate it to their daily lives. | The activity's content contextualisation provided a better understanding of the subject and made it more realistic. Thus, schools must consider the importance of playful activities in student development and propose learning situations enabling teachers to diversify their teaching methods and make classes more dynamic and differentiated. |
| 24 | (Bruno, 2019) | The international year of the periodic table and the teaching of | Portugues e | To examine the use of the periodic table in teaching chemistry, with a focus on production. The review aims to uncover how the | A review was conducted on papers from six chemistry journals that focused on Chemical Education between 2009 and | The analysis of 28 articles revealed four categories: level of education, approach, strategy, and didactic/pedagogical resource. Among the publications, 40% utilised |

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| | | chemistry: From letters to digital | | periodic table has been utilised in chemistry education and identify the didactic strategies employed. | 2018. The analysis of these papers identified four main categories: level of education, approach, strategy, and didactic/pedagogical resource. | didactic/pedagogical approaches. The most commonly employed techniques were clarity (43%), bibliographic survey (25%), and didactic sequences (18%). Regarding didactic/pedagogical resources, card games, board games, and digital games, emerged as the most frequently utilised resource in the journals' publications. |
| 25 | (Lopper, 2019) | A Digital Periodic Table That Instructors Can Use in The Classroom to Highlight Elements and Illustrate Periodic Trends | United State | describes a responsive digital periodic table that has been specifically designed as a visual aid for high school or college chemistry classrooms and lecture halls. | to draw students' attention to specific elements and style schemes that can be used to colour groups of elements and illustrate periodic trends | The periodic table is written in HTML, CSS, and JavaScript, which gives users the flexibility to customise its appearance; its size can be adjusted to fit the screen in the classroom in which it is used. Users can also add atomic data to expand the periodic table's capabilities if desired. |
| 26 | (Yayon et al., 2019) | Do-It-Yourself: Creating and Implementing a Periodic Table of The Elements Chemical Escape Room | Israel | To explore ChEsRm (PTOE Chemical Escape Room) offers an engaging and immersive learning experience by combining chemistry puzzles with captivating information about elements, their everyday applications, properties, as well as subatomic particles. In addition to actual experiments, this unique educational activity includes non-laboratory tasks to enhance understanding and retention of chemical concepts. | Participants will be provided with a detailed narrative surrounding the mysterious demise of an individual. Rather than conducting experiments in a laboratory setting, they will rely on their analytical abilities to piece together evidence, examine witness statements, and explore various leads. | While many escape rooms typically rely on locks and keys, this escape room utilises a different and adaptable mechanism to unveil the solution. Below, we offer a comprehensive description of all the puzzles involved and provide instructions on how to operate the escape room within a school laboratory setting. |
| 27 | (Joaquina De Oliveira Barboza, n.d.) | Periodic Race: Demystifying the Scientific Language of The Chemical Elements | Portuguese | analysing the role of the didactic game Periodic Race in appropriating the symbology characteristic of the content of the Periodic Table. | It is qualitative research carried out in two classes in grade 10 at a Secondary School in Salgadinho-PE. The game was proposed by the researchers and applied by the class teacher. We used the researcher's field diary and interviews with some students as instruments. | Show the interactions between the teacher and the students in the game and the student's points of view in the interview. During the game, we noticed that the students knew only the most commonly seen chemical elements in their daily life and presented difficulties in the periodic properties, besides not understanding the importance of the symbology of this content. With the game, the students could have direct contact with the |

Periodic Table, knowing it properly and slowly demystifying its language, understanding that it brings a knowledge-based to studies and effectively contributes to various chemistry contents.

## RESULT AND DISCUSSION

A systematic Literature Review (SLR) has the main objective to identify journals that discuss related to this central issue to be taken as a reference. So, this section answers the research questions by reporting and examining the use of a gamification approach in mastering the periodic table (chemistry). Furthermore, this section also analyses the various impacts of using the gamification approach, which includes three main aspects, namely in terms of understanding, motivation and usability. This study also develops a conceptual framework based on gamification, which past researchers most often use. Research results from previous research articles found 27 articles that meet all criteria. It has thus summarised the purpose of the selected articles' study and will provide an overview of the research carried out on each paper. Therefore, the purpose of the study for the selected documents, which will give an overview of the survey carried out on each article, has been summarised in Table 1. The table summarises various research studies related to the teaching and learning of the periodic table, specifically focusing on innovative methods and strategies. Each entry includes the authors, their location, and their studies' purposes, methodology and findings. The studies aim to enhance student motivation, reduce alternative concepts, explore different teaching aids, examine learning strategies, investigate the role of gaming elements, introduce alternative periodic tables, and utilise augmented reality and mobile learning tools. These studies highlight the importance of incorporating interactive and playful approaches to make the periodic table more engaging and accessible for students.

### *Study Location*

The collected studies have been published in several countries. The majority of published articles are from Brazil (26%), followed by the United States (15%), Portuguese (11%) and Spain 4%. Next, 11 countries (Croatia, Singapore, Malaysia, Japan, India, Palestine, Indonesia, Israel, Rusia, Pakistan & Africa) have the same number of publications with only one article (4%). Among the articles published from Brazil (Carabelli et al., 2023)(da Silveira et al., 2021)(Siquiere, 2021)

De Oliveira Freitas, Sérgio; Da Silva Maia, Pedro Ivo; Costa, Carla Regina (2021); De Souza Et Al (2020); De Oliveira, Alex Santos; Merlin, Bruno; Ferreira, João Elias Vidueira; Fülber, Heleno; Veras, Allan (2019); Guerra, Genaina Fernandes; Felicio, Cinthia Maria; Ferreira, Julio Cesar; Noll, Matias (2019). United State (Haimovich I., Yayon M., Adler V., Levy H., Blonder R., Rap S. (2022); Traver, V. Javier; Leiva, Luis A.; Martí-Centelles, Vicente; Rubio-Magnieto, Jenifer (2021); Watson, Gregory S.; Green, David W.; Watson, Jolanta A. (2021); Lopper, Matthew E. (2019)) and Portuguese (Estudante A., Dietrich N. (2020); Leite, Bruno (2019); Barboza R.J.D.O., Nascimento A.M.D.S., de Lira M.M.R. (2019)). \

Spain (Álvarez-Herrero, Juan Francisco; Valls-Bautista, Cristina, 2021; Stojanovska, Marina, 2021), Singapore (Canbek G., Taskaya Temizel T., Sagiroglu S., 2023), India (Sundaram S., Ramesh R., 2022), Pakistan (Ali, Numan; Ullah, Sehat; Raees, Muhammad, 2022), Palestine (Ewais A., Hodrob R., Maree M., Jaradat S., 2021), Malaysia (Balasundram, Nilavathi; Karpudewan, Mageswary, 2021) and Japan (Horikoshi, Ryo, 2021). Next is Mexico, (Montejo Bernardo, Jose M.; Fernández González, Alfonso, 2021), Rusia, (Rychkova A., Korotkikh A., Mironov A., Smolin A.,

Maksimenko N., Kurushkin M. (2020), Indonesia (Setiawan, Alexander; Rostianingsih, Silvia; Widodo, Timotius Reinaldo, 2019), Morocco (Daaif, Jabran; Zain, Siham; Zerraf, Soufiane; Tridane, Malika; Khyati, Abderrahim; Benmokhtar, said; Belaaouad, Said, 2019), Croatia (Domjanić Drozdek, Sandra; Feher Turković, Lana; Mojsović Ćuić, Ana; Digula, Ozren, 2019), Israel (Yayon, Rap, Adler, Haimovich, Levy & Blonder, 2019).

***Types of research instruments***

Previous studies have been divided into three methodological categories, namely quantitative, qualitative and mixed methods. The complete list of past studies based on the three methodological categories shows in Table 2.

Table 2. Methodology and The Impact of Study Participants Through Gamification in The Periodic Table of Elements of past research articles.

QN- Quantitative QL-Qualitative MM-Mixed Method

| Study | Research Design | Understanding | Motivation | Usability | No Impact |
|---|---|---|---|---|---|
| 1 | MM | | / | | |
| 2 | QN | | | / | |
| 3 | QN | / | / | | |
| 4 | QN | | / | / | |
| 5 | QN | / | / | | |
| 6 | MM | / | / | / | |
| 7 | QL | / | / | / | |
| 8 | MM | / | | | |
| 9 | QN | | | | / |
| 10 | QN | | / | | |
| 11 | QN | | / | | |
| 12 | QN | / | | / | |
| 13 | QN | | | | / |
| 14 | QN | / | / | / | |
| 15 | QN | | / | | |
| 16 | QN | / | / | | |
| 17 | MM | / | | / | |
| 18 | QN | | / | | |
| 19 | QL | | | | / |
| 20 | QN | / | | | |
| 21 | QL | / | | | |
| 22 | QN | | | | / |
| 23 | QL | | / | | |
| 24 | QL | | | | / |
| 25 | QN | | | | / |
| 26 | QN | | | | / |
| 27 | QL | / | / | | |
| | | 12 | 14 | 7 | 7 |

Based on Table 2, most past studies use quantitative research methods. A total of 63%, 17 out of 27 articles used a set of questionnaires. However, the quantitative approach is less able to provide a general interpretation regarding the issue to be discussed in more depth. It is likely due to the constraints of the Covid-19 pandemic, which limits the dissemination of this questionnaire and is only carried out online. In addition, the researcher can also know an issue in more depth and contextually by using this mixed method. Using a set of questionnaires and semi-structured

interviews to obtain research data is among the methods used in four out of 27, i.e15% of the article studies use mixed methods. Meanwhile, the qualitative method is as much as 22%, six out of 27 articles.

The table also assesses the impact of different gamification approaches on various aspects, such as understanding, motivation, and usability, based on the frequency of their mention in the journals. The table also includes a category for approaches that have no impact. The data in Table 2 shows the effect of using gamification, which has been divided into three characteristics: understanding, motivation and attitude. The findings recorded that most of the impact of gamification in mastering the periodic table was motivation in 14 articles (52%). Next, the survey focusing on understanding is 44% followed by 26%, which is the usability from 2019 to 2023. The article that does not involve any impact is about 26%. The article that studies all three effects is about 11%. Aspect understanding and motivation showed about 15% studied them, followed by experience and usability, about 7%. Lastly, motivation and usability in only one journal contribute only 4%.

Table 3. Types of gamification approaches in mastering the periodic table of Elements (chemistry)

| Journal | Gamification Approaches |
|---|---|
| 5,17 | Cubes in Virtual Periodic Table (CIVPT), Virtual Immersive Reality |
| 8 | Writing activity using 'Popplet.' |
| 9 | LEGO |
| 2,6,7,10 | Project and WebQuest, mobile-malware classification, E-Guess, mobile learning |
| 11 | Digital cards as an aid in memorising group and element number |
| 12 | Pseudo, iPad application, fruit and beans, meat and superheroes. |
| 13 | Period table from metal theme |
| 1,3,14,24, | Chemical Battleship version, digital and game card |
| 15,26 | Game and riddle/ Riddle escape Room, |
| 16 | Domino game |
| 18,19 | AR 3d Chemical Compound / AR electron arrangement, AR diffuse escape game |
| 20 | Inclusive. Electronic Configurations |
| 4,21,22 | Virtual Laboratory |
| 23,27 | Playful activity, didactic (dice) |
| 25 | Click and show |

## CONCLUSION

A systematic survey was conducted to identify the gamification approaches used to enhance mastery of the Periodic Table in Chemistry. This review explains the relationship between impact variables when using gamification for the Periodic Table. Understanding and motivation are two main aspects of the impact variable in mastering the Periodic Table through gamification. The researcher utilised an electronic database, Scopus, to obtain relevant articles. A total of 27 articles meeting the criteria were analysed. The findings highlight that researchers commonly studied Project and WebQuest, mobile-malware classification, E-Guess, mobile learning and Chemical Battleship version, digital and game card approaches.

Regarding impact, the second part of the study reveals that 14 articles demonstrate a motivational effect. In comparison, 12 articles report an improvement in student understanding compared to only seven pieces indicating changes in usability. Therefore, implementing

gamification to master the periodic table can enhance student motivation and academic performance. Majid, Nazatul Aini Abd; Majid, Nur Faizah Abd (2018) suggest combining virtual and real data in gamification can increase enjoyment and engagement and improve academic performance.

## AUTHORS' CONTRIBUTION

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.
Author 2: Conceptualization; Data curation; In-vestigation.

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