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USING ADDIE MODEL TO DEVELOP AND EVALUATE *LITTLE PERIODIC* LEARNING THE PERIODIC TABLE OF ELEMENTS

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ABSTRACT

Learning the periodic table of elements can pose a challenge for students due to the complex organization and relationships between the different elements. Game-based interventions have been shown in past studies to be one of the feasible ways to overcome this challenge. In this research, a tabletop game, called "Little Periodic" was developed to improve students' chemical representation and conceptual understanding. Following the five phases of the ADDIE model—Analysis, Design, Development, Implementation, and Evaluation—the study first analyzed students' needs and identified key concepts for mastery. Additionally, an overview of the five phases is discussed in detail within this study, providing insight into the systematic process to develop and evaluate the tabletop game. Three teachers were interviewed to see the appropriate content that will be included in the tabletop game based on the *Dokumen Standard Kurikulum dan Pentaksiran (DSKP)*. A tabletop game was designed and developed that could be used in physical learning environments. To evaluate the effectiveness of the developed tabletop game, validation forms and questionnaires were administered to three validator experts. The results indicated that the tabletop game was valid and effective, with high scores for content suitability, potential effectiveness, and overall satisfaction. The feedback received from chemistry teachers indicated a significant level of satisfaction with the tabletop game. The developed tabletop games can be employed in various learning situations, including in-person learning, and the effects of tabletop games need to further be investigated to ensure and enhance students to achieve deeper learning outcomes.

Keywords: *Game-Based Learning, Tabletop Games, Periodic Table Of Elements, Little Periodic, Chemistry Education*

INTRODUCTION

Chemistry is the scientific field concerned with the study of substances and their interactions. It encompasses a broad range of topics from the composition and structure of matter to the properties, changes, energy, and dynamics of chemical reactions. Chemistry, at its core, revolves around comprehending the behaviour of atoms and molecules, and gaining insight into how they interact with each other, leading to the creation of novel substances with unique properties. This knowledge forms the foundation of numerous scientific fields and plays a vital role in advancing our understanding of the natural world.

One of the key features of chemistry is its use of chemical representation to help explain chemical phenomena. This representation can be divided into three levels: macroscopic, symbolic, and microscopic (Rahmawati et al., 2022). The macroscopic level deals with observable phenomena that can be seen with the naked eye through experiments. The symbolic level uses diagrams, pictures, and formulas to represent chemical phenomena, while the microscopic level deals with the observation of particles, including their interactions, chemical bonding, and movements, which are too small to be seen without the aid of specialized tools.

The periodic table of elements is an essential tool in the study of chemistry, serving as a visual representation of the connections between the three levels of representation: macroscopic, microscopic, and symbolic (Camara Olim et al., 2023). This chart organizes all known elements in ascending order of their atomic numbers and electron configurations, providing chemists with a predictive framework for understanding the chemical behaviour of elements and their compounds. The periodic table's significance to the scientific community cannot be overstated, as it serves as the foundation for the classification, prediction, and exploration of matter at the atomic level, leading to numerous technological advances and groundbreaking discoveries in various scientific fields (Bylikin et al., 2023). The periodic table also provides a macroscopic representation of elements, as it shows their physical properties such as melting and boiling points, densities, and atomic radii**.** These properties can be observed and measured through experiments (Eichler, 2019). The periodic table also provides a symbolic representation of the elements through their atomic symbols and a microscopic view of the elements through their electronic structures and bonding (Eichler, 2019). However, the integration of these levels of representation can pose a challenge for both students and teachers of chemistry. Students may find chemistry challenging due to the complex interplay of these levels, while teachers need to fully grasp and communicate the concepts to their students (Narod & Narrainsawmy, 2022).

To identify challenges in chemistry education, we conducted a preliminary study by interviewing experienced chemistry teachers, followed by a needs analysis. The results of this study revealed that students often struggle with mastering the subject due to difficulties in understanding chemical representations. Teachers have also faced difficulties in effectively visualizing and explaining representations of the periodic table during their teaching sessions. The complex relationships and patterns between the various elements can be challenging to convey to students in a way that is both clear and engaging. This can hinder students' ability to develop a deep conceptual understanding of the periodic table and its importance in chemistry (Bierenstiel & Snow, 2019). The main issue identified was the confusion caused by the complexity of chemical representations, which hindered students' understanding of the chemistry subject. While the macroscopic properties of the elements, such as their physical states, melting points, boiling points, and densities, are often easier for students to grasp as they can be observed and measured directly, it can still be challenging for students to understand how these properties relate to the organization of the periodic table (Narod & Narrainsawmy, 2022; Tóthová et al., 2021; Traver et al., 2021).

On the other hand, the microscopic properties of the elements, such as their electron configurations and chemical reactivity, can be more difficult for students to visualize and understand. This is because they require an understanding of the interaction and behaviour of atoms and molecules, which is not always intuitive**.** Therefore, students may struggle to understand how the organization of the periodic table relates to these microscopic properties. In addition to this, the symbolic notation used to represent the elements and their properties, such as atomic symbols, electron configurations, and valence electron counts, can be challenging for students to learn and understand. This can make it difficult for students to connect the symbols to the macroscopic and microscopic properties of the elements and to understand the organization of the periodic table (Bierenstiel & Snow, 2019; Salame et al., 2011).

Based on the identified challenges in learning the periodic table of elements, it can be concluded that the difficulties in understanding chemical representations may stem from various factors, including the complexity of the subject matter and individual learning preference. There are several suggested approaches to learning the periodic table of elements, ranging from traditional teaching styles to more modern and interactive methods. The traditional approach often involves memorization of the elements'

names, symbols, atomic numbers, and other properties, which can be challenging and tedious for some learners (Rahmawati et al., 2022). These materials often fail to cover the essential concepts of chemical representation and lack interactive and engaging features that can help students to master the subject. Game-based learning (GBL) is the utilization of games to enrich the learning process. It harnesses the collaborative and interactive nature of gaming within educational contexts, enabling educators to leverage game mechanics to foster targeted activities aimed at achieving specific learning objectives (Plass et al., 2020). Educators and researchers are turning to Game-Based Learning (GBL) as a means of enhancing the teaching and learning of science subjects in creative and engaging ways (Cardinot & Fairfield, 2022; Napes & Sharif, 2022). The popularity of using games in the classroom has grown, as studies have demonstrated their potential to facilitate learning and bring about positive changes to the school curriculum. Furthermore, GBL has been found to be effective in promoting social development and teamwork skills in students, further adding to its appeal as a teaching tool (Jonathan & Recard, 2021; Li & He, 2022; Saleem et al., 2022; Tsai et al., 2020).

As the popularity of games continue to grow, educators and researchers are becoming more convinced of their potential as effective teaching tools. By incorporating games into the classroom, students are able to engage with subject material in an interactive and dynamic way, which has been shown to improve learning outcomes. Furthermore, GBL has been found to have a positive impact on social development and teamwork skills, which are valuable in both academic and real-world settings (Howell, 2022).

STUDY OBJECTIVES

Given the challenges highlighted in the preceding discussion, the aim of this study is to design and develop tabletop games that are both valid and effective in enhancing students' understanding of chemical representations in the periodic table of elements.

METHODOLOGY

Research Design

The current study employed the Research and Development approach, utilizing the ADDIE Model as a procedural guide. According to Bond & Dirkin (2020), the ADDIE model is a widely used model in the field of instructional design, serving as a framework for creating effective designs. The ADDIE model consists of five phases, namely Analysis, Design, Development, Implementation, and Evaluation. Each phase plays a crucial role in the overall success of the instructional design process (Bond & Dirkin, 2020).

The initial phase of the study involved conducting interviews with chemistry teachers to identify existing issues in chemistry learning. The goal was to analyze their needs and provide solutions to these problems. The appropriate content for development was identified through the use of content analysis based on the Malaysia National Chemistry Curriculum -*Dokumen Standard Kurikulum dan Pentaksiran* (DSKP). The interviews revealed that the teachers had highlighted Periodic Table is one of the boring and at the same time challenging topic to be taught. Besides, teachers also proposed to have interactive teaching materials to teach the Periodic Table concepts such as to have learning resources in the form of tabletop games that could be used in face-to-face settings. This finding highlights the potential of tabletop games as an effective learning tool in the chemistry classroom.

Game-Based Learning is a suitable model of learning for teaching chemistry, and a fun and engaging way to promote active, constructive learning (Napes & Sharif, 2022; Nkadimeng & Ankiewicz, 2022). Designing a tabletop game centered on the periodic table of elements provides an opportunity for students to engage with the subject matter in an educational environment. Little Periodic is adapted and designed to help players learn about atomic radius, atomic number, increase and decrease of atomic mass, and changes of ionization energy in a fun and interactive way. The periodic trends refer to patterns that are observed in the properties of elements on the periodic table. By understanding these trends, players can better understand how the elements behave and interact with one another. In the

game, players activate one of the five periodic trends. Players can choose to either spend energy tokens to activate multiple trends at once or gain energy tokens by activating only one trend. This adds a strategic element to the game, as players must carefully manage their energy tokens and decide when to activate multiple trends for a big move and activate only one trend. For example, if a player activates the increase of atomic radius trend, they may be required to move their game piece to a space on the board that corresponds to an element with a larger atomic radius than the one they are currently on. By doing so, players can learn about how atomic radius changes as they move across a period or down a group on the periodic table. The game likely includes multiple stages, each of which challenges players to activate a different periodic trend. By progressing through the stages and mastering the periodic trends, players can become more familiar with the elements and their properties.

The design phase for the proposed Little Periodic tabletop game involves several key steps. First, the learning objectives of the tabletop which are mastering chemical representation and conceptual understanding must be identified and translated into game mechanics that will effectively achieve those objectives. Little Periodic was designed to help players understand key concepts related to the periodic table, such as atomic structure, periodic trends, and atomic mass. Once the learning objectives have been identified, the rules and mechanics of the Little Periodic were established. This includes defining the actions that players can take, the types of challenges they will face, and the victory conditions for the game. Game mechanics were designed in a way that effectively tests the skills and knowledge that are central to the learning objectives. For example, the game involves activating different trends such as atomic radius, and ionization energy in order to obtain more Goal Cards. Players must strategically use their energy tokens to activate trends and collect goal cards to win the game. Additionally, the game involves the use of Agenda Cards and Awards Tiles, which allow players to perform actions and add an element of strategy and unpredictability to the game, making it more engaging and challenging for players.

The implementation phase of Little Periodic involved a thorough process of validating the game's effectiveness in achieving the identified learning objectives. Three experts were engaged to provide their input on the game's design and to evaluate its effectiveness in promoting chemical representation and conceptual understanding. The first expert, a chemistry teacher, reviewed the game's learning objectives and provided feedback on the game's alignment with key concepts in the chemistry curriculum. The expert completed a validation form assessing the suitability of the game's content in achieving the identified learning objectives. The expert also provided feedback on the game's accuracy in representing chemical concepts.

The second expert, an experienced chemistry teacher with a background marking SPM Chemistry Paper, evaluated the game mechanics and provided suggestions on how to improve the gameplay experience while maintaining the educational content. The expert completed a validation form assessing the potential effectiveness of the game mechanics in promoting the identified learning objectives. The expert also provided feedback on the game's overall engagement and replayability.
The study employed purposive sampling, which is a non-probability sampling technique that involves the selection of participants based on specific criteria chosen by the researcher. The participants in this study were validator experts who were selected based on their willingness to provide feedback on a tabletop game. The data obtained from the participants were analyzed using a percentage calculation to derive the validation score. The percentage result was compared to the validation score, which is presented in Table 1.

Table 1. Validation of criteria

Percentage	The validity criteria
75.00 – 100	Valid
50.00 – 74.99	Quite Valid
25.00 – 49.99	Less valid
0.00 – 24.99	Invalid

To evaluate the feedback of the experts, they were given an opportunity to play and review the tabletop game then to evaluate its effectiveness. The third expert, a chemistry educator with more than 15 years of teaching experience, evaluated the game's effectiveness in promoting chemical representation and conceptual understanding. The expert observed gameplay sessions and collected data on players' learning outcomes. The expert completed a validation form assessing their overall satisfaction with the game's effectiveness in achieving the identified learning objectives. The expert also provided feedback on the clarity and accuracy of the game's chemical representations. Based on the feedback from the expert and the completion of the validation forms, the game mechanics, components, and educational content were further refined to optimize the game's effectiveness in promoting chemical representation and conceptual understanding. The result was obtained in percentage and compared to the criteria response of users as shown in Table 2.

Table 2. Criteria response of users

Percentage	The validity criteria
75.00 – 100	Very good
50.00 – 74.99	Good
25.00 – 49.99	Less Good
0.00 – 24.99	Not Good

The presented scoring system provides a structured system to assess the validity of *Little Periodic* using a percentage scale. It divides scores into four categories: very good, good, less good, and not good. A score between 75.00% and 100% is considered very good, indicating high validity. Scores falling within 50.00% to 74.99% are labeled as good, indicating satisfactory validity. Scores ranging from 25.00% to 49.99% are categorized as less good, suggesting somewhat limited validity. Scores from 0.00% to 24.99% are deemed not good, indicating a lack of validity. This system offers a clear guideline for interpreting the validity of *Little Periodic* based on its percentage score, with higher percentages reflecting better validity.

Little Periodic

After conducting preliminary research and analysis, it was clear that there is a requirement for a tabletop game that can support the development of students' conceptual understanding of chemistry and is suitable for in-person learning. Little Periodic, a tabletop game adapted from PERIODIC: A Game of The Elements by John Coveyou, was designed to meet this need with four lessons, each tailored for face-to-face learning. Little Periodic includes engaging activities designed to foster students' conceptual understanding of the periodic table of elements through gameplay. As players move across the periodic

table to collect elements, they learn about its structure and function, as well as some of the fundamental principles of chemistry. Figure 1(a) shows the gameboard used in this study.

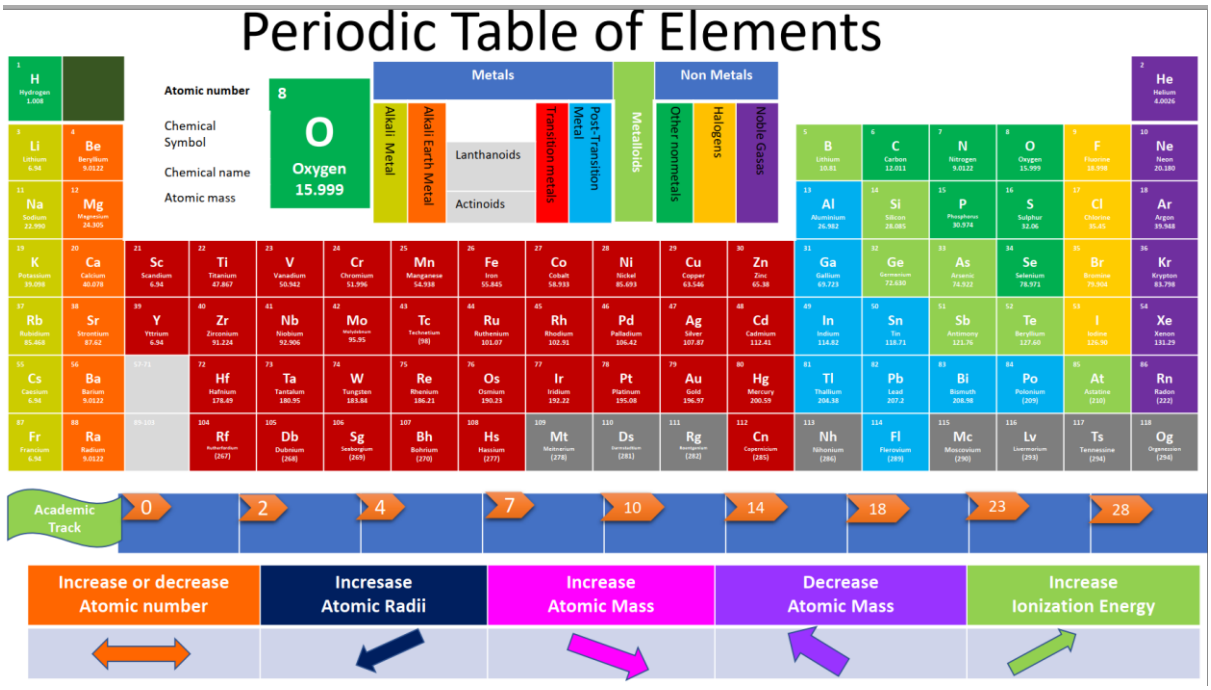

Figure 1. The Game Board of Little Periodic

Little Periodic will be using periodic trends to move across the periodic table to score points by researching certain elements. The periodic table is the centrepiece of the game board. Table 3 shows the explanation of chemical representation in Little Periodic.

Table 3. The Explanation of Chemical Representations in the *Little Periodic*

Chemical representation	**Activities**
Macroscopic	The periodic table has several families (columns), blocks (sets of columns) and other classifications that unite certain elements according to their similar properties. One element of the game is the "Element Group Track". At the beginning of the game, each player places a microscope on the appropriate "Element Group Cards". By ending the turn with any flask on any of the elements within your next element group, the player advances on the "Element Group Track" and earn points.
Microscopic	The organisation of the periodic table inspired groups and classification of elements that are listed on the "Element Group Cards". It also helps explain the periodic trends such as atomic number, atomic mass, atomic radius and ionisation energy which are the trends the player will use to move around the game board.
Symbol representation	In Little Periodic, players research elements by landing on a specific element at the end the movement. Players will see which elements are available for research because they're shown on face-up Goal cards. Each Goal card has a collection of elements related by some use or other fact.

Little Periodic is a tabletop game in which players navigate the Periodic Table by utilizing periodic trends to gain advantages and score points by researching elements. The objective of the game is to research specific elements listed on Goal Cards to earn points, and the player with the highest score at the end of the game wins. The gameplay can be enhanced by utilizing Agenda Cards and Award Tiles. Figure 2(a) shows the example of Goal cards with 5 points and Figure 2(b) shows the example of Goal Cards with 7 points.

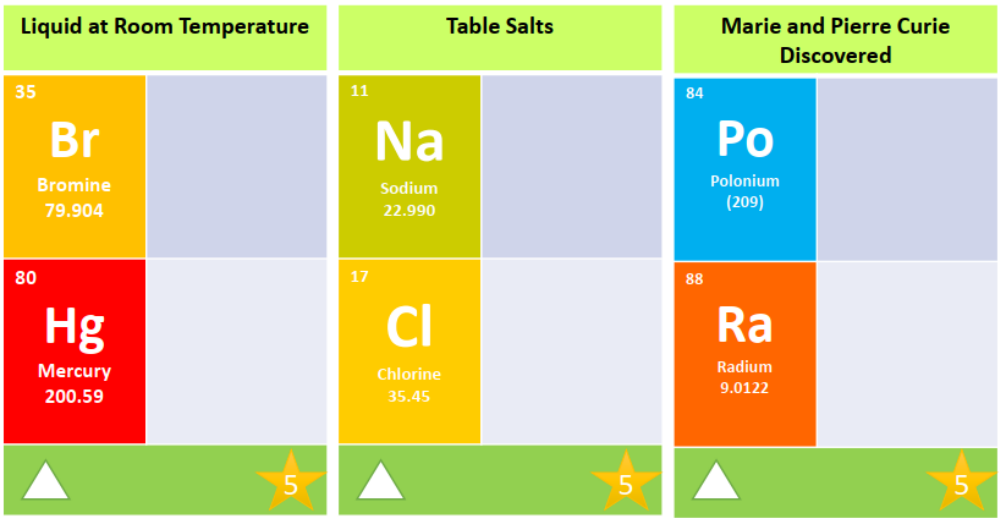

Figure 2(a). Goal cards with 5 points.

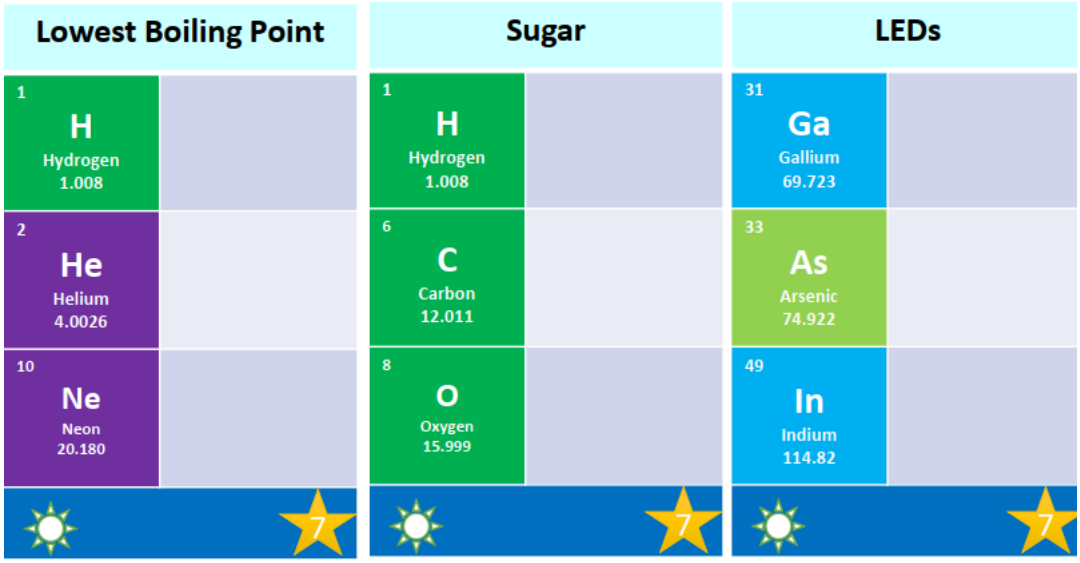

Figure 2(b). Goal cards with 7 points.

In Little Periodic, players not only research elements to score points but also compete with each other to end their turn within specific families of elements to earn Academic Points. Additionally, players have the opportunity to earn additional points by achieving a unique combination of objectives listed on the Agenda Cards. These objectives do not have to be completed together and players can earn points for either or both of the objectives listed on the card. Figure 3 displays a list of the different unique combinations of objectives that can be achieved.

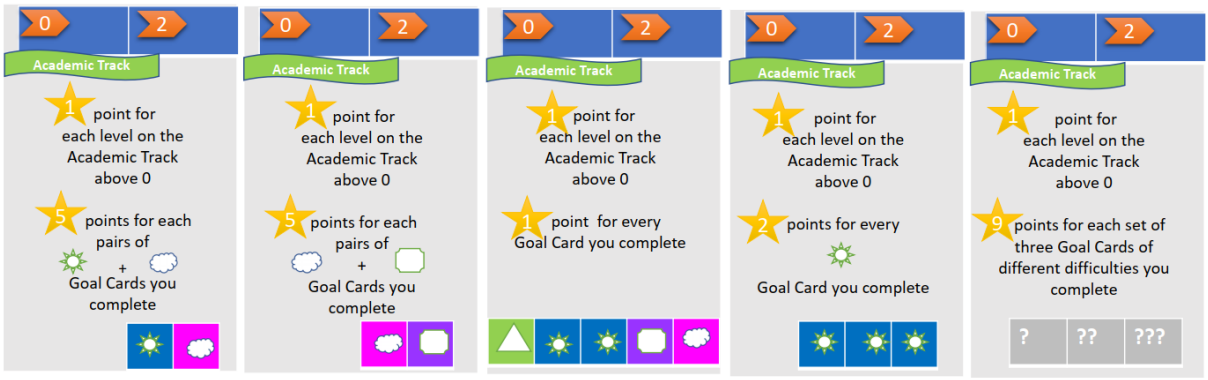

Figure 3. Agenda Cards

As players progress through the game and successfully complete Goal Cards, they are rewarded with Award Tiles which grant them one-time bonus abilities that can be used during their turn. The player can use as many of their earned Award Tiles as they wish to gain these bonuses. Figure 4 illustrates the four different types of Award Tiles available in the game.

Figure 4. Different Award Tiles

The periodic trends are patterns that emerge in the properties of elements as player moves across the periodic table. For example, elements on the left side of the periodic table are typically more reactive than those on the right side, and elements at the top of a column tend to have similar properties. By incorporating periodic trends into gameplay, the game provides an interactive and engaging way for players to learn about the periodic table and the properties of elements. In the game, players also collect Goal Cards by collecting sets of elements that match specific criteria, such as elements with similar properties or elements from specific groups or periods on the periodic table. This adds a set collection element to the game, providing players with additional opportunities to learn about the properties and characteristics of different elements.

The game's design and mechanics make it suitable for use in a classroom setting, as it can be used to teach students about the periodic table and chemistry concepts. The game can be used as a teaching tool to supplement lectures and textbook readings, or it can be used as a fun and engaging way to reinforce concepts learned in class. On the other hand, it provides an accurate and educational game that covers elements, groups, periodic trends, and vocabulary that are commonly taught in chemistry classes. The accuracy of the game's content makes it a valuable teaching tool for science teachers, as it provides an interactive and engaging way for students to learn and reinforce their understanding of chemistry concepts. In addition, Little Periodic can be played by multiple players, which requires them to collaborate and communicate effectively with each other to achieve their goals. This can help players

develop their teamwork and interpersonal skills, as well as their ability to communicate complex ideas and information clearly and effectively (Johnson et al., 1994).

RESULTS AND DISCUSSION

Validity

The aim of this study was to develop tabletop games as an intervention to enhance teachers' ability to support students' knowledge of chemical representation and conceptual understanding in the Periodic table of elements. According to Jamal (2019), to ensure that the developed tabletop games are appropriate and easy to comprehend for players, it is crucial to assess their validity (Jamal et al., 2019). In this study, the validity of the tabletop games was evaluated based on their content suitability, potential effectiveness, and overall satisfaction. When developing tabletop games for educational purposes, content validity is essential as it ensures that the content of the games is accurate (Ramli et al., 2017). The validity result for the content aspect is presented in Table 4.

Table 4. The result of the suitability of content aspect validity of the tabletop game

Suitability of Content Aspect Items	**Average of percentage from validators' Assessment**	**Validity Criteria**
1.The composition of the learning objectives in the tabletop game is clear.	91.7	Valid
2.The composition of the objectives of the tabletop game can be achieved based on the teaching activities used.	83.3	Valid
3.The composition of the objectives of the tabletop game can be achieved based on the strategies used.	100.0	Valid
4.Learning objectives are defined for each activity according to the gameplay suggested.	83.3	Valid
5.Teaching objectives can achieve tabletop game objectives.	91.7	Valid
6.Teaching objectives are expressed in measurable behaviour.	83.3	Valid
7. Teaching objectives that are stated to lead to the achievement of learning outcomes.	91.7	Valid
8.Tabletop games content can meet the stated learning objectives.	100	Valid
9. The tabletop games content is complete in terms of evaluation.	83.3	Valid

Based on Table 4, it can be concluded that Little Periodic is valid in terms of content. For instance, experts have judged that the composition of the objectives of the tabletop game can be achieved based on the strategies used, and the tabletop game's content can meet the stated learning objectives with a 100.0% consensus rate. Additionally, the experts assessed that the composition of the learning objectives in the tabletop game is clear, teaching objectives can achieve tabletop game objectives, and teaching objectives stated to lead to the achievement of learning outcomes with a 91.7% consensus rate.

Other components such as the composition of the objectives of the tabletop game can be achieved based on the teaching activities used, learning objectives defined for each activity according to the suggested gameplay, and teaching objectives expressed in measurable behavior, as well as the tabletop game's content being complete in terms of evaluation, were also found to be valid with a consensus

rate of 83.3%. Therefore, it can be concluded that all components of the tabletop game are valid in terms of content.

Potential effectiveness. Table 5 shows the result of potential effectiveness aspect validity of Little Periodic.

Table 5. The result of the potential effectiveness aspect validity of Little Periodic

Potential Effectiveness Aspect Items	Average percentage from validators' Assessment	Validity Criteria
1. The learning strategy in each activity is in line with the students' level of thinking.	83.3	Valid
2. The techniques used in tabletop games can be applied effectively.	83.3	Valid
3.The teaching strategy applied is in accordance with the syntax in Game-Based Learning.	91.7	Valid
4.The learning model applied to the tabletop game challenges students to think.	91.7	Valid
5. Activities proposed to use appropriate techniques to stimulate student activity in participating in Chemistry classes.	83.3	Valid
6.The scope of topics in the tabletop game corresponds to the developmental needs of students.	83.3	Valid
7.The order of topics in the tabletop game corresponds to the developmental needs of students.	75.0	Valid
8. The proposed activities are in line with the material presented.	83.3	Valid
9.The content presented in the tabletop games can be used by all parties in teaching chemistry.	91.7	Valid
10.The tabletop games content is suitable for use in different contexts such as at home.	100.0	Valid
11.The tabletop games content is suitable for use in different contexts such as at school.	100.0	Valid
12. The tabletop games content is suitable for use in different contexts such as cafes.	100.0	Valid
13. The learning media provided are in accordance with the learning objectives in the lesson plan.	91.7	Valid

Based on Table 5, the result of the validators' assessment of the tabletop game was valid in terms of its form, strategy, and techniques used. Specifically, the gameplay mechanics and learning strategies in Little Periodic were found to be appropriate for students' level of thinking (83.3%), the techniques used in the game can be effectively applied (83.3%), and the teaching strategy applied is in line with the syntax of game-based learning (91.7%). The game mechanics also challenged students to think critically (91.7%) and proposed appropriate techniques to stimulate student participation in chemistry classes

(83.3%). Additionally, the topics in the game corresponded to the developmental needs of students (75.0%) and the proposed activities were aligned with the content presented (83.3%). The game's content was also deemed suitable for use by all parties in teaching chemistry (91.7%) and suitable for use in different contexts such as at home (100.0%), school (100.0%), and cafes (100.0%). On the other hand, the tabletop game provided is in accordance with the learning objectives in the lesson plan.

All the results of the game assessment based on potential effectiveness are in line with previous studies that emphasized the importance of considering students' needs, suitable strategies and students' participation. The game also takes into account students' potential, knowledge transfer, and skills from context to reality.

Overall satisfaction. The overall satisfaction of the tabletop's validation can be seen through Table 6.

Table 6. The result of overall satisfaction aspect validity of tabletop game

Overall Satisfaction Aspect Validity	Average percentage from validators' Assessment	Validity Criteria
1. Activities in the tabletop games support students' knowledge in learning Chemistry.	91.7	Valid
2. The tabletop games provide multiple representations (microscopic, symbolic and macroscopic) in learning chemistry clearly.	83.3	Valid
3. Tabletop games make students directly involved in learning.	91.7	Valid
4. The activities presented in the tabletop games are in accordance with the characteristics of Game-based learning.	91.7	Valid
5. The tabletop game can help teachers to guide multiple representations of chemistry among students.	83.7	Valid

The result of validators' assessment shows that activities in the tabletop support students' knowledge in learning chemistry (91.7%), the tabletop games provides multiple representations (microscopic, symbolic, and macroscopic) in learning Chemistry clearly (83.3%), Tabletop games makes students directly involved in learning (91.7%), the activities presented in the tabletop games are in accordance with the characteristics of Game-Based Learning (91.7%), and overall, the tabletop game can help teachers to guide multiple representations of chemistry among students (83.7%). Therefore, this tabletop game can be an alternative to teachers in guiding chemical representation in learning the periodic table of elements. The summary of the results of tabletop game validity can be seen in Table 7 and Figure 4.

Table 7. The summary of result of tabletop game validity

	Percentage of Aspects			Validity Criteria
	Content	Potential Effectiveness	Overall Satisfaction	
Validator 1	100	94.2	100.0	Valid
Validator 2	86.1	88.5	85.0	Valid
Validator 3	88. 9	84.6	85.0	Valid
Average	**91.7**	**89.1**	**90.0**	**Valid**

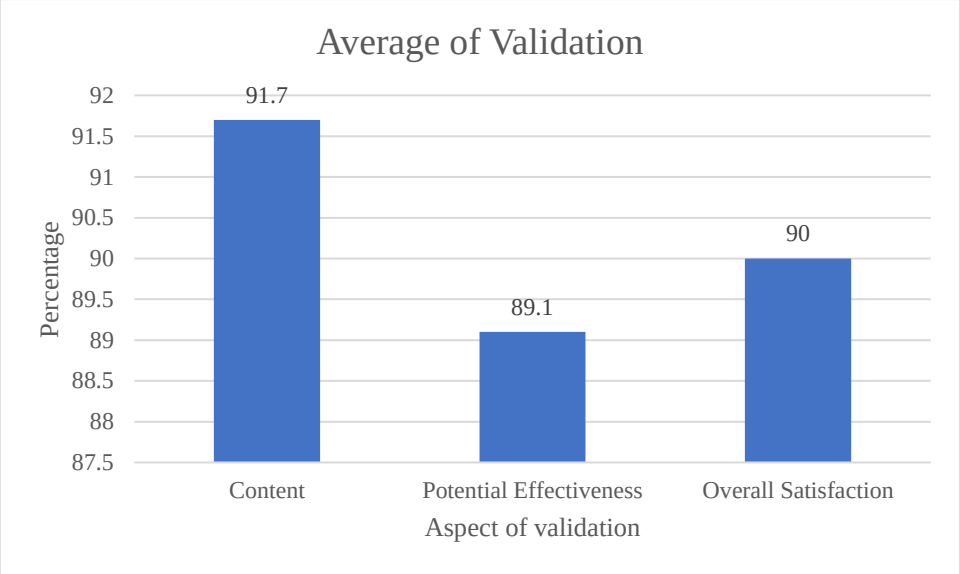

Figure 5. Bar chart of average of validation

Table 8. The summary of Teacher's Response

Items of Teachers' Response	**Average of percentage from validators' Assessment**	**Criteria Response of Users**
1. The tabletop games can help my students to understand the Periodic table of elements clearly.	91.67	Very Good
2. Tabletop games can improve my students' conceptual understanding.	100.0	Very good
3. The tabletop games can encourage my students to know the chemical representation.	91.67	Very good
4. The tabletop games can make my teaching and learning be students-center	100.0	Very good
Average	**95.8**	**Very good**

Based on Table 8, it is found that the expert validators gave a positive response to the tabletop game. In detail, Little Periodic can help the students to understand the Periodic Table of Elements clearly with a success rate of 91.67%. The tabletop game was also found to improve the students' conceptual understanding with a perfect score of 100%. Tabletop game encourages the students to learn chemical representation (91.67%) and can make teaching and learning more student-centered (100%). When the percentage of teachers' positive responses falls between 75.00% to 100%, it is considered to be a very good response. In this study, the average percentage of positive responses from expert validators was 95.8%, indicating that the tabletop game received a very positive response. Therefore, this tabletop game is recommended for use in teaching and learning chemistry as it follows a student-centered approach, encouraging students to learn by doing and providing new experiences (Ramli et al., 2017). Moreover, it can be used as an alternative to help teachers who face challenges in preparing lesson plans, as stated by Ramli et al. in their research (2017). Thus, Little Periodic is a intervention tool for teachers to improve teaching and learning outcomes.

CONCLUSION

This research aimed to develop a tabletop game named "Little Periodic" to address issues encountered in learning chemistry, specifically regarding the periodic table of elements. Little Periodic utilized game-

based learning and integrated chemical representation and conceptual understanding to facilitate learning. Validity testing indicated that the game achieved a content suitability score of 91.7%, potential effectiveness of 89.1%, and an overall satisfaction rate of 90%, suggesting its potential as a learning tool. Based on the findings from experts' perspectives, it can be concluded that the tabletop game developed has the potential to be implemented in real classroom settings. However, the extent to which Little Periodic enhances students' understanding of periodic table concepts, as well as its effects on other affective, cognitive, psychological, and psychomotor domains such as learning experiences, motivation, attitudes, values, and thinking skills, remains unknown. Therefore, further exploration of the effects of Little Periodic in promoting and enhancing the aforementioned domains is important.

However, it is worth noting that this study focused only on the periodic table of elements topic and there is a need for further research to develop tabletop games for other chemistry topics. By exploring other forms of game-based learning, future research can innovate and address issues encountered in learning chemistry across various topics, bridging the gap between traditional teaching methods and modern learning techniques.

REFERENCES

Bierenstiel, M., & Snow, K. (2019). Periodic universe: A teaching model for understanding the periodic table of the elements. *Journal of Chemical Education*, *96*(7), 1367-1376.

Bond, J., & Dirkin, K. (2020). What models are instructional designers using today? *The Journal of Applied Instructional Design*, *9*(2).

Bylikin, S., Horner, G., Grant, E. J., & Tarcy, D. (2023). *Oxford Resources for IB DP Chemistry: Course Book ebook*. Oxford University Press-Children.

Camara Olim, S. M., Nisi, V., & Rubegni, E. (2023). *"Periodic Fable Discovery" Using Tangible Interactions and Augmented Reality to Promote STEM Subjects.* Proceedings of the Seventeenth International Conference on Tangible, Embedded, and Embodied Interaction,

Cardinot, A., & Fairfield, J. A. (2022). Game-based learning to engage students with physics and astronomy using a board game. In *Research Anthology on Developments in Gamification and Game-Based Learning* (pp. 785-801). IGI Global.

Eichler, R. (2019). The periodic table of elements: superheavy in chemistry. *Nuclear Physics News*, *29*(1), 11-15.

Howell, E. (2022). *Using gamification and game-based learning to increase student engagement.* California State University, Stanislaus.

Jamal, S. N. B., Ibrahim, N. H. B., & Surif, J. B. (2019). Concept cartoon in problem-based learning: A systematic literature review analysis. *Journal of Technology and Science Education*, *9*(1), 51-58.

Johnson, D. W., Johnson, R. T., & Holubec, E. J. (1994). *The new circles of learning: Cooperation in the classroom and school*. ASCD.

Jonathan, F. C., & Recard, M. (2021). The implementation of gamification concept inside online classroom activities to promote students'engagement. *International Journal of Indonesian Education and Teaching*, *5*(2), 176-184.

Li, L., & He, T. (2022). Card Lab: An Educational Game to Support Chemistry Laboratory Learning. *Journal of Chemical Education*.

Napes, M. M., & Sharif, A. M. (2022). A Needs Analysis for The Game-Based Learning Tools Development for Form Four Chemistry Subject. *Journal of Science and Mathematics Letters*, *10*, 1-11.

Narod, F., & Narrainsawmy, V. (2022). Educators' reflections on the teaching and learning of the periodic table of elements at the upper secondary level: a case study. *Physical Sciences Reviews*.

Nkadimeng, M., & Ankiewicz, P. (2022). The affordances of minecraft education as a game-based learning tool for atomic structure in junior high school science education. *Journal of Science Education and Technology*, *31*(5), 605-620.

Plass, J. L., Mayer, R. E., & Homer, B. D. (2020). *Handbook of game-based learning*. Mit Press.

Rahmawati, Y., Hartanto, O., Falani, I., & Iriyadi, D. (2022). Students' conceptual understanding in chemistry learning using PhET interactive simulations. *Journal of Technology and Science Education*, *12*(2), 303-326.

Ramli, A., Ibrahim, N., Surif, J., Bunyamin, M. A. H., Jamaluddin, R., & Abdullah, N. (2017). Teachers' readiness in teaching STEM education. *Man in India*, *97*, 343-350.

Salame, I. I., Sarowar, S., Begum, S., & Krauss, D. (2011). Students' alternative conceptions about atomic properties and the periodic table. *Chem. Educator*, *16*, 190-194.

Saleem, A. N., Noori, N. M., & Ozdamli, F. (2022). Gamification applications in E-learning: A literature review. *Technology, Knowledge and Learning*, *27*(1), 139-159.

Tóthová, M., Rusek, M., & Chytry, V. (2021). Students' procedure when solving problem tasks based on the periodic table: An eye-tracking study. *Journal of Chemical Education*, *98*(6), 1831-1840.

Traver, V. J., Leiva, L. A., Martí-Centelles, V., & Rubio-Magnieto, J. (2021). Educational videogame to learn the periodic table: Design rationale and lessons learned. *Journal of Chemical Education*, *98*(7), 2298-2306.

Tsai, J.-C., Chen, S.-Y., Chang, C.-Y., & Liu, S.-Y. (2020). Element enterprise tycoon: Playing board games to learn chemistry in daily life. *Education Sciences*, *10*(3), 48.