Diversitas Journal
ISSN 2525-5215
Volume 11, Issue 2 (Apr./Jun. 2026) p. 0367 – 0382
https://diversitasjournal.com.br/diversitas_journal

Development and Validation of *Perioble*: A Board Game for Learning the Periodic Table of Elements

DIVINA, Reynaldo[(1)]; HAJA, Enilgen[(2)]; LASALA, Nestor Jr[(3)]

[(1)] 0009-0009-4289-3007; Sorsogon State University, Sorsogon City, Philippines, reydiv20@gmail.com
[(2)] 0009-0005-2188-0371; Sorsogon State University, Sorsogon City, Philippines, enilgenhaja14@gmail.com
[(3)] 0000-0002-8910-9613; Sorsogon State University, Sorsogon City, Philippines, nestor.lasala@sorsu.edu.ph

ABSTRACT

The Periodic Table of Elements is often difficult for junior high school students to learn, largely because of its abstract arrangement and the amount of recall it requires. This makes it important to explore instructional materials that can make the topic more engaging and easier to understand. To address this need, the present student developed and validated Perioble- a researcher-made board game intended for Grade 8 learners. The study followed a descriptive-developmental design and used the ADDIE framework to plan, develop, and improve the game. In designing the materials, emphasis was placed on student-centered learning, clear game goals and rules, interactive participation, and immediate feedback. Nine expert science teachers first evaluated the game using the DepEd LRMDS tool for manipulatives, focusing on content quality, scientific accuracy, and instructional and technical design. Their feedback was used to revise the material before it was tried out with students. The revised version was then pilot-tested with nine Grade 9 students, who evaluated its content and format using the adapted instrument. Findings showed that the experts viewed the game as relevant, accurate, and instructionally sound, while recommending minor improvements. The students, on the other hand, gave the Perioble favorable ratings, especially for its layout, mechanics, and clarity of concepts. Overall, the result shows that the game developed has potential as supplementary classroom material to support engagement and understanding in chemistry. Further studies must be conducted to assess its effectiveness in actual classroom implementation and other parameters.

ARTICLE INFORMATION

Article process:
Submitted: 11/15/2025
Approved: 04/23/2026
Published: 06/29/2023

Keywords:
perioble, periodic table of elements, educational board game, instructional material validation, game-based learning.

RESUMO

A Tabela Periódica dos Elementos costuma ser difícil de aprender para os estudantes do ensino fundamental, principalmente por causa de sua organização abstrata e da quantidade de memorização que exige. Isso torna importante explorar materiais instrucionais que possam tornar o tema mais envolvente e mais fácil de compreender. Para atender a essa necessidade, o presente estudo desenvolveu e validou o Perioble, um jogo de tabuleiro elaborado pelo pesquisador e destinado a alunos do 8º ano. O estudo seguiu um delineamento descritivo-desenvolvimental e utilizou o modelo ADDIE para planejar, desenvolver e aprimorar o jogo. No desenvolvimento do material, deu-se ênfase à aprendizagem centrada no estudante, a objetivos e regras claras do jogo, à participação interativa e ao feedback imediato. Nove professores especialistas em Ciências avaliaram inicialmente o jogo utilizando o instrumento LRMDS do DepEd para materiais manipuláveis, com foco na qualidade do conteúdo, na precisão científica e no design instrucional e técnico. Os comentários desses avaliadores foram utilizados para revisar o material antes de sua aplicação com os estudantes. A versão revisada foi então submetida a um teste piloto com nove alunos do 9º ano, que avaliaram seu conteúdo e formato por meio do instrumento adaptado. Os resultados mostraram que os especialistas consideraram o jogo relevante, preciso e pedagogicamente adequado, embora tenham recomendado pequenos aprimoramentos. Os estudantes, por sua vez, atribuíram ao Perioble avaliações favoráveis, especialmente quanto ao layout, à mecânica e à clareza dos conceitos. De modo geral, os resultados indicam que o jogo desenvolvido tem potencial como material complementar de sala de aula para apoiar o engajamento e a compreensão em Química. Estudos futuros ainda precisam ser realizados para avaliar sua eficácia em contextos reais de implementação em sala de aula e em outros parâmetros.

Keywords:
perioble, tabela periódica dos elementos, jogo educativo de tabuleiro, validação de material instrucional, aprendizagem baseada em jogos.

DOI: 10.48017/dj.v11i2.3712

Introduction

The periodic table of elements serves a cornerstone in chemistry education as it acts as a unifying framework for the composition and characteristics of different elements (Chowdhury, 2022). By organizing the elements into a systemized tabular form, the learning of the elements and their properties are simpler to grasp (Jalmasco et al., 2025); Nsabayezu et al., 2023). The Matatag Curriculum in its outlined competency for Grade 8 students focuses on the mastery of the Periodic Table particulary on elemental symbols, periodic arrangements, and recurring trends (Department of Education, 2023), emphasizing that early conceptual understanding a keystone for success in suceeding chemistry topics.

Nonetheless, numerous students struggle in acquiring the basic concepts of the topic. As a concept taught in the secondary level, Students tend to have persistent misconceptions regarding valency, atomic number, atomic mass, and the meaning of periods and groups (Chowdhury, 2022). The topic is oftenly viewed as dull, theoretical, and overly subjugated by memorization (Saleh & Ismail, 2024). Specifically, Filipino students, displays unsubstantial grasp of the concept, inadequate motivation, and poor problem-solving performance in tasks related to Periodic table(Holme, 2020). Likewise, Teachers face difficulties in translating abstract representations—such as atomic structure and periodicity—into an engaging and contextualized concept due to the topic's complexity requiring high cognitive function (Mokiwa, 2017). These challenges are mirror in the international assessments such as PISA 2022 with Filipinos performing below from the standards (OECD, 2023).

Game-based learning has become prominent in recent years as a pedagogical approach as it supports deeper understanding in science while at the same time increasing engagement. Enhanced cognitive processing, memory retention, emotional engagement, and collaborative learning have been some of the benefits of this (Alotaibi, 2024). Board games, in particular, bring about methodical and interactive atmosphere that enhances pattern recognition, strategic thinking, and sustained attention—skills which are needed in total understanding of periodic trends and elemental properties (Alejandria et al., 2023). Nevertheless, despite the emphasis of the JHS curriculum in the Philippines, especially on the topics of the Periodic table, it lacks validated instructional materials that put together game-based learning with sound content accuracy and alignment in the curriculum

To address this gap, the present inquiry developed and validated Perioble to help Grade 8 learners, master fundamental concepts of the Periodic table via student-centered, interactive, and feedback-rich gameplay. Specifically, the study sought to (1) developed game-based activity in teaching concepts on the Periodic Table of Elements, (2) determine how expert science teachers evaluate its content accuracy, up-to-dateness, and instructional and technical design, and (3) assess students' level of acceptability of the game in terms of content and format. By answering these questions, the study aims to deliver a validated, pedagogically sound instructional material that can enhance tecahing and learning process and aid more engaging, meaningful, and conceptually articulated chemistry instruction in junior high school science.

Methodology

This research utilized a descriptive–developmental research design incorporating the ADDIE instructional design model—Analysis, Design, Development, Implementation, and Evaluation—to methodically develop and validate *Perioble*, a board game intended to aid the junior high school learners in understanding the Periodic Table of Elements. The ADDIE framework is extensively used in the development of instructional materials as it guarantees an iterative, organized, and evidence-driven procedure that augments both the usability of the learners and pedagogical quality (Branch, 2009; Molenda, 2015). In line with this, a sequence of needs analysis, conceptual design, prototype construction, expert validation, revision, and student acceptability testing were done by the researchers.

The Analysis phase connects the review of empirical studies on learners' difficulties with the periodic table. Several studies consistently describe students' misconceptions and disengagement (Chowdhury, 2022; Zaragozá, 2021) as well as the challenges among teachers in simplifying abstract, symbolic concepts such as periodicity (Mokiwa, 2017). The Matatag Curriculum, with its outlined competencies among Grade 8 Learners further highlighted the necessity for instructional materials related to elemental symbols, periodic trends, and chemical properties (DepEd, 2023). This needs assessment justifies the extent of the content and pedagogical direction of the game.

In the Design phase, representational features, game's mechanics, scoring system, components, and feedback structures were outlined. The indispensable drivers of engagement and conceptual understanding in a Game-Based Learning are student-centeredness, rule clarity, interaction, and immediate feedback (Sailer et al., 2017; Alotaibi, 2024). These principles guided the devising of tile and board design, card functions, game rules, and overall flow of the gameplay. To ensure that all content elements and mechanics closely matched Grade 8 science competencies, alignment matrices were recruited—a commended step in educational material development (Plomp & Nieveen, 2013).

In the Development phase, Perioble prototype was created, comprising of the game board, tiles, group cards, power cards, and instruction set. Before any external validation, the researchers conducted an Internal review to check clarity, alignment, and logistical feasibility. This phase established the first set of formative modification, to be in line with ADDIE's iterative character.

In the Implementation–Evaluation phase, the conduct of expert validation which was subsequently followed by student acceptability testing were administered at Casiguran Technical Vocational School (CVTS) where Nine purposively selected science Teachers validate the game- chosen for their teaching experiences, knowledge with the Matatag Curriculum, and prior experience evaluating instructional materials. They assessed the game through the DepEd LRMDS Assessment and Evaluation Tool for Manipulatives (DepEd, 2009).

Several criteria including content completeness, accuracy and currency of information, and instructional/technical design were assessed. The descriptive rating and scale ranges used by the experts are presented in Table 1, which is placed immediately after its first citation for clarity and methodological transparency.

Table 1:

Scale Range Descriptive Rating

Scale Range	Descriptive Rating
3.28-4.00	Very Satisfactory (VS)
2.52-3.27	Satisfactory (S)
1.76-2.51	Poor (P)
1.00-1.75	Not Satisfactory (NS)

Qualitative commentaries of the Experts were descriptively adapted and used to improve the prototype, parallel with ADDIE's iterative revision prior to the implementation. Following this is the conduct of a small-group pilot test involving nine purposively selected Grade 9 students from one of the public high schools in Sorsogon, Philippines who had completed Grade 8 chemistry, guaranteeing there are no disruptions to the current instructions as well as sufficient prior knowledge to measure clarity and usability of the Perioble; at this stage, the emphasis is acceptability instead of learning outcomes (Nieveen, 2013).

The instrument used for the pilot testing were adapted from Lasala (2022), which measured format, clarity, layout, ease of play, and content understanding by means of a five-point Likert scale. Table 2 shows the descriptive interpretation of the scale, placed immediately after its first reference as suggested in APA and Scopus guidelines.

Table 2:

Descriptive Interpretation of the Board Game

Scale Range	Verbal Interpretation	Descriptive Rating
4.5-5.0	Strongly Agree	Excellent
3.5-4.49	Agree	Very Good
2.5-3.49	Undecided	Good
1.5-2.49	Disagree	Fair
1.0-1.49	Strongly Disagree	Poor

Using weighted means, Expert's and students evaluation data were summarized, while mode was used to specify the extent of experts' agreement on the fittingness of the board game for usage in the classroom. Additionally, the responses of students to the open-ended questions were analyzed thematically and incorporated into game amendments, in line with the ADDIE's developmental focus, where students' suggestions were considered to further improve the materials yet not to be interpreted as a measure of its effectiveness.

Ethical protocols were rigorously followed throughout the conduct of the study; informed consent was protected, approval was asked and gained from school administrators, partaking was voluntary, and confidentiality was supported. The feedback collected are only used to polish and improve the instructional material.

Results and Discussion

The periodic table of Elements is a fundamental topic in chemistry, as it contains the physical and chemical properties of elements. However, learning its basic concepts (chemical symbols, periods, groups, etc.) may seem monotonous and tiring (Bernardo & González, 2021). Hence, this study's objective is to develop and validate a board game that aims to gamify the learning of the Periodic table among Grade 8 students.

Development of Perioble: An Instructional Game-board and its features

The instructional game board, coined as Perioble, merges the Periodic Table of Elements with Scrabble to provide learners with and interactive, strategy-driven, and congnitively engaging way to master periodic table concepts. It integrates scrabble-style gameplay mechanics with core chemistry concepts, resulting in a 30 x 20-inch game set with 118 tiles, 19 group/property cards, and two power cards, as shown in Figures 1 and 2.

Figure 1: *The Perioble board game*

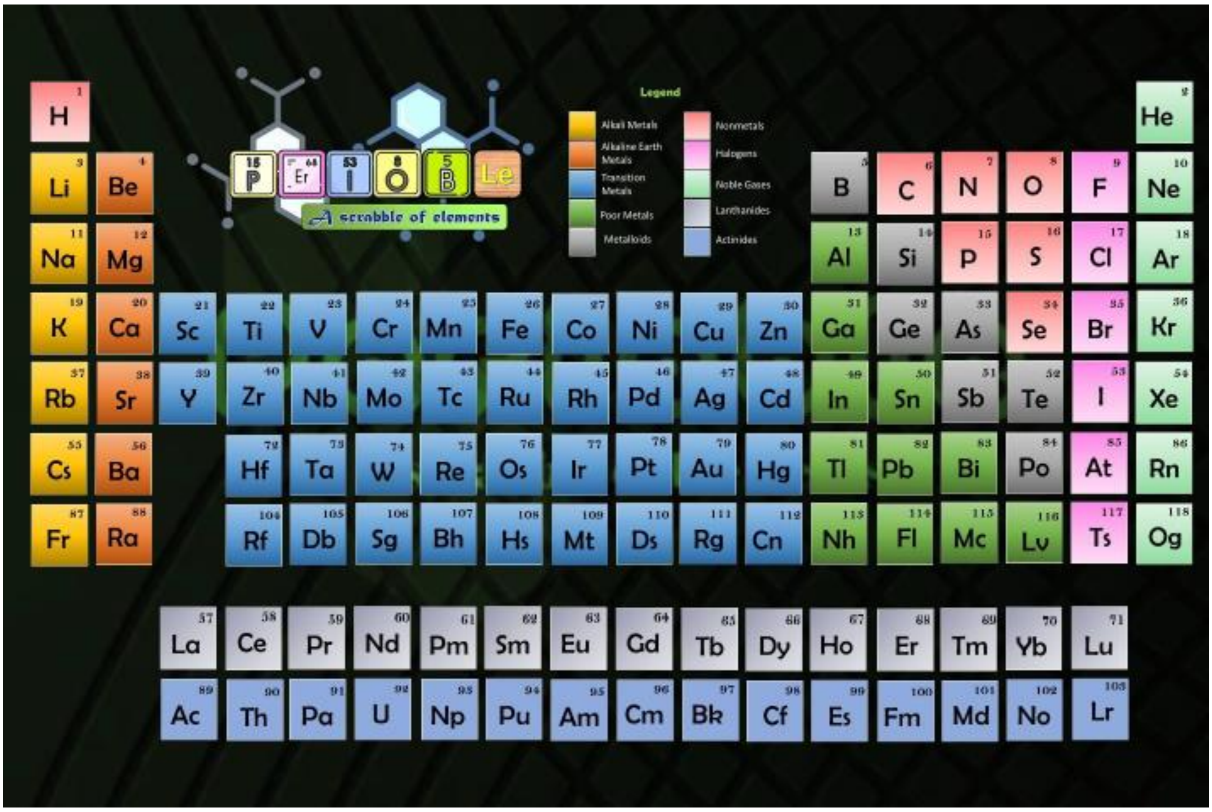

Figure 2:

Cards and tiles used in the developed Perioble

Periodic Board in Figure was intentionally and pedagogically designed to mirror the standard arrangement of the periodic table, this maintains the periodic table's familiar spatial arrangement, minimizes unnecessary cognitive effort by allowing learners to draw on existing mental schemas when identifying groups and periods, thereby reducing extraneous load and supporting clearer concept acquisition. Prior studies on innovative learning tools show that preserving scientific fidelity in instructional design anchors engagement in correct disciplinary structures and maintains alignment with curriculum standards (Gestiada et al., 2025; Jalmasco et al., 2025).

Likewise, perioble's tile-and-card design (Figure 2) follows instructional principles supported by recent local studies: element tiles promote learning retention through repeated, visual-tactile manipulation similar to E-Selfimo (Lasala et al., 2025), while group/property cards provide scaffolding that supports pattern recognition and categorization, consistent with findings from interactive digital instruction (Laciste et al., 2025).

The inclusion of power cards that introduce guided randomness and strategic decision-making aligns with results from validated game-based biology activities, where strategic choice and autonomy significantly enhanced student motivation and conceptual engagement (Lasala, 2024a). Similar benefits of strategic play and rule-based movement in reinforcing scientific concepts were also demonstrated in the physics-based Laro-ng-Lahi activities, which improved learners' conceptual understanding through culturally grounded, game-driven decision tasks (Besa et al., 2025). With these instructional components, Perioble provides structured yet adaptive mechanics that may enhance conceptual reasoning, support motivation, and align strategically with curriculum requirements.

Student-Centered Design: Another feature integrated with the design and development of perioble is student-centered design. Perioble engages learners through visual and tactile interaction and peer strategy, supporting socio-constructivist learning as students manipulate materials, justify choices, and negotiate solutions (Bada, 2015; Gillies, 2016). Its multisensory cues reduce anstraction in learning symbolic periodic concepts (Tabler, 2013), while the rule-based group play and point system promote communication, strategic thinking, and sustained motivation through challenge and feedback (Deci & Ryan, 2000; Vlachopoulos & Makri, 2017).

Goal- and Rule-Oriented: Meanwhile, perioble aligns with Grade 8 Matatag competencies, and a brief pre-game orientation to objectives and rules helps students plan strategies while reducing extraneous load (Paas & Sweller, 2012). Each component is purpose-built to reinforce periodicity, atomic numbers, and classification, with rewards and penalties prompting self-monitoring and strategy adjustments. Such goal-driven mechanics support meaningful engagement and the use of concepts in learning games (Plass et al., 2015).

Immediate Feedback system: Moreover, the developed perioble was designed with an immediate feedback loop through peer responses, teacher-modertaor checks, scoring cues, and on the spot correctons. With this, students are able to reflect on their answers, correct their misconception and monitor their own learning, all while playing the game (Shute, 2008; Hattie & Timperley, 2007; Sadler, 1989).

Interactivity and Collaborative Engagement: At the same time, peioble sustains multi-layered interactivity between students, teachers, peers, and game components, so learners actively manipulate information, justify and negotiate moves, and engage in science-focused discourse while teacher facilitation and scaffolding further strengthen reasoning and conceptual clarity (Chi & Wylie, 2014; Lasala, 2024b; Webb, 2009; Furtal et al., 2012; Plass et al., 2015).

With these and by combining these features, perioble has the potential to turns the teaching and learning of periodic table of elements into a collaborative, less intimidating learning experience where all students are allowed to commit mistakes in a safe environment, which may boosts motivation, and supports both conceptual and procedural understanding. Grounded in cognitive, constructivist, and motivational principles, it can function as both a supplementary resource and a driver of more active, inquiry-oriented science instruction.

Experts' Validation of the Developed Perioble Board Game

The developed board game was validated by 9 Expert Science Teachers from Casiguran Technical and Vocational School (CVTS). They played the game and afterwards they rated the game by answering the Evaluation Tool for manipulatives which was adapted from DepEd LRMDS (2009). The validators evaluated three factors from the board game which are; a.) Content; B.) Accuracy and Up-to-date-ness of Information; and c.) Technical Design, each with its own criteria. The weighted mean of each criteria indicate a descriptive rating, which specifies if it's satisfactory or needs further modification. The following shows the results of Validation of the Board Game. Additional suggestions of the panels were also given as well as the tally if they recommend the board game for public school use. The table below indicates the tally of results for each factor evaluated by the 9 validators with the likert scale mean and its descriptive rating.

Table 3:

Results of the Expert's validation of the Perioble Board game

Criteria	Points to Pass (Deped, 2009)	Jurors Evaluation									Mean	Likert Scale Mean	DR
		J1	J2	J3	J4	J5	J6	J7	J8	J9			
A. Content	At least 30 out of 40	33	39	37	38	36	36	35	38	38	36.67	3.68	VS
B. Accuracy and Up-to-datedness	At least 16 out of 16	14	16	12	14	15	14	12	14	14	13.89	3.47	VS
C. Instructional and Technical Design	At least 18 out of 24	22	23	23	24	23	23	24	23	22	23.00	3.89	VS

Notes: J1, J2 J3 J4 J5 J6 J7 J8 J9- Jurors of the Game DR: Descriptive Rating VS: Very Satisfactory

In terms of Content, experts rated this as Very Satisfactory, indicating strong alignment between the game elements and the Grade 8 competencies of the Matatag Curriculum. This further implies that the developed gameboard may support mastery of the concepts through repeated and context-rich gameplay. According to Haynes et al. (1995), ensuring content alignment of the developed instructional material is important for keeping learning tasks coherent and preventing surface-level understanding (Haynes et al., 1995). Validators also noted that the activities are fitted to Grade 8 learners' cognitive level and may naturally reinforce concept recall, reflecting constructivist schema-building supported by coherent game mechanics (Fosnot, 2013; Plass et al., 2015).

Accuracy and up-to-dateness also obtained a Very Satisfactory rating, showing that the board game presents information that is current, correct, and consistent with the periodic table concepts expected at the high school level. This is important because instructional materials must not only engage learners but also present scientific ideas clearly and correctly. Previous studies have emphasized that updated and accurate content helps prevent misconceptions and supports smoother learning by minimizing unnecessary cognitive load (Taber, 2012; Paas & Sweller, 2014). While the experts did not find any serious inaccuracies in the material, they suggested a few refinements, particularly updating some group labels to align with IUPAC conventions and clarifying categories that may confuse learners, such as metalloids. These recommendations were incorporated into the revised version during the evaluation phase of the ADDIE framework. Making these adjustments strengthens the representational accuracy of the material, which is essential in helping students develop clearer and more stable conceptual understanding (Gilbert & Tragust, 2009; Richey & Klein, 2007).

Lastly, experts rated Instructional and Technical Design Very Satisfactory, highlighting its usability, visual clarity, and potential classroom fit. The expert found the layout, color coding, and organization intuitive and aligned with the Universal Design for Learning (UDL) Principles, noting that the board's resemblance to a periodic table supports quick scanning and a smooth transfer to lessons (CAST, 2018). Validators also praised the readable typography and sturdy components, with minor suggestions such as thicker tiles and laminated cards to improve durability. These are consistent with good educational game design that reduces cognitive load and sustains engagement (Plass et al., 2015; Mayer, 2014; Hunicke et al., 2004). Overall, Periobld experts' rating met all the criteria for classroom use, with some requiring minor revisions; the researchers ensured that all of these were incorporated into the final revision of the board game.

Students' Level of Acceptability of the Developed Perioble Board Game

Following the completion of expert validation and the subsequent revisions informed by their recommendations, the enhanced version of Perioble was subjected to learner validation to assess its acceptability from the perspective of its intended end-users. Whereas expert evaluation established the board game's curricular alignment, scientific accuracy, and technical soundness, student evaluation provides equally critical insight into its actual usability, motivational appeal, and pedagogical value during authentic classroom interaction. In developmental research, this complementary process of expert and learner validation is foundational to ensuring both the instructional soundness and practical classroom viability of newly developed educational materials (Plomp & Nieveen, 2013).

After integrating expert recommendations, the revised Perioble board game was pilot-tested with nine Grade 9 students from Sorsogon State University Laboratory High School, who engaged in gameplay and subsequently evaluated the material using the Student Evaluation Tool adapted from Lasala (2022). This instrument measured two core dimensions—Format and Content—through a five-point Likert scale. As shown in Table 4, both domains exceeded the DepEd-LRMDS performance benchmarks and received Very Satisfactory descriptive ratings, indicating high student acceptability and affirming the game's pedagogical suitability for facilitating learning of the periodic table.

Table 4:

Results of the Students' Validation of the Board game

Components	Mean Evaluation on Developed Perioble Board Game	Description
Content	4.62	VERY SATISFACTORY
Format	4.75	VERY SATISFACTORY
Mean	4.69	VERY SATISFACTORY

Table 4 shows that student evaluators rated both criteria, Content and Format, Very Satisfactory, with weighted means of 4.62 and 4.75, respectively. The high ratings suggest that learners view Perioble as a potential instructional resource for learning about the periodic table. Format was given the topmost rating, as students described the design as clear, engaging and easy to understand. The color coding, font size, arrangement of elements and symbols enable them to play the game systematically, emphasizing that the design closely bear similarity to the actual periodic table of elements used in the schoolroom, which makes it simpler to determine the periods and groups. Such a layout associates with cognitive load theory, which claims that clear visual design lessens processing complexity and aids learners concentrate on the main content (Paas & Sweller, 2014; Mayer, 2009).

Students also indicated that the simple mechanics and evident objectives, uniform with research proves that simple rules may help in the progress of the useableness of instructional materials and game flow in the context of education (Kiili, 2005). Furthermore, Student described that the visual features of the Perioble aided in gaining their attention, which is corelated with the results of several studies about the importance of coherence between aesthetics and interactivity enhancing engagement and motivation (Moreno & Mayer, 2007; Hamari et al., 2016).

On the other hand, Content was also rated with a Very Satisfactory rating (4.62) from the student-evaluators, demonstrating that students perceived the concepts understandable and clear. As stated by one of the students, "Malaking tulong iyong perioble sa pag-aaral ko ng periodic table of elements, mabilis ko naiintindihan kasi paulit-ulit naming naeencounter sa laro iyong mga terms (*Through the help of the Perioble, I managed to understand the Periodic Table of Elements. I did not just memorize it but I understand the concepts because I always encounter it in the game) "* The interactive manipulation of tiles reinforced a more profound encoding of information, paralleled with the constructivist learning theory by which findings shows that active participation improves conceptual mastery (Olakanmi, 2017).

Students also depicted the game as entertaining and motivating, sharing that *"Nakakaenjoy and I love competing with my classmates in a friendly manner and I really didn't expect na ganito sya kaganda na laro (It's fun and competitive. I didn't expect the periodic table to be this fun and enjoyable."* This emphasizes the worth of motivation in a game-based learning, exclusively when the outline assists autonomy, ability, and social interaction (Sailer et al., 2017).

Additionally, students extended constructive recommendations that uncover thoughtful engagement with the tool. Some suggested enlarging particular tiles to increase visibility during group play—*"Some tiles are small; it would be better if they were bigger so we can see them clearly in groups."*—while others implied adding more challenge elements or informational cues, such as *"Maybe add more power cards so the game becomes more exciting,"* and *"Include short facts about the elements so we can learn more while playing."* These comments present constructive insights for potential iterations under the ADDIE Development and Revision phases demonstrating learners' aspiration for deeper content incorporation and improved strategic complexity.

Overall, the Very Satisfactory ratings in both Format and Content show that Perioble is well positioned with student needs andperceptions, backing both engagement and conceptual understanding. The ensemble of positive insights and thoughtful recommendations highlights the game's robust potential as a pedagogical tool that can improve engagement, strengthen periodic table concepts, and encourage enjoyable and active learning experiences in chemistry education.

Conclusion

This study design developed and validated Perioble, an instructional board game designed for Grade 8 students to support the learning of concepts related to the periodic table of elements. Following the ADDIE framework and grounded in student-centered learning, clear goals, active learning, and immediate feedback. Experts' validation yielded favorable results across content and instruction, technical design, and accuracy, indicating that the material is aligned with curricular expectations and suitable for classroom use.

Minor revisions were made based on expert recommendations, particularly in improving accuracy, further strengthening the quality of the game. Students' evaluations also reported high acceptability, with high ratings for both format and content, and described the game as clear, engaging, and helpful for reencountering periodic table concepts. Despite these positive findings, the study was limited by the small number of validators and its implementation within a single-school context. In addition, the investigation focused only on the development and validation of the material and did not examine its effectiveness in improving learning outcomes.

Thus, future research may explore the instructional effects of the perioble, and broader implementation across various educational settings may be conducted. Overall, the findings suggest that perioble is a valid and promising supplementary classroom material that can make learning the periodic table of elements more fun, engaging, interactive, and accessible.

REFERENCES

Alejandria, L., Domingo, J., & Dalmacio, M. (2023). *The use of educational board game as a supplemental tool in learning periodic table of elements among senior high school students.* ResearchGate. https://www.researchgate.net/publication/369247052_The_Use_of_Educational_Board_Game_as_a_Supplemental_Tool_in_Learning_Periodic_Table_of_Elements_Among_Senior_High_School_Students

Alotaibi, M. S. (2024). Game-based learning in early childhood education: A systematic review and meta-analysis. *Frontiers in Psychology, 15*, Article 1307881. https://doi.org/10.3389/fpsyg.2024.1307881

Bada, S. O. (2015). Constructivism learning theory: A paradigm for teaching and learning. *Journal of Research & Method in Education, 5*(6), 66–70.

Besa, R., Surbano, J. D., & Lasala, N. Jr. (2025). *Effectiveness of traditional Filipino games on senior high school students' conceptual understanding of physics. Diversitas Journal, 10*(3), 1269–1288. https://doi.org/10.48017/dj.v10i3.3510

Branch, R. M. (2009). *Instructional design: The ADDIE approach*. Springer. https://doi.org/10.1007/978-0-387-09506-6

CAST. (2018). *Universal Design for Learning guidelines version 2.2*. CAST, Inc.

Chi, M. T. H., & Wylie, R. (2014). The ICAP framework: Linking cognitive engagement to active learning outcomes. *Educational Psychologist, 49*(4), 219–243. https://doi.org/10.1080/00461520.2014.965823

Chowdhury, P. (2022). Learners' misconceptions in the periodic table: An analysis of cognitive skills development. *Universal Journal of Educational Research, 10*(1), 57-66. https://doi.org/10.13189/ujer.2022.100106

Deci, E. L., & Ryan, R. M. (2000). The "what" and "why" of goal pursuits: Human needs and the self-determination of behavior. *Psychological Inquiry, 11*(4), 227–268. https://doi.org/10.1207/S15327965PLI1104_01

Fosnot, C. T. (2013). *Constructivism: Theory, perspectives, and practice* (2nd ed.). Teachers College Press.

Furtak, E. M., Seidel, T., Iverson, H., & Briggs, D. C. (2012). Experimental and quasi-experimental studies of inquiry-based science teaching: A meta-analysis. *Review of Educational Research, 82*(3), 300–329. https://doi.org/10.3102/0034654312457206

Gestiada, R. J., Tisoy, F. J., & Lasala, N. L. Jr. (2025). The 360° view: Contextualized virtual reality tours as innovative teaching tool in ecology for elementary school students. *Journal of Basic Education Research, 6*(1), 35–48. https://doi.org/10.37251/jber.v6i1.1213

Gilbert, J. K., & Treagust, D. F. (2009). *Multiple representations in chemical education*. Springer. https://doi.org/10.1007/978-1-4020-8872-8

Gillies, R. M. (2016). Cooperative learning: Review of research and practice. *Australian Journal of Teacher Education, 41*(3), 39–54. https://doi.org/10.14221/ajte.2016v41n3.3

Hamari, J., Shernoff, D. J., Rowe, E., Coller, B., Asbell-Clarke, J., & Edwards, T. (2016). Challenging games help students learn: An empirical study on engagement, flow, and immersion. *Computers in Human Behavior, 54*, 170–179. https://doi.org/10.1016/j.chb.2015.07.045

Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of Educational Research, 77*(1), 81–112. https://doi.org/10.3102/003465430298487

Haynes, S. N., Richard, D. C. S., & Kubany, E. S. (1995). Content validity in psychological assessment: A functional approach to concepts and methods. *Psychological Assessment, 7*(3), 238–247. https://doi.org/10.1037/1040-3590.7.3.238

Holme, T. A. (2020). Will 2020 Be an Inflection Point in the Trajectory of Chemistry Teaching and Learning?. *Journal of Chemical Education*, *97*(12), 4215-4216.

Hunicke, R., LeBlanc, M., & Zubek, R. (2004). MDA: A formal approach to game design and game research. In *Proceedings of the AAAI Workshop on Challenges in Game AI* (pp. 1–5).

Jalmasco, A. C., Loberes, J. M., & Lasala, N. L. Jr. (2025). Interactive story for teaching ecosystem topics using Twine application for elementary school students. *Journal of Basic Education Research, 6*(2), 66–78. https://doi.org/10.37251/jber.v6i2.1480

Kiili, K. (2005). Digital game-based learning: Towards an experiential gaming model. *The Internet and Higher Education, 8*(1), 13–24. https://doi.org/10.1016/j.iheduc.2004.12.001

Laciste, C., Ellaine, S., & Lasala, N. J. (2025). Enhancing Students' Understanding of Image Formation in Optics through a Bilingual Electronic Science Module (e-BiSciMo). *Diversitas Journal*, *10*(4). https://doi.org/10.48017/dj.v10i4.3520

Lasala Jr, N. (2024a). Effects of Game-Based Activities on Student's Social Skills and Attitudes toward Learning Science. *Recoletos Multidisciplinary Research Journal*, *12*(1), 181–194. https://doi.org/10.32871/rmrj2412.01.14

Lasala Jr, N. L. (2022). Validation of game-based activities in teaching Grade 7-Biology. Jurnal Pendidikan IPA Indonesia, 11(4), 519-530. https://doi.org/10.15294/jpii.v11i4.39185

Lasala Jr, N. L. (2024b). STUDENTS ' INTRINSIC MOTIVATION USING GAME-BASED ACTIVITIES. Dalat University Journal of Science, 50-70. https://doi.org/10.37569/DalatUniversity.14.2.1161(2024)

Lasala Jr, N., Ricafort, J., & Prado, J. (2025). Effect of E-learning Self-directed Interactive Module (E-SelfIMo) on Students' Understanding of Earth Science Concepts

Mayer, R. E. (2014). *The Cambridge handbook of multimedia learning* (2nd ed.). Cambridge University Press.

Mokiwa, H. O. (2017). Reflections on teaching periodic table concepts: A case study of selected schools in South Africa. *Eurasia Journal of Mathematics, Science & Technology Education, 13*(6), 2085–2096. https://www.ejmste.com/download/reflections-on-teaching-periodic-table-concepts-a-case-study-of-selected-schools-in-south-africa-4732.pdf

Molenda, M. (2015). In search of the elusive ADDIE model. *Performance Improvement, 54*(2), 40–42. https://doi.org/10.1002/pfi.21461

Moreno, R., & Mayer, R. E. (2007). Interactive multimodal learning environments. *Educational Psychology Review, 19*(3), 309–326.

Nieveen, N. (2013). Formative evaluation in educational design research. In T. Plomp & N. Nieveen (Eds.), *Educational design research: Part A* (pp. 152–169). SLO –

Netherlands Institute for Curriculum Development. https://slo.nl/publish/pages/2904/educational-design-research-part-a.pdf

Nsabayezu, E., Mbeh, G. N., & Niyitanga, J. B. (2023). Online periodic table of elements: A digital learning tool for students. *Education and Information Technologies*. https://doi.org/10.1007/s10639-023-11650-7

OECD. (2023). *PISA 2022 results (Volume I): The state of learning and equity in education*. OECD Publishing. https://doi.org/10.1787/53f23881-en

Olakanmi, E. E. (2017). *The effects of a flipped classroom model of instruction on students' performance and attitudes towards chemistry. Journal of Science Education and Technology, 26*(1), 127-137. https://doi.org/10.1007/s10956-016-9657-x

Paas, F., & Sweller, J. (2012). An evolutionary upgrade of cognitive load theory: Using the human motor system and collaboration to support the learning of complex skills. *Educational Psychology Review, 24*(1), 27–45. https://doi.org/10.1007/s10648-011-9179-2

Paas, F., & Sweller, J. (2014). Implications of cognitive load theory for multimedia learning. In R. E. Mayer (Ed.), *The Cambridge Handbook of Multimedia Learning* (2nd ed., pp. 27–42). Cambridge University Press. DOI: https://doi.org/10.1017/CBO9781139547369.004

Plass, J. L., Homer, B. D., & Kinzer, C. K. (2015). Foundations of game-based learning. *Educational Psychologist, 50*(4), 258–283. https://doi.org/10.1080/00461520.2015.1122533

Plomp, T., & Nieveen, N. (Eds.). (2013). *Educational design research: An introduction and illustrative cases*. SLO.

Richey, R. C., & Klein, J. D. (2007). *Design and Development Research: Methods, Strategies, and Issues*. Lawrence Erlbaum Associates.

Sadler, D. R. (1989). Formative assessment and the design of instructional systems. *Instructional Science, 18*(2), 119–144. https://doi.org/10.1007/BF00117714

Sailer, M., Hense, J. U., Mayr, S. K., & Mandl, H. (2017). How gamification motivates: An experimental study of the effects of specific game design elements on psychological need satisfaction. *Computers in Human Behavior, 69*, 371-380. https://doi.org/10.1016/j.chb.2016.12.033

Saleh, S. B., & Ismail, W. S. A. O. W. (2024). Systematic literature review on the use of gamification approaches in mastering the periodic table of elements (Chemistry). *International Journal of Educational Narratives, 2*(5), 448–465. https://research.adra.ac.id/index.php/ijen/article/view/507

Shute, V. J. (2008). Focus on formative feedback. *Review of Educational Research, 78*(1), 153–189. https://doi.org/10.3102/0034654307313795

Taber, K. S. (2013). Revisiting the chemistry triplet: Drawing upon the nature of chemical knowledge and the psychology of learning to inform chemistry education. *Chemistry Education Research and Practice, 14*(2), 156–168. https://doi.org/10.1039/C3RP00012E

Vlachopoulos, D., & Makri, A. (2017). The effect of games and simulations on higher education: A systematic literature review. *International Journal of Educational Technology in Higher Education, 14*, 22. https://doi.org/10.1186/s41239-017-0062-1

Webb, N. M. (2009). The teacher's role in promoting collaborative dialogue in the classroom. *British Journal of Educational Psychology, 79*(1), 1–28. https://doi.org/10.1348/000709908X380772

Zaragozá, F. T. (2021). Periodic table of the elements, history, education and evaluation. *Nereis. Interdisciplinary Ibero-American Journal of Methods, Modelling and Simulation, 8*(13), 147-164. https://doi.org/10.46583/nereis_2021.13.808