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Chem-Okey card game: a supplementary learning material to introduce acid-base concepts to undergraduate students

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ABSTRACT

Teachers play an important role in adopting teaching strategies that foster active, constructive learning and make challenging subjects engaging and enjoyable. This study aimed to design, develop, and evaluate Chem-Okey, an educational card game, as a supplementary tool to master the acid-base concepts using game-based learning (GBL) theory. The evaluation process utilized a Likert scale based on the five criteria of GBL results indicated high acceptance and effectiveness in all criteria, demonstrating Chem-Okey's potential to significantly enhance student engagement and learning outcomes. The learning resources management and development system (LRMDS) of the Philippines' education standards were applied to validate the educational merit of the game, confirming its suitability for interactive content delivery. Furthermore, the results revealed that students had positive in-game, post-game, and social presence experiences, underscoring the game's ability to foster a collaborative and immersive learning environment. Chem-Okey's gameplay, requiring team strategy and peer dialogue, effectively promoted social interaction and cognitive engagement, making learning more enjoyable and effective. Chem-Okey is an effective supplementary learning tool, helping students enhance their understanding of acid-base concepts while enjoying the game. The findings highlight the value of well-designed educational tools in transforming learning experiences and promoting both academic and social competencies among students.

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1. INTRODUCTION

The 2022 PISA scores revealed a significant concern in the Philippine education system, with Filipino students ranking sixth lowest in science, technology, engineering, and mathematics (STEM) competencies among 81 participating countries [1]. Several challenges are preventing effective learning and mastery of complex concepts among STEM students in the Philippines [2]. For example, the abstract nature of chemistry often requires visualization and deep understanding, which traditional teaching methods need to provide [2], [3]. These methods, which are primarily lecture-based, struggle to facilitate meaningful engagement with the material, thus posing a significant challenge for students attempting to master these complex concepts [3]. Moreover, the predominance of teacher-centered strategies in chemistry instruction further exacerbates the issue. These strategies, while structured, do not encourage the active participation and critical thinking

necessary for understanding scientific principles [3], [4]. This reliance on traditional methods restricts the potential for more dynamic and interactive educational experiences, which have been shown to enhance student understanding and retention of complex topics [5], [6]. Additionally, the engagement and motivation of students are crucial for successful learning outcomes, particularly in subjects perceived as challenging, like chemistry. A learner's level of interest profoundly impacts their ability to absorb and apply new knowledge. When students lack interest, their cognitive, emotional, and physical engagement with the content significantly diminishes, negatively affecting their learning achievements [5], [6]. The critical role of student interest in promoting better learning outcomes is well-supported in educational research. These collective challenges underscore the necessity for innovative approaches in chemistry education. Implementing strategies, for example, games, that promote more significant interaction, student-centered learning, and personal engagement can transform the learning experience and improve educational outcomes in chemistry [7].

To address these problems, exploring a more student-centric learning approach and interactive teaching approaches that can enhance engagement and cater to individual learning preferences is essential [8]. Innovative approaches, such as practical activities, can help students develop science process skills that they can practically apply in their natural environment. Game-based learning (GBL) is one of the innovative and engaging strategies used in science teaching, which promotes a learner-centered environment [9], [10].

While various GBL strategies have been explored in chemistry education, few studies have effectively integrated multiple core concepts of acids and bases into a single, cohesive learning tool. This study introduces a novel approach by incorporating all fundamental aspects-definition, naming, properties, applications, and real-world relevance-within a unified game format tailored for undergraduate students. Additionally, the use of Okey game mechanics in a card-based format enhances accessibility and cost-effectiveness, addressing limitations of prior board- and tile-based adaptations. By synthesizing these elements, this study presents a more comprehensive and structured approach to game-based chemistry learning, offering a replicable model for future instructional innovations.

GBL has emerged as a compelling alternative to traditional teacher-centered and lecture-driven education methods, sparking a significant reevaluation of teaching approaches within STEM disciplines [11], [12]. The appeal of GBL stems from its ability to inject dynamic engagement and interactive learning into the educational environment [13]. Theoretical models define GBL, demonstrating how the role of playfulness in learning and games can optimize learning by integrating cognitive, motivational/behavioral, affective, and sociocultural foundations [14]. Numerous studies in chemistry education have shown the effects of GBL on learning outcomes [14], [15], motivation [16], and student performance [17], to name a few.

Various studies have investigated the effectiveness of different teaching strategies in chemistry, mainly focusing on acids and bases. Researchers presented a hybrid board game to teach acid-base concepts, using storytelling and gameplay to impart critical knowledge about acid-base regulation [18]. Others have introduced mobile augmented reality applications that enable hands-on learning experiences for titration experiments [19]. Developers have also created a card game adapted from Texas Hold 'em to illustrate acids and bases, allowing players to use their knowledge of these properties to achieve the highest possible rank with five cards [20]. Another game, similar to Rummikub, uses a set of 106 plastic or wooden tiles to help students learn the names and symbols of common ions and their compounds [21]. While these studies show the effectiveness of utilizing games to learn important concepts in acids and bases, they are only limited to the definition, naming, application, properties, and examples separately at the secondary level. More so, the study that utilized Okey game mechanics was limited to familiarizing names and symbols of common ions and utilized wooden tiles. This highlights the gap in combining all these important concepts in one game to ensure a thorough and complete understanding of acids and bases in an undergraduate curriculum. In addition, using Okey rules in a card game addresses the concern about the cost of wooden tiles as well as replicability and ease of use.

As such, this study aims to design, develop, and evaluate a card game as supplementary teaching material on acids and bases based on GBL principles to undergraduate chemistry students based on Okey [22] game mechanics. Furthermore, the study also aims to analyze the game experience of undergraduate students when exposed to the game.

2. METHOD

2.1. Research design

This research employed a design and development research design under the instructional design theory (IDT) [23], [24]. The goal of this research design is to generate new information and validate current teaching practices [24]. The researchers designed and created a card game using GBL foundations [14]. The card game was used as supplementary material on undergraduate topics on acids and bases. The game evaluation consisted of two components: i) the Philippines' Department of Education's (DepEd) learning resources management and development system (LRMDS) [25]–[27] and ii) the GBL evaluation scale [7].

Science teachers were included as expert respondents to evaluate the card game using the LRMDS tool, while one in-tact undergraduate class served as a participant in a GBL evaluation scale tool. Students' game experience was also analyzed using the game experience questionnaire [28], [29].

2.2. Research participants and context

The study participants were first-year nursing students (N=40, and are roughly 19-22 years old) and science teachers (N=40) from PHINMA Cagayan de Oro College (PHINMA-COC), Pedro 'Oloy' N. Roa Senior High School (PONRSHS), Misamis Oriental General Comprehensive High School (MOGCHS), and University of Science and Technology of Southern Philippines. In the Philippine education standards, a single undergraduate semester spans five months. Biochemistry and its allied subjects are sometimes integrated into one comprehensive course, where acids and bases are among the topics commonly covered [30]. At the first-year undergraduate level, students are expected to gain a robust understanding of the fundamental principles of acid-base chemistry, including the properties, behavior, and reactions of acids and bases and their relevance in biological systems [31], [32]. In the nursing program, biochemistry is considered a major course and the only introductory chemistry course. Basic concepts in general chemistry are deemed to have been taken up in the senior high school program under the basic education curriculum either as separate courses (i.e., general chemistry 1 and 2) or as integrated courses (earth and life sciences and physical sciences).

Teachers who evaluated the game were selected based on their teaching experience of more than five years, a graduate degree in science education, and experience of employing similar activities in their classroom for the past two years. Only teachers with chemistry and allied sciences degrees were considered, as there were in-science teachers who did not possess a science major degree. The teachers who participated in the evaluation of the game did not receive any monetary remuneration for their involvement. However, to acknowledge their contributions, they were provided with meal tickets as a token of appreciation for their time and effort.

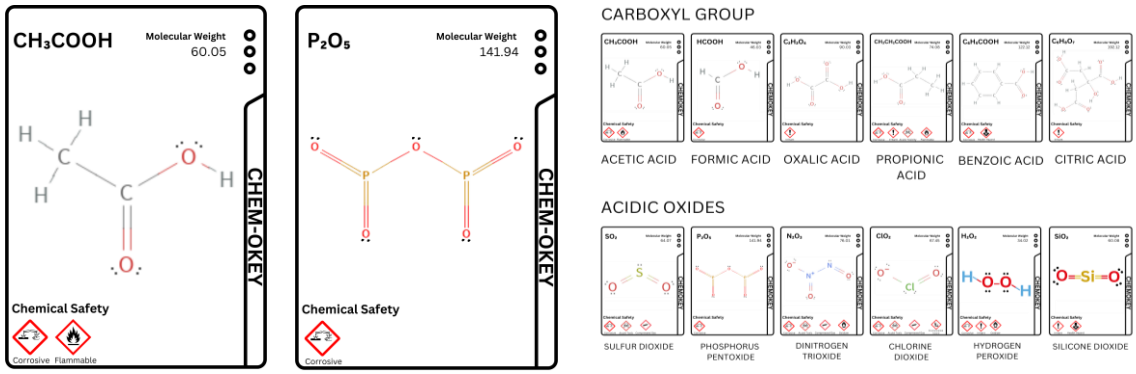
2.3. Card design and game mechanics

2.3.1. Game objectives

The Chem-Okey card game was developed as a supplementary learning material that can be used to foster familiarization with common examples of acids and bases. The game is intended to be used after the introduction of the concepts to the students as a means to have a more engaging and fun way of familiarizing acids and bases instead of the usual seat/board work utilized in traditional instruction. In this manner, students get to interact with the game and their peers while familiarizing themselves with the concepts.

2.3.2. Card game design

Chem-Okey is a card game that consists of 100 cards. The deck is divided into four main categories: carboxylic acids and acidic oxides representing the acids, shown in Figure 1, and hydroxides and basic oxides representing the bases, shown in Figure 2, each category containing 12 cards of 4 sets plus wild cards, shown in Figure 3. The acid cards are divided into two categories, each consisting of six compounds, as shown in Figure 1. Figure 1(a) is an example of an acid with a carboxyl group while Figure 1(b) is that with an acidic oxide group. Figure 1(c) shows the complete set of acid cards.



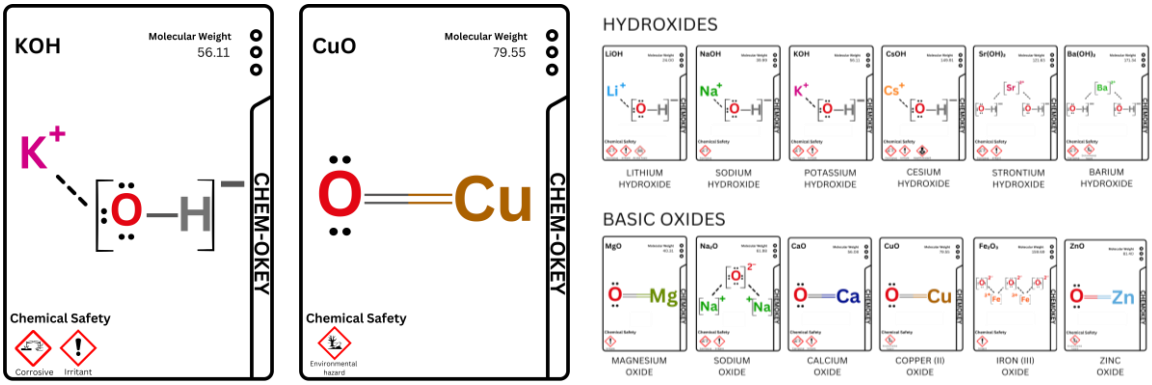
(a) (b) (c)

Figure 1. Chem-Okey card game design for acid (a) carboxyl group, (b) acidic oxide group, and (c) complete set of acid compounds

As shown in Figure 2, the base cards are divided into two categories, each consisting of six compounds. Figure 2(a) shows an example of a base with a hydroxide functional group while Figure 2(b) is a base with an oxide group. Figure 2(c) shows all complete sets of the base compound cards.

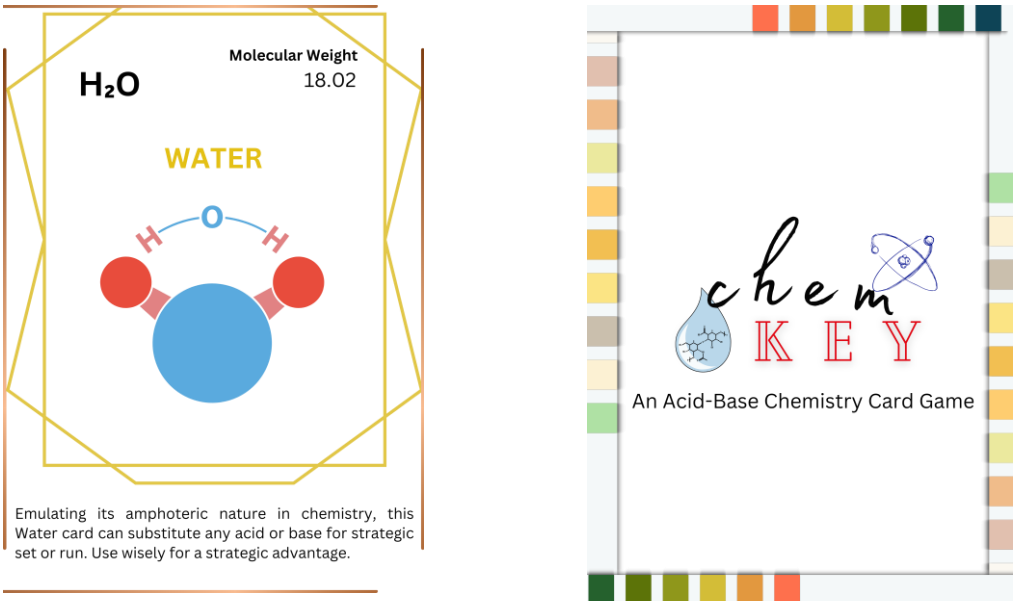
Special water molecule cards, shown in Figure 3(a), act as wild cards. These wild cards can substitute for any card to complete a set or run, mimicking water molecules' versatile role in real-world chemical processes. Players can use these cards for a strategic advantage.

Lastly, as depicted in Figure 3(b), the reverse side of each card uniformly features the card game developed logo, ensuring that all cards appear identical when face down, which is key for maintaining the element of surprise and strategy during gameplay. This card game is designed to serve as a supplementary tool for teaching and learning acid and base.



(a) (b) (c)

Figure 2. Chem-Okey card game design for base (a) hydroxide group, (b) basic oxide group, and (c) complete set of base compounds



(a) (b)

Figure 3. Chem-Okey card (a) wild card design and (b) back side card design

The deck is divided into four categories: for acids-carboxylic group (12 cards) and acidic oxide (12 cards). For bases-hydroxides (12 cards) and basic oxides (12 cards), each card contained its chemical structures, names, molecular weights, and safety hazard symbols. We also have four special water molecule cards that act as wild cards to spice up the game.

2.3.3. Game mechanics

The Chem-Okey gameplay mechanics are structured to reinforce core chemistry concepts through interactive learning, as outlined below:

- There will be four individual players in each game. The deck consists of acid and base cards, shuffled by the dealer before the start of the game. Each player is dealt 14 cards, and the first dealer gets an additional card, totaling 15.
- The game is played anticlockwise, starting with the player to the dealer's right. Each turn involves drawing one card from either the draw pile or the discard pile and then discarding one card face-up onto the discard pile.
- Players aim to form sets or runs of acid-base pairs based on chemical properties, structures, molecular weights, and safety symbols. A set consists of three or four cards of the same category, while a run is a sequence of acid or base cards from different categories.
- Special water molecule cards, acting as wild cards, can substitute for any card to complete a set or run. These cards mimic water molecules' versatile role in real-world chemical reactions.
- Each player continues to draw and discard cards, striving to be the first to form a hand consisting entirely of valid sets or runs of acid-base pairs.
- If a player cannot form a valid set or run on their turn, they must pass and draw an additional card from the deck.
- The game continues until one player successfully forms a complete hand of sets or runs and declares victory.
- In case of a tie or if the draw pile is exhausted, the game proceeds with players calculating the points based on the molecular weights and properties of their remaining cards.
- The player with the highest points, based on their cards and any special wild cards, wins the game.

2.4. Research instruments

In the study, before the full implementation of the final card game, select science teachers employed specific evaluation tools to ensure the effectiveness and compliance of the game with educational standards. LRMDS was utilized as a standard measure to ensure that the card game adhered to the prescribed educational guidelines and was compliant with the curricular requirements set by the DepEd [26]. The LRMDS tool consists of three key parameters that were used to assess the game. Content (factor A) focuses on the information's accuracy, relevance, and comprehensiveness. Other findings (factor B) include various qualitative and quantitative assessments on pedagogical effectiveness, usability, and accessibility, such as conceptual and factual errors, grammatical and typographical errors, and other errors. Manipulatives (factor C) examine the quality and durability of the physical components and their effectiveness in engaging students in interactive learning experiences. These parameters provide a thorough evaluation of the game's educational value. The rating was based on a scale from one (1-not satisfactory) to four (4-very satisfactory) for factors A and C, while for factor B, one (1-poor) to four (4-not present)

For the collection of data on students' evaluations of the card game and game experience, the study utilized a GBL evaluation scale [7] and a game-experience questionnaire (GEQ) [29] were administered. The GBL evaluation scale explored the development of affective, behavioral, cognitive, and sociocultural engagement during gameplay, thereby yielding four subscale scores. The GEQ was also employed to evaluate students' overall game experience. This tool is specifically designed to measure the impact of the game on students' learning experiences, focusing on aspects such as in-game experience, social presence, and post-game experience.

2.5. Data gathering procedure and statistical treatment

The data-gathering process was meticulously segmented into procedures for teacher-expert evaluators and student participants. Initially, authorization was secured from the principals of PONRSHS and MOGCHS, along with the deans of the University of Science and Technology of Southern Philippines, and PHINMA-COC. Subsequently, science teachers from these institutions, having been chosen for their expertise, undertook the evaluation of the developed card game. After receiving the necessary endorsements, the research instruments a GBL evaluation scale and the GEQ were administered to the targeted first-year nursing students. The study also ensured strict compliance with the ethical research guidelines stipulated in the research ethics manual of the University of Science and Technology of Southern Philippines to ensure the safety and protection of both the researchers and the participants. The means and standard deviations were used to summarize and interpret the card game evaluation and experience data.

3. RESULTS AND DISCUSSION

3.1. Evaluation of the card game

The teachers evaluated the Chem-Okey card game using the LRMDS tool, adhering to the standard set by the DepEd. As shown in Table 1, the LRMDS evaluation of the Chem-Okey educational materials

demonstrates a commendable alignment with the DepEd standards, highlighting these resources' high quality and educational appropriateness. With high scores in content clarity, other findings, and the physical design of manipulatives all rated as 'very satisfactory,' the results validate the materials' effectiveness in presenting complex chemistry concepts in an accessible and engaging manner. This meticulous attention to detail ensures accuracy and relevance, fostering a conducive learning environment. The findings underscore the significance of high-quality educational resources in enhancing learning outcomes, particularly within GBL strategies like those employed in the Chem-Okey study. By meeting the stringent criteria set by the LRMDS, the Chem-Okey materials exemplify the potential of well-crafted educational tools to transform learning experiences, especially in challenging subjects such as chemistry.

Students assessed the card game based on four key GBL foundations: affective, behavioral, cognitive, and sociocultural engagement. Tables 2 to 5 summarize the ratings across all criteria, highlighting its significant potential to enhance student engagement and improve learning outcomes in chemistry education based on GBL principles. Affective engagement is an important element in fostering a supportive and conducive learning environment, as it maintains students' motivation and receptiveness to new information [33], [34]. This dimension of engagement specifically targets the emotional experiences, attitudes, and beliefs of the learners, which play a pivotal role in their overall educational journey [14].

The Chem-Okey card game utilizes a variety of shapes, such as rectangles, rounds, and lines, to depict cards, atoms, and bonds, respectively. Additionally, it features prominent colors like white, yellow, blue, and red. These visual elements play a vital role in enhancing students' affective engagement, which is crucial for cultivating an effective learning environment. Research indicates that specific shapes and colors, particularly round shapes and bright, warm colors, can elicit positive emotional responses, reduce cognitive load (perceived task difficulty), and facilitate comprehension and transfer performance [33], [35]. The shape and layout of the game significantly impact students' affective engagement, including their interest, excitement, and enjoyment. The high level of acceptability of Chem-Okey can be attributed to the deliberate and meticulous selection of shapes, colors, and figures designed to evoke positive emotions conducive to learning [28]. This intentional design supports the development of students' affective engagement, underscoring the importance of visual elements in educational games. Moreover, including points and rewards within the game significantly contributes to the observed high levels of affective engagement. Research suggests that game rewards generate positive emotions, which expand cognitive resources.

The findings of this study, as depicted in Table 2, reveal that students perceive the game as fun, engaging, and exciting. They also strongly prefer the game's shape and color, further validating the positive impact of these visual elements on their overall learning experience. This alignment of game design with educational outcomes highlights the potential of well-crafted educational tools in fostering an engaging and effective learning environment. Educators can develop educational games that significantly enhance students' affective engagement and overall learning outcomes by carefully considering visual elements essential to learning.

Behavioral engagement, or motivation, is predominant in ensuring that games captivate and motivate players through enjoyable and engaging experiences. Key game design elements, such as challenge, curiosity, and fantasy, are inherently motivating for players [36], [37]. Challenges can drive motivation by providing tasks that escalate in difficulty, ensuring players remain optimally challenged and engaged [38]. Research shows that games presenting challenging tasks enhance critical thinking and problem-solving skills, leading to higher engagement [39]. As shown in Table 3, high student behavioral engagement ratings support their claims that the game promoted critical thinking and offered an enjoyable experience. The game's challenging tasks required players to apply critical thinking skills to solve problems, enhancing behavioral engagement. This aligns with the self-determination theory, which posits that competence is a critical intrinsic motivator [40]. The study underscores the importance of motivation in eliciting positive attitudes toward the game, thereby enhancing behavioral engagement in GBL environments.

Table 1. Teacher's evaluation of the Chem-Okey card game based on LRMDS (N=40)

Criteria	Mean±SD	Interpretation
Factor A: content	3.91±0.29	Very satisfactory
Factor B: other findings	3.84±0.37	Very satisfactory
Factor C: manipulatives	3.78±0.42	Very satisfactory

Table 2. Student's evaluation of the Chem-Okey card game based on affective engagement (N=40)

No	Statements	Mean±SD	Interpretation
1.	Chem-Okey is exciting and inviting to me.	4.88±0.33	Strongly agree
2.	I feel bored by the Chem-Okey activities.	1.23±0.42	Strongly disagree
3.	I like the Chem-Okey card game's shape and color design.	4.70±0.46	Strongly agree
4.	I am interested in the activities I can do with Chem-Okey.	4.85±0.36	Strongly agree
5.	Chem-Okey is a fun game to play.	4.83±0.38	Strongly agree

Table 3. Student's evaluation of the Chem-Okey card game based on behavioral engagement (N=40)

No	Statements	Mean ± SD	Interpretation
1.	The layout and design of Chem-Okey is aesthetically pleasing, which encourages me to keep playing.	4.70±0.46	Strongly agree
2.	The game mechanics of Chem-Okey are easy to understand, which makes me want to play more.	4.18±0.68	Agree
3.	I was engaged and focused the entire game.	4.85±0.36	Strongly agree
4.	Chem-Okey encourages me to think critically and to improve my application and analysis abilities.	4.93±0.27	Strongly agree
5.	The competition and challenge of the game provided me with an engaging experience.	4.95±0.22	Strongly agree

Cognitive engagement refers to how much students invest their mental effort and strategies into learning and mastering content [41]. In the Chem-Okey card game, cognitive engagement effectively engages students' thinking skills and deepens their understanding of chemistry concepts, as indicated in Table 4. The card game developed, Chem-Okey, requires players to meticulously organize sets and runs of cards based on various acid-base properties and molecular weights. This intricate gameplay necessitates a deep understanding and practical application of theoretical chemistry, ensuring students engage actively with the material. The functional aspect of Chem-Okey involves students in active learning, emphasizing the importance of putting theoretical knowledge into practice, which aids their comprehension of acids and bases. This hands-on approach translates directly to the high cognitive engagement ratings observed, as the game encourages critical thinking and problem-solving skills. By integrating complex game mechanics that require strategic thinking and in-depth knowledge, Chem-Okey ensures that cognitive engagement is stimulated and sustained, resulting in meaningful and impactful learning experiences. This high level of cognitive engagement highlights the effectiveness of the card game in translating theoretical concepts into practical understanding, thereby enhancing students' overall grasp of chemistry.

Table 4. Student's evaluation of the Chem-Okey card game based on cognitive engagement (N=40)

No	Statements	Mean ± SD	Interpretation
1	I find the difficulty of Chem-Okey appropriate to my level.	3.98±0.77	Agree
2	I find the game to be challenging and complex.	4.73±0.45	Strongly agree
3	I think that Chem-Okey will be useful for understanding the topic.	4.88±0.33	Strongly agree
4	When Chem-Okey introduces me to acid-base concepts, I ask myself questions to make sure I understand what they represent.	4.90±0.30	Strongly agree
5	I think that the game mechanics of Chem-Okey were clear.	4.83±0.45	Strongly agree

Socio-cultural engagement refers to how learners interact and collaborate within a learning environment, fostering a sense of community and shared educational goals. Table 5 indicates that the Chem-Okey card game achieved a high level of socio-cultural engagement, the highest among the parameters. This high engagement level highlights the game's effectiveness in uniting players around common educational objectives. Rooted in Vygotsky's social development theory, which emphasizes the social nature of learning [42]. Chem-Okey's gameplay requires team strategy and peer dialogue to assemble chemical sets and runs, fostering a collaborative learning model. This approach promotes the sharing and integration of knowledge and aligns with research suggesting that academic collaboration leads to optimal learning outcomes. The Chem-Okey card game design, which includes complex tasks in a supportive setting, meets the psychological needs of learners for competence, autonomy, and relatedness, which makes them more interested and helps them learn more [40], [43], [44] The high socio-cultural engagement of Chem-Okey card game underscores its efficacy in creating a cooperative learning environment beyond traditional knowledge acquisition, promoting essential social competencies and positive attitudes toward learning.

Table 5. Student's evaluation of the Chem-Okey card game based on social/cultural engagement (N=40)

No	Statements	Mean ± SD	Interpretation
1	By playing Chem-Okey, I can learn from and form meaningful connections with the other players.	4.53±0.55	Strongly agree
2	I can learn more about the game and see things from different points of view by sharing ideas and strategies.	4.95±0.22	Strongly agree
3	Playing Chem-Okey can be a great way to foster conversation and build relationships with others.	4.93±0.27	Strongly agree
4	Chem-Okey provides a space for me and other players to come together and learn from each other.	4.43±0.78	Strongly agree

3.2. Student's game experience

Game experience refers to an individual's overall feelings and responses after playing a game. It encompasses various dimensions, including in-game experience, post-game experience, and social presence, as shown in Tables 6-8. The in-game experience encompasses learners' interactions and perceptions within the game environment, significantly affecting their engagement and learning outcomes. Table 6 demonstrates the game's success in inducing high levels of sensory-imaginative immersion, feelings of competence, and a flow state, suggesting a population of deeply absorbed and motivated students. The supportive learning environment, characterized by low affective load (tension and negative emotions), fostered a relaxed atmosphere conducive to knowledge acquisition [14], [45]. Furthermore, the game's optimal challenge level ensured sustained student interest while mitigating frustration, underscoring the importance of well-calibrated tasks in educational games. As reported by students, the positive effect further emphasized the game's potential to be emotionally supportive, a substantial element for maintaining motivation and enriching the overall learning experience in chemistry education [34], [41]. These findings illuminate the substantial role a meticulously designed in-game experience plays in promoting cognitive engagement and achieving positive learning outcomes.

The post-game experience captures students' reflections and emotions after participating in a game, including their overall satisfaction and sense of achievement. As presented in Table 7, the evaluation of the Chem-Okey card game's post-game experience revealed high levels of positive experiences, showing that the game effectively provided satisfaction, energization, and revival among students, consistent with the principles of GBL [46], [47]. Conversely, the study showed minimal negative experiences and tiredness, indicating that the game did not cause significant physical or emotional fatigue. The social interactions facilitated by the game likely helped mitigate any potential tiredness [48], [49]. Furthermore, students reported a moderate urge to return to reality following gameplay. This suggests that the game successfully immerses students, a critical factor for enhancing learning outcomes as it can increase attention and motivation [38]. Chem-Okey's gameplay involves various stages that contribute to these post-game experiences. For instance, after completing rounds of assembling chemical sets and runs and interacting with peers, students reflect on their performance, strategy, and the knowledge they have gained. These reflective moments, paired with positive social interactions during gameplay, enhance the overall learning experience. Understanding the post-game experience is imperative for this study as it points out the lasting impact of the game on student engagement and learning effectiveness, emphasizing the value of immersive and enjoyable educational tools.

Social presence refers to how connected and involved participants feel with others in a shared environment, fostering a sense of community and emotional engagement. Table 8 indicates that the students reported high levels of empathy, which may imply the potential of the game to promote understanding and shared emotional experiences [50]. Students reported low levels of negative feelings, suggesting a positive and supportive game environment that mitigates distress and promotes cooperation [42]. The game's ability to engage players in strategic thinking and collaborative decision-making further enhances overall engagement and involvement Chem-Okey's gameplay, which requires team strategy and peer dialogue for assembling sets and runs, naturally fosters a high level of social presence. This cooperation builds shared understanding and emotional connections among players, making the learning process more enjoyable and effective. By fostering empathy, reducing negative emotions, and encouraging behavioral involvement, the Chem-Okey card game effectively promotes social skills and positive attitudes toward learning, which is essential for its success in educational settings.

Table 6. Student's evaluation of the Chem-Okey card game based on in-game experience (N=40)

Criteria	Mean ± SD	Interpretation
Sensory and imaginative immersion	4.18±0.63	Agree
Competence	4.10±0.78	Agree
Tension	1.55±0.72	Strongly disagree
Flow	4.22±0.85	Agree
Challenge	4.53±0.76	Strongly agree
Negative affect	1.42±0.59	Strongly disagree
Positive affect	4.12±0.81	Agree

Table 7. Student's evaluation of the Chem-Okey card game based on post-game experience (N=40)

Criteria	Mean ± SD	Interpretation
Positive experience	4.63±0.51	Strongly agree
Negative experience	1.14±0.37	Strongly disagree
Tiredness	1.13±0.35	Strongly disagree
Returning to reality	2.66±0.59	Neither/nor agree

Table 8. Student's evaluation of the Chem-Okey card game based on social presence (N=40)

Criteria	Mean ± SD	Interpretation
Psychological involvement-empathy	3.46±0.73	Strongly agree
Psychological involvement-negative feelings	0.67±0.93	Strongly disagree
Behavioral involvement	3.04±0.86	Agree

4. CONCLUSION

This study investigated the effectiveness of the Chem-Okey card game in promoting student understanding of acid-base concepts through a card game. Guided by the foundations of GBL, the game integrates principles from cognitive, behavioral, affective, and sociocultural learning theories, aiming to create a comprehensive and engaging educational experience. The findings demonstrated that Chem-Okey achieved high ratings across all LRMDS criteria, including content clarity, error minimization, and manipulative design. This validation confirms the game's ability to effectively present complex chemical concepts in an engaging and accessible manner. Furthermore, student participants reported positive experiences with the game's design, activities, and mechanics. They particularly appreciated the opportunities for collaboration and strategic thinking, indicating a high level of affective and socio-cultural engagement. This engaging learning environment fostered by Chem-Okey suggests its potential to maintain student interest and motivation, which are eminent factors for sustained learning outcomes. This study emphasizes the importance of integrating GBL into complex subjects such as Chemistry, particularly through developing and evaluating innovative tools like the Chem-Okey card game. The Chem-Okey card game demonstrates significant potential as a supplementary learning tool, effectively helping students engage actively in the learning process. While the study presented evidence on the evaluation of Chem-Okey and the benefits of using GBL towards students' game experience, these findings must be taken cautiously as the data were taken from self-reported scales. A more robust experimental design could be done to demonstrate the efficacy of using games in developing student's learning outcomes.

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C : **C**onceptualization
M : **M**ethodology
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D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

INFORMED CONSENT

We have obtained informed consent from all individuals included in this study.

ETHICAL APPROVAL

The research related to human use has been complied with all the relevant national regulations and institutional policies in accordance with the tenets of the Helsinki Declaration and has been approved by the authors' institutional review board or equivalent committee.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author, [AMPW], upon reasonable request

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