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Let's get on-board: a practical framework for designing and implementing educational board games in K-12 classrooms

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Educational board games are a promising tool for implementing game-based learning to improve the teaching-learning process. However, the absence of comprehensive scholarly guidance on designing educational board games impedes the effective implementation of game-based learning in classrooms. The sparsely available studies on game design frameworks often confine themselves to the design of the educational game itself, without including guidelines for the classroom integration of such games within the design framework. Additionally, the literature often neglects that teachers, burdened by limited time and excessive workload, are often the sole participants in the game design process. To address these gaps, we introduce a practical framework for educators to design and seamlessly integrate educational board games in their classrooms. Our approach prioritizes minimizing additional teacher workload while using game-based learning to foster student-led problem-solving sessions and game revision. Drawing from game design principles and existing literature on game-based learning, we propose a comprehensive framework that guides educators through the design and implementation of educational board games tailored for conducting problem-solving sessions. The framework is validated and refined using qualitative analysis of teacher and student feedback after its seamless integration into the regular mathematics instruction and curriculum of a Philippine K-12 high school. Results indicate positive student experiences and highlight the framework's efficacy in promoting student engagement, learning outcomes, and teacher convenience. Thematic analysis of student feedback highlights key design preferences and game features that enhance student experiences in GBL sessions. The study contributes to the advancement of GBL methodologies by offering practical guidelines for independent use by educators and promoting exchanges between teacher colleagues. Overall, the proposed framework offers a systematic and feasible approach to designing and implementing educational board games, fostering effective learning experiences in diverse educational contexts.

KEYWORDS

game-based learning, educational board games, gamification, mathematics education, game design, serious games, teacher guide, non-digital educational games

1 Introduction

Educational board games are increasingly recognized as effective tools for implementing game-based learning (GBL) in educational settings. Despite the growing body of research supporting their efficacy (Bochennek et al., 2007; Naik, 2014; Noda et al., 2019; Talan et al., 2020; Dondio et al., 2023; Naderi and Moafian, 2023), their widespread adoption in classrooms presents challenges for educators. One primary obstacle is the lack of expertise among educators in game design principles and the science of game development (Watson and Yang, 2016; Dimitriadou et al., 2021). The lack of professional expertise, coupled with challenges such as managing additional workload to align the curriculum with educational games, limited institutional support, and a lack of resources for collaboration with game design experts (Dimitriadou et al., 2021), makes conducting GBL sessions exceedingly challenging for teachers. Furthermore, the lack of scholarly guidance on game design frameworks exacerbates these challenges, leaving educators without clear direction (Cardinot et al., 2022).

In addressing these challenges, it is essential to understand the obstacles perceived by educators in integrating GBL sessions into their classrooms. Watson and Yang (2016) identified four main barriers: difficulties in effective game implementation, technological challenges, limitations within the educational system, and obstacles in acquiring games. While some of these challenges are specific to digital educational games, others apply to both digital and non-digital educational board games. Even after overcoming these initial hurdles, designing educational games that effectively combine fun, learning, and pedagogy remains a significant challenge (Carrión et al., 2017). Educational games often fall short of their learning objectives due to superficial and oversimplified game structures (Klopfer et al., 2009), leading to perceptions of low entertainment value or inefficiency in aiding learning processes (Cardinot et al., 2022). Moreover, these games must align with established learning theories, such as social constructivism and flow theory, to maximize their educational impact (Qian and Clark, 2016).

We aim to tackle these obstacles and provide practical solutions to facilitate the seamless integration of educational board games into classroom settings. Informed by recent studies (Savvani and Liapis, 2019; Cardinot et al., 2022) which proposed frameworks for designing educational board games, we present a unique approach which integrates implementation, student feedback, and reusability of the games into the design framework. Our framework includes classroom observation by teachers during GBL sessions (Algayres et al., 2022) and collecting student feedback post-sessions as integral components. By emphasizing game reusability and exchange among teachers, our approach facilitates independent implementation of GBL sessions with minimal resources, addressing constraints identified in prior research (Watson and Yang, 2016; Dimitriadou et al., 2021). Our proposed framework uses a trivia-based model to reinforce existing knowledge instead of introducing new concepts. This approach of extrinsic integration of learning content with game mechanics is suitable for assessment preparation and ensures adaptability across educational contexts (Nicholson, 2011).

We directly address the highlighted barriers in GBL by presenting an easily implementable, five-step framework tailored for educators to design educational board games and conduct GBL sessions, complementing their existing teaching methods. To illustrate the practicality of the framework, we designed and implemented two board games for GBL sessions in a high school in the Philippines. Additionally, we gathered students' feedback to analyze their attitudes toward the board game-based GBL sessions. A thematic analysis of the qualitative feedback provided by the students was conducted to enhance future GBL sessions and identify specific design elements that influenced their experience, either positively or negatively. This analysis also validated the design elements proposed in the framework as the student feedback was directly correlated to the proposed framework.

This study is driven by the following research questions (RQs):

> ***RQ 1.*** *What key strategies might enable educators to design and implement engaging educational board games for seamless conduct of problem-solving sessions?*
>
> ***RQ 2.*** *What design elements and features of teacher-developed educational board games enhance students' and educator's experience of GBL-facilitated problem-solving sessions?*

2 Pedagogical principles

This section addresses *RQ 1*. First, we introduce a 5-step design and implementation framework (Figure 1). The proposed framework is tailored for teachers to develop engaging educational games and conduct GBL sessions in their classrooms. The framework involves a game design phase (Phase 1) which results in a developed game, and a classroom implementation phase (Phase 2) which involves implementation, student feedback, and repurposing of games. Next, we demonstrate the applicability of this framework by developing two educational board games and implementing them in a K-12 classroom. Within the implementation phase (Phase 2), we gathered feedback using a mixed methods approach. This involved (1) a quantitative Likert-type student survey, (2) qualitative student feedback, (3) a classroom observation tool for teachers, and (4) qualitative teacher feedback. This comprehensive feedback approach serves two purposes: first, as an example for implementing Phase 2 of the framework, and second, as an evaluation of the framework as a whole. Overall, this study design exhibits rigor in its method triangulation (more than one method), data triangulation (different data sources), and use of validated tools (Wilson, 2014; Fereday and Muir-Cochrane, 2006). These align with aims to refine future GBL sessions and promote effective integration of educational games into teaching practices.

2.1 The five-step game design and implementation framework

We introduce a five-step design and implementation framework designed to assist educators in integrating problem-solving GBL sessions into their regular classroom teaching. The games developed through this framework are intended to enhance regular mathematics lesson delivery without replacing classroom instruction or requiring out-of-class sessions. Central to the framework are considerations for prioritizing student enjoyment and engagement in GBL, alongside

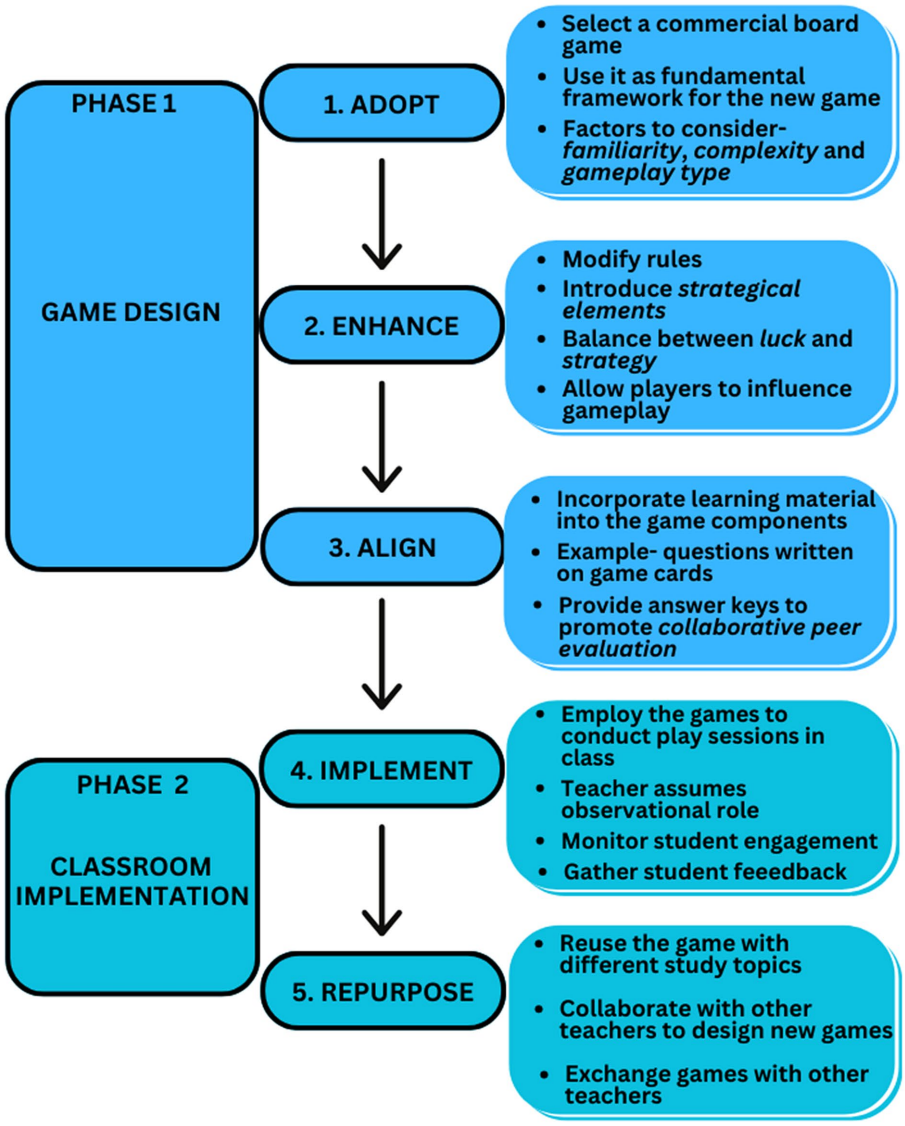

FIGURE 1
The 5-step design and implementation framework for designing educational board games and conducting GBL sessions.

ensuring the framework's convenience and practicality for teachers. The five steps of the framework, outlined in Figure 1, include:

Step 1-Adopt: The initial step of the game design process involves the teacher selecting an existing popular or commercial game that can be *adopted* for redesign or modification as an educational board game. Key considerations in this selection encompass three primary factors: *familiarity*, *complexity*, and *gameplay type*.

Level of *familiarity* and *complexity* hold significance as GBL prioritizes "learning through the game" over "learning to play the game" (Wu et al., 2012). Opting for popular and simple games minimize the effort and time required for student orientation, emphasizing learning objectives over game mechanics. Additionally, the choice of *gameplay type* empowers educators to customize classroom dynamics, curriculum alignment, session duration, and physical spatial constraints. This strategic approach empowers educators to integrate pedagogical elements for alignment with instructional goals, such as using collaborative games to foster student interactions and cooperative learning, or single-player competitive games to enhance individual lesson engagement and cultivate healthy competition among students.

Step 2-Enhance: During this step, educators modify game rules and integrate elements to boost enjoyment and educational value of GBL sessions (Malone and Lepper, 2021). Gough's (1999) delineation of essential game traits gains significance in this stage. Gough posits that a game involves multiple players taking turns, each striving to achieve a winning situation, and exercising freedom of choice during their moves. However, some games like *Snakes and Ladders* lack these characteristics as they include taking turns for a race to the goal but lack player choice. Relying solely on dice rolls, the game's outcome hinges on chance, devoid of interaction between players. Each turn's result does not impact subsequent turns, resulting in a lack of strategic interaction among players. The *enhance* stage advocates for educators to introduce elements that

empower players to influence gameplay, fostering strategic interaction and balancing strategy with luck. This intentional design approach aims to enrich the overall educational experience in GBL sessions.

We emphasize that the term *enhance* in this context does not pertain to esthetic improvements. While esthetic modifications to the physical components of the game can add novelty and visualize theme alterations, they should be secondary and moderate to prevent distracting learners from core learning objectives. Teachers may opt to directly use the physical components of the selected board game and focus on gameplay enhancement as outlined in this step.

Step 3-Align: During this step, the teacher incorporates learning material or practice modules into the gameplay, ensuring that the game is seamlessly integrated within the lesson plan and achieves the learning objectives. Teachers should ensure that the learning materials or practice items, after being translated into game components such as game cards, still align with the learning goals. An example is printing questions on game cards, where correct answers lead to specific advantages that players can later use to influence the gameplay.

The teacher should ensure that the type of questions on the cards and the time required to answer them are suitable within the duration of the gameplay session. Students should be provided with an answer key for verifying their responses, fostering teacher-independent learning and facilitating collaborative peer evaluation (Gueldenzoph and May, 2002). This approach also promotes immediate feedback from peers, a factor demonstrated to positively impact students' learning (Liu and Carless, 2006).

Step 4-Implement: In this step, the educator introduces the designed board game to the students and conducts game-based problem-solving sessions as integrated within the lesson plan. It is crucial to note that since the modified game is based on an existing popular game, students quickly scaffold and learn the game mechanics, so no additional time or effort is required for play-testing, as ensured in the *adopt* stage. Likewise, student-centered gameplay and provision of answer keys from the *enhance* and *align* stages allow the teacher to take on an observational role while the students lead the sessions.

We advocate that during GBL sessions, the teacher should prioritize monitoring student engagement and gathering feedback to enhance future GBL sessions, rather than explaining unfamiliar rules or moderating gameplay. Recording class observations for post-reflection further enriches the teaching-learning process using GBL, as it allows the teacher to identify factors that affect student engagement and motivation during the game-based practice sessions. We recommend that utilizing a research-validated observation tool such as the Playful Learning Observation Tool (PLOT) developed by Algayres et al. (2022), can be highly beneficial for monitoring student engagement during GBL sessions.

Step 5-Repurpose: In the final step, the teacher considers a new lesson with which the same game might be aligned with minimal changes to its elements, such as using new topics and questions for game cards or using the game for another subject discipline. Here, teachers can collaborate—exchanging games and ideas, reducing individual effort while introducing novelty in game types.

This collaborative stage seamlessly integrates GBL into regular teaching methods, fostering engagement of students and teachers and effectively attaining learning outcomes. While similar to *align* stage, *repurpose* stage emphasizes the opportunity for teachers to collaborate, critique, and synergize, not only refining individual game design efforts but also promoting team innovations. Collaborative teacher efforts like these play a vital role in enhancing the educational process, correlating with improved student achievement (Goddard et al., 2007).

2.2 Emergence of framework from previous research

The proposed framework is grounded in existing research on GBL. For instance, in the design phase (Steps 1–3), we applied a redesign approach to educational board games (Echeverría et al., 2012; Savvani and Liapis, 2019). The redesign approach is a well-established technique used in previous research where an existing game is redesigned for educational purposes (Rahimi and Kim, 2021; Savvani and Liapis, 2019). Further, the proposed modifications in Step 2 of our framework are grounded in the mechanics, dynamics and esthetic (MDA) framework proposed by Hunicke et al. (2004). This framework enabled us to incorporate additional gaming elements so that the designed game is engaging and fulfills the criteria of a "game" as defined by Gough (1999). Finally, in the implementation phase (Steps 3–5), we propose research-based methods such as collaborative peer assessment (Van Gennip et al., 2010), classroom observations (Algayres et al., 2022), student feedback, and teacher collaboration (Goddard et al., 2007) to be included in the design process.

3 Learning environment and methods

3.1 Setting, students, and faculty

The K–12 educational system in the Philippines which started in April 2012 comprises 1 year of kindergarten, 6 years of elementary education, 4 years of junior high school, and 2 years of senior high school (Department of Education, 2024; Presidential Communications Office, 2015). Our study targeted junior high school students in year 7 within the K–12 system. The purpose of choosing junior high school students was twofold. First, by integrating GBL with regular classroom teaching, we aim to improve students' attitudes toward STEM disciplines (Sung and Hwang, 2013; Divjak and Tomić, 2011). Positive attitudes toward mathematics have been shown to correlate directly with improved performance in the subject among Filipino junior high school students (Capuno et al., 2019; Andamon and Tan, 2018). Second, we sought to address the general challenges faced by high school teachers in implementing GBL in their classrooms, as highlighted by Watson and Yang (2016).

The study involved the purposive sampling of 59 grade 7 students (aged 10–12) from two classes ($n_1 = 30$, $n_2 = 29$) from a selective, meritocratic high school in the Philippines. With a highly competitive admission process and rigorous teacher selection (Larroder, 2021), the institution caters to high-achieving students and expert educators. As a result, all participants in the GBL sessions were high-achieving students, contributing to a conducive learning environment. Consequently, the results of this study may apply to schools and students with similar learning contexts (Navarrete-Ulloa and Munoz-Rubke, 2022).

The framework was applied to a mathematics class with five 50-min sessions per week. The school's post-pandemic pedagogy involved delivering learning modules primarily through in-person instruction by teachers, supported by an online learning management system facilitating access to all modules and managing online submissions. Although classes primarily transitioned to in-person

instruction, the school's blended approach allows for flexible modality shifts (Salvador and Nautiyal, 2024) as necessary in the post-pandemic setup. The learning modules follow the THINK framework (Albarico, 2013), which includes defining learning objectives (target), engaging students (hook), delivering the lesson content (ignite), formatively assessing progress (navigate), and summarizing the lesson (knot).

3.2 Materials

3.2.1 Student feedback form

A feedback form was distributed to students to assess their perceptions of GBL sessions, focusing on preferences, concerns, and the impact of board games on math practice engagement. Consisting of 10 questions, including seven Likert-style inquiries (Table 1) and three open-ended questions, the form aimed to gather insights into students' experiences with GBL sessions and their feedback on board games' features.

3.2.2 Classroom observation tool

We used the Playful Learning Observation Tool (PLOT; Algayres et al., 2022) to monitor student engagement and observe classroom dynamics throughout the GBL sessions. Developed after extensive review of classroom observation best practices, GBL evaluation criteria, and cognitive psychology theories of motivation, the 51-item PLOT observation sheet is suitable for diverse playful learning activities. Its user-friendly design ensures accessibility even for non-gaming observers. The items in the tool facilitate a descriptive and evaluative approach to observation and assessment. Following the methods of Algayres et al. (2022), students' general behaviors are listed once per GBL session regardless of the number of occurrences.

3.3 Pedagogical format: application of the proposed framework

3.3.1 Phase 1: game design

The game design phase involves *adopt, enhance,* and *align* (Figure 1). We applied these steps to design two board games: i. *Stairs, Pits and Ropes*, inspired by the popular Snakes and Ladders, and ii. *Race to Mars*, derived from Ludo and Trouble. *Stairs, Pits and Ropes* was designed to cover topics such as signed numbers, properties of integers, operations on integers, rational numbers and operations on fractions. *Race to Mars* focused on rational number conversion, irrational numbers, order of operations on real numbers, and real-world applications of real numbers. Figure 2 highlights key considerations integrated into the game design phase, driven by the *enhance* and *align* stages of our framework. These insights might aid educators in ensuring that the designed educational games elicit sufficient student engagement during GBL sessions. For esthetic modifications and improvements, we used online AI image generators Gencraft (Hive.ai, 2023) and Craiyon (Dayma, 2023), encouraging teachers with limited resources to use widely available freeware as needed. We direct the reader to our Supplementary Material for a detailed account of the game design considerations for the two educational games developed using the 5-step design and implementation framework for GBL sessions.

3.3.2 Phase 2: classroom implementation

The classroom implementation phase consists of *implement* and *repurpose* (Figure 1). These steps were performed by the teacher to facilitate mathematics problem-solving sessions, aligned with the school's curriculum and delivery schedule. Following the school's post-pandemic pedagogy, GBL was integrated as follows: The teacher introduced the lesson in the first three sessions of the week, followed by two problem-solving sessions using the designed board games in the subsequent sessions. Particularly, the GBL sessions corresponded to the *navigate* and *knot* phases of the THINK framework (Section 3.1) utilized by the school, thus seamlessly integrated into the school's regular instruction. Practice questions from the learning modules were incorporated into the game cards, accompanied by an answer key prepared by the teacher. Students were instructed to self-evaluate their answers using answer keys managed by assigned classmates during gameplay, fostering peer evaluation and collaboration (Gueldenzoph and May, 2002).

The teacher was equipped with an observation sheet to monitor student engagement and classroom dynamics during the gameplay. While the playtesting stage was intentionally omitted due to the familiarity of students with the game mechanics, qualitative feedback from students remains indispensable for enhancing future GBL sessions. To gather insights, we utilized PLOT (Algayres et al., 2022) to observe GBL sessions and conducted interviews with select students. This approach underscores the significance and feasibility of classroom observation and student feedback in refining educational gaming experiences.

4 Results and assessment

In this section, we address *RQ 2* by examining student feedback through thematic analysis of qualitative data. This

TABLE 1 Student feedback on their overall experience with GBL sessions.

Feedback question	Agree (%)	Neutral (%)	Disagree (%)
Board games made solving maths problems fun for me	96.6	0	3.4
I enjoyed interacting with my friends to solve math problems while playing math games	93.2	5.1	1.7
I did not enjoy practicing maths through board games	3.4	11.9	84.7
Board games had no effect on my interest toward mathematics	8.5	16.9	74.6
We should have teaching sessions with math games every week in school	81.4	16.9	1.7
I will play similar games at home with my friends to practice mathematics	49.1	44.1	6.8
I enjoy game sessions more than regular math lectures	71.2	25.4	3.4

A total of $N = 59$ students responded to the survey.

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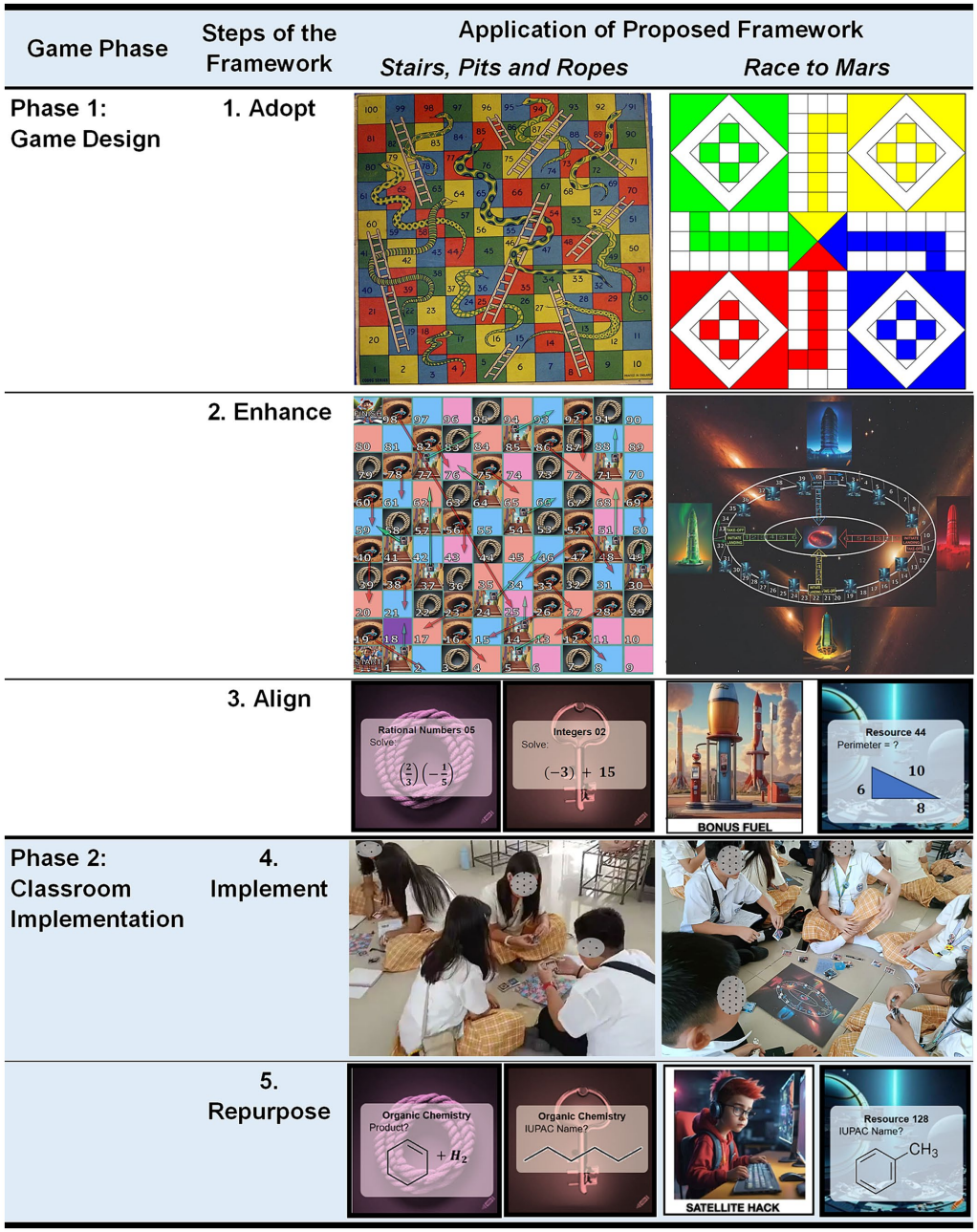

FIGURE 2
Application of the proposed framework to design two board games and implement problem-solving GBL sessions. For *Stairs, Pits and Ropes,* the framework was applied by Step 1: adopting the board game *Snakes and Ladders* (Auckland Museum, 2019); Step 2: enhancing by replacing snakes with pits and ladders with stairs, and adding ropes; Step 3: aligning with Grade 7 mathematics curriculum; Step 4: implementing in the Grade 7 mathematics class; and Step 5: repurposing for a new lesson or subject, i.e., Grade 11 Chemistry (not performed in the study). Additionally in *Step 2: Enhance*, several elements were introduced: the *element of luck* (possibility of landing on a *Stair*, *Pit, or Rope* tile), *element of learning* (answering questions to earn rope cards), and *element of strategy* (choice to use rope cards to climb out of a pit or to make opponents miss their turn). For *Race to Mars,* the framework was applied by Step 1: adopting the board game *Ludo* (Tsamuel, 2022); Step 2: enhancing by adding international space stations and advantage cards; 3: aligning with Grade 7 mathematics curriculum; Step 4: implementing in the Grade 7 mathematics class; and Step 5: repurposing for a new lesson or subject, i.e., Grade 11 Chemistry (not performed in the study). Additionally in *Step 2: Enhance*, several elements were introduced: the *element of luck* (possibility of landing on an international space station), *element of learning* (answering questions to earn advantage cards), and *element of strategy* (choice among four types of advantage cards to pick and use for varied actions). Free AI image generation software Gencraft (Hive.ai, 2023) and Craiyon (Dayma, 2023), were used for optional esthetic modifications of game components.

analysis uncovered aspects of the board games and GBL sessions that students found engaging or lacking. Furthermore, we explore teacher feedback on session facilitation to assess the convenience and practicality of the proposed framework for implementation.

4.1 Students' feedback

4.1.1 Likert-style responses

Table 1 presents students' responses to Likert-style questions regarding their overall experience with GBL sessions. Feedback

indicates that the majority enjoyed solving math problems using the designed board games, with 96.6% agreeing that board games made solving math problems fun. Overall, responses reflect positive experiences and favorable attitudes toward this type of GBL session.

4.1.2 Thematic analysis of students' game-design preferences

Students' qualitative answers to the prompt: "*My favorite game was… because…*" were thematically analyzed following Braun and Clarke (2006) and following the step-by-step guide by Dawadi (2020) and Maguire and Delahunt (2017) to discern preferences in educational board game design. First, the textual qualitative responses were read to familiarize with the data. Next, initial codes were generated and clustered into initial themes. Then we convened to review and develop themes and subthemes based on relevance and distinctiveness. Five main themes emerged for educational board game design preferences, with corresponding subthemes shown in Figure 3. Finally, the definitions for the themes were developed from data extracts.

Theme 1—Enjoyment in learning: Students prefer games that blend enjoyment with learning, expressing a desire for pure *fun* through easy questions, familiar topics, and topic-game alignment. They also seek increased *learning* opportunities, including critical thinking, solving more items, skill enhancement, and the chance to correct mistakes. Responses, such as "*fun along with solving math problems that helped me enhance my skills*" and "*so simple yet so fun*," highlight the intertwining of enjoyment and learning in their preferred gaming experience.

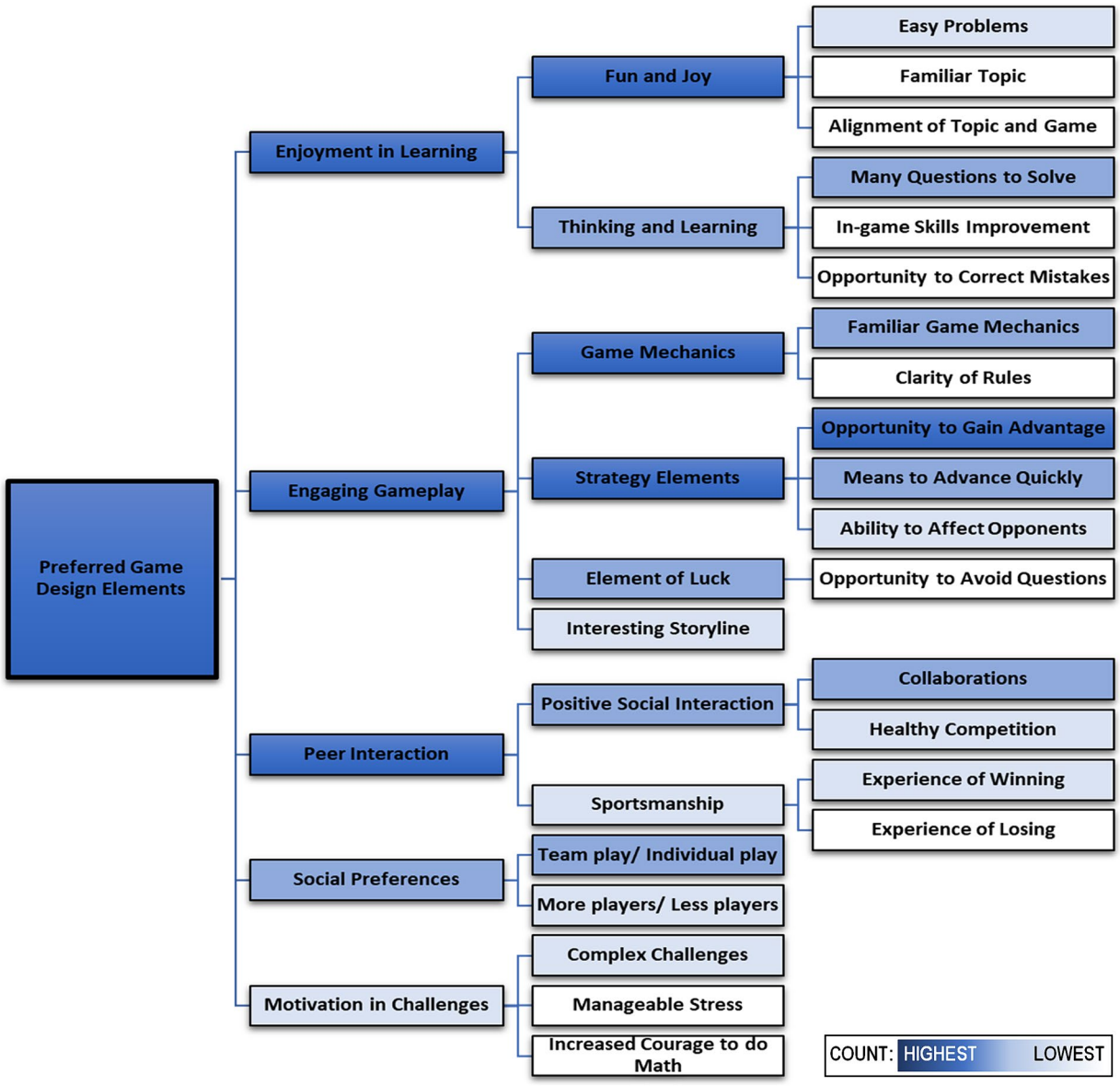

FIGURE 3
Themes related to game design elements derived from qualitative feedback obtained from students. Themes have been developed from clusters of related codes and organized into main themes, subthemes and sub-subthemes based on relevance and distinctiveness. Main themes include: (highest to lowest count) enjoyment in learning, engaging gameplay, peer interaction, social preferences, and motivation in challenges. Subthemes and sub-subthemes are mapped accordingly.

Theme 2—Engaging gameplay: Students expressed a preference for games with simple *mechanics*, valuing *familiarity* and clear rules. They enjoy *strategic elements*, opportunities for gaining advantages, quick progression, and the ability to impact opponents. The inclusion of an element of *luck*, like landing on blank tiles, is also valued. Some express a preference for games with an *interesting storyline* or narrative. One student notes, "*With more 'power-ups' the game seems to be more interesting; strategy is the main [consideration] other than luck*."

Theme 3—Peer interaction: Students appreciate *positive social interactions* with their peers, emphasizing collaboration and healthy competition. While some highlight the enjoyable aspect of winning, one student also acknowledges the learning experience associated with losing. These diverse in-game experiences contribute to the richness of students' interactions with their peers. Student responses capture this sentiment: "*I have a teammate that can help me; I could help my teammate so that we could both win*."

Theme 4—Social preferences: Social dynamics play a crucial role in influencing student preferences for games. While the majority gravitates toward games with more players that enable *team play*, a minority expresses a preference for fewer players and *individual gameplay*. This diversity underscores the varied values students place on social interaction within the gaming experience.

Theme 5—Motivation in challenges: Students have shown a keen interest in GBL sessions conducted using our designed board games, which offer a manageable level of complexity. One student noted that the game fostered *courage* in practicing mathematics. Responses include sentiments such as, "*it was interesting and fun, had a different concept, but I liked the challenge to it*."

The five emergent main themes align with literature recommendations for the features of educational board games. Nurnberger-Haag et al. (2023) observed that games featuring turn-taking and chance enhanced student motivations and engagement in the classroom, while speed-based and skill-exclusive games induced stress and decreased motivation. Cardinot et al. (2022) derived from literature that game mechanics and obstacles ensure that games stay fun and interesting. Similarly, game mechanics and genre were identified by Greenhalgh et al. (2019) to be relevant predictors of game ratings in a survey of secondary data on 208 educational games. These literature, however, are limited in their use of secondary data, deductive approaches (Samarasinghe et al., 2021), different intended audience, educational level or setting, and mode (Carrión et al., 2017). In contrast, these 5 themes are emergent and inductively determined from students' responses. Particularly, peer interaction and social preferences are uniquely highlighted as significant game features preferred by students.

4.1.3 Student experiences of board game-based problem-solving sessions

Student experiences of board-game-based problem-solving sessions resulted in four main positive themes and four main negative themes. It is noteworthy that only 39% of students reported negative experiences associated with the GBL sessions. We show the themes and subthemes associated with student experiences in Table 2.

TABLE 2 Themes related to student experiences of GBL sessions derived from qualitative feedback obtained from students.

Experiences in board game-based problem solving sessions	Themes	Subthemes
Positive	1. Balance of Learning and Fun	**Math Improvement** *(sub-subthemes: Comprehension Skills / Accuracy, Speed, Mental Math, Subject Interest)* **Feedback Mechanism** *(sub-subthemes: Immediate Feedback, No penalty for wrong answers)* **Nature of questions** *(sub-subthemes: Familiar Topics, Variety)*
	2. Personal Empowerment	Strategic Thinking Sense of achievement Motivation in challenges Sportsmanship/ Holistic learning
	3. Gaming Experience	Game Reward System Novelty Opportunity to Practice Math
	4. Peer Interaction	Collaborative Learning Competitive Learning Social Affirmation
Negative	1. Complex Questions	Disappointment Long calculation time
	2. Game Features	No Limit to Calculation Time Navigating Unfavorable Game Outcomes Long Game Completion time Complex rules Non-Intrinsic Learning
	3. Social Pressure	**Perceived lack of time** **Lack of encouragement from peers** **Low engagement of peers**
	4. Session Organization	**Unsuitable Play Area** **Physical Discomfort**

4.1.3.1 Positive experiences

Students have expressed a clear preference for a game that strikes a *balance between learning and fun*, emphasizing self-perceived improvements in mathematics comprehension, skills, speed, mental calculation, and overall interest. Immediate feedback on the accuracy of their answers and the absence of penalties for incorrect responses are aspects they appreciate. The familiarity of topics and the diversity of questions within the game contribute to a positive experience.

Moreover, students derive a sense of personal empowerment from strategic thinking, a feeling of achievement, motivation to face challenges, and the cultivation of sportsmanship or holistic learning. Within the gaming experience, students value the reward system, the novelty of the game, and the opportunity to practice math. Peer interaction is seen as valuable for collaborative and competitive learning, fostering affirmations that contribute positively to the students' learning journey. Integrating these preferences can enhance the overall effectiveness and appeal of educational games in supporting students' mathematical learning experiences.

4.1.3.2 Negative experiences

Although the majority of students showed no dissatisfaction with the GBL sessions, educators and game designers must pay close attention to the insights provided by those who identified aspects of dissatisfaction. Noteworthy concerns include the *complexity of questions* leading to disappointment and prolonged calculation times, negative experiences related to certain game features such as unrestricted calculation time, extended game completion durations, unfavorable outcomes, intricate rules, and a perceived lack of intrinsic learning.

Interestingly, one student observed the extrinsic learning associated with the game as designed: "*The board game itself cannot completely teach you how to solve*." Additionally, *social pressures* emerged as a significant theme, with concerns about inconveniencing others due to perceived time constraints, a lack of encouragement from peers, and *low engagement* from those waiting for their turns. Lastly, *organizational aspects* like an unsuitable play area and physical discomfort during extended game sessions were highlighted. Acknowledging and addressing these negative aspects can contribute to refining GBL sessions for a more inclusive and effective learning experience. This process forms an important part of our design framework itself as student feedback is taken in the *implementation* stage of the framework.

4.2 Teacher's feedback

4.2.1 Teacher's observations

During the GBL sessions, the teacher-observer conducted in-class observations, capturing key features of the framework. The PLOT observations were analyzed following the methods of Algayres et al. (2022). Observed behaviors were categorized based on six motivational constructs: amotivation, extrinsic (non-self-determined or self-determined), and intrinsic motivation (challenge, knowledge, or stimulation and social). Items in the PLOT were deductively coded under these motivational constructs. The GBL sessions were then characterized by motivational constructs expressed as percentages of the total items coded. The *Stairs, Pits, and Ropes* sessions were found to be similar to the *Race to Mars* sessions in that student motivations were mostly extrinsic (non-self-determined) at 42% followed by intrinsic (stimulation and social) at 22 and 26%, respectively. In sessions, amotivation (complete lack of value) was not observed. These results indicate that student motivation can be significantly influenced by desirable game features. This further highlights the significance of seeking student feedback in designing and implementing games.

Excerpts from the PLOT exceeded expectations of feasibility in game development and implementation and further illustrated successful attainment of target features such as heightened student engagement, teacher convenience and student-led dynamics. The following are a few of the observations made by the teacher—"*Participants actively engaged in self-directed gameplay, adeptly negotiating challenges without the need for constant guidance. Inquiries were infrequent, indicating a noteworthy level of comprehension regarding provided instructions.*"; "*Remarkably, the game captivated and engaged all participants, including students with lower academic performance in mathematics. Individuals who occasionally displayed disinterest or drowsiness during typical class discussions were visibly absorbed and enthusiastic during the game*."

5 Discussion

5.1 Novelty of the proposed framework

Several studies have introduced educational game design frameworks, each offering distinct purposes and perspectives. Echeverría et al. (2012), Rooney (2012), and Tang and Hanneghan (2014) aimed to balance playfulness, pedagogy, and fidelity in educational games. Groff et al. (2015) explored game design, assessment methods, and content development for comprehensive integration. Van Staalduinen and De Freitas (2011) correlated game design elements with desired learning outcomes. Zarraonandia et al. (2015) emphasized enhancing gameplay for an immersive experience. To et al. (2016) examined transformational game design, aiming for shifts in player perspectives or behaviors. Linehan et al. (2011) and De Lope et al. (2017) proposed refined digital game design principles. Cardinot et al. (2022) developed a GBL framework for physics board games, while Savvani and Liapis (2019) introduced a framework focusing on students as co-designers. This study distinguishes itself through its emphasis on easy implementation for non-expert game designers, focus on teacher convenience, seamless integration into regular classroom pedagogy, and production of primary data through an immediate demonstration of the framework's applicability.

5.2 Addressing research questions and research gaps

Integrating GBL into regular classroom sessions presents significant challenges for educators. To assist educators to design and implement engaging educational board games for mathematics problem-solving sessions *(RQ 1)*, we proposed a five-step design and implementation framework aimed at creating engaging educational board games for seamless problem-solving sessions. The framework simplifies complex game design principles and instructions, addressing the lack of expertise among educators regarding game design (Watson and Yang, 2016). Illustrated with easy-to-follow instructions per step, the proposed framework alleviates issues such as excessive teacher workload, resource limitations, and the lack of collaboration between educators, researchers,

and game designers (Dimitriadou et al., 2021), by allowing for extrinsic alignment of learning objectives with chosen games without requiring additional classroom sessions.

Regarding design elements and features of teacher-developed board games that enhance students' GBL experience *(RQ 2)*, the student feedback form yielded valuable insights. It affirmed the entertainment and learning value of the games while offering clear directions for improvement, addressing challenges in GBL development such as balancing fun, learning, and pedagogy (Carrión et al., 2017), avoiding inefficiency in learning (Cardinot et al., 2022), and preventing oversimplification of games (Klopfer et al., 2009). Technological challenges (Watson and Yang, 2016) were mitigated through familiar document editors, AI-assisted free images, and hands-on materials instead of digital interfaces. The proposed framework maximized educational impact through ensuring alignment with the school's pedagogical approach (Qian and Clark, 2016) and prioritizing teacher convenience throughout game development and implementation. This empowers teachers to create effective educational board games and conduct GBL sessions, even without extensive expertise in educational research or design principles.

5.3 Alignment of themes to the game design and implementation framework

The qualitative analyses yield insightful themes that affirm the efficacy of our proposed design and implementation framework, elucidated through the words of the students themselves. In *adopt (step 1)*, students express genuine fondness for the familiarity of game mechanics, with one noting, "*Snakes and Ladders has always been a favorite game of mine since I was small.*" *Enhance (step 2)* resonates positively with students valuing the inclusion of strategic gameplay elements, as exemplified by a student's comment, "*The game was well thought out and had a higher degree of complexity.*" In *align (step 3)*, students underscore the importance of suitable learning topics and collaborative learning opportunities, with remarks such as, *"It was fun to play, especially with geometry questions,"* and *"I learn mostly from my mistakes, so I gained a lot of knowledge while playing this game."* *Implement (step 4)* reflects student-centered practice through self-directed gameplay, as observed by the teacher noting, *"Participants actively engaged in self-directed gameplay, adeptly negotiating challenges without the need for constant guidance."* Finally, *repurpose (step 5)* demonstrates the potential for game reuse with different topics, as evidenced by the incorporation of varied topics such as *integers, rational numbers, operations on real numbers*, and applications involving *real numbers* in the games. These student and teacher insights illuminate the adaptability and versatility of the proposed framework.

In summary, identified themes highlight the multifaceted nature of students' preferences in educational board game design, encompassing aspects such as gameplay mechanics, peer interaction, social dynamics, and the desired level of complexity. Students exhibit a strong inclination toward games that seamlessly integrate enjoyment with learning, emphasizing the significance of a holistic and engaging educational experience. These insights form a robust foundation for educators and game designers to craft tailored and effective educational games that address the diverse preferences and needs of students. Students' experiences, marked by both positive and negative themes, provide valuable guidance for enhancing the overall effectiveness and inclusivity of game-based learning approaches in various educational domains.

5.4 Recommendations for use of teachers

5.4.1 Designing the games without esthetic modifications

While our designed games involved esthetic modifications to create immersive gaming environments, we emphasize that these are optional. Priority should be given to empowering players to influence gameplay through problem-solving based on the topic, aligning with Gough's criteria for a 'game' (1999). Educators can use original materials (e.g., game board and game pieces) without esthetic modifications and focus on enhancing gameplay. For example, using the Snakes and Ladders game board, educators can introduce 'potion' question cards which, when correctly answered, could prevent players from falling back when bitten by a snake. Similarly, players could earn cards to hinder opponents' progress in Trouble board game. This approach minimizes efforts on esthetic modifications while ensuring engaging gameplay that rewards subject knowledge and skills.

5.4.2 Discretion when repurposing games

Our recommendation is for the teacher to exercise discretion when developing and implementing games throughout the school year, with the following considerations: (1) GBL integration serves to supplement and add to the diversity of existing instructional strategies, rather than replacing or monopolizing. This ensures that the GBL sessions remain a unique learning experience that the students can look forward to. (2) For teachers preparing for multiple GBL sessions in the same classroom, we recommend applying the framework starting from Step 1 to adopt varied popular games. This will help the school produce a diverse and engaging selection of games for effective GBL implementation. (3) The repurposing of a previously developed educational game (Step 5) by applying minimal changes (i.e., altering rope card questions) is recommended for implementation across different classes or subject areas through teacher sharing and collaboration. When a game is repurposed for the same class, there should be a sufficient time gap and diversity of strategies implemented between the two lessons. All these recommendations ensure that the games do not lose their appeal to students.

6 Summary and conclusion

In this study, we proposed a five-step design and implementation framework aimed at creating engaging educational board games for seamless integration into problem-solving sessions. Our framework addresses the need for applicability within a reasonable timeframe, ease of use for teachers lacking design and research knowledge, and inclusion of both game design and classroom implementation. It emphasizes the teacher's multifaceted role as a game designer, GBL session facilitator, and student feedback collector. Through a practical demonstration, we applied the framework to design two educational board games and implement a two-week GBL-based mathematics instruction in a K-12 high school in the Philippines. Student feedback about the developed board games and the GBL sessions, both products of the proposed framework, serves as a measure of the proposed framework's effectiveness.

We highlight specific design elements and features of board game-based GBL sessions that can enhance the overall student experience. In our framework's game-creation phase, we drew upon established game design principles such as the redesign approach (Savvani and Liapis,

2019), and fundamental design principles (Cardinot et al., 2022). These included considerations like gameplay components, alignment with learning objectives, and targeted problem-solving sessions. The qualitative analysis of student feedback revealed that the design elements integrated into the framework had a positive impact on the student experience. Overall, students expressed a positive attitude toward the GBL sessions conducted using our framework, as indicated by thematic analysis. This underscores the importance of including student feedback as part of the classroom integration phase, demonstrating its significance for educators in implementing the framework. Further, thematic analysis highlights that students experienced positive social interactions, such as productive interactions with peers, graceful acceptance of defeat, identification and correction of mistakes, and the development of a spirit of healthy competition. All these qualities are essential not only for academic growth but also for personal development.

Given students' favorable response to the features of the developed board games and their positive experiences during the GBL sessions, we assert the effectiveness of our proposed five-step framework for designing GBL sessions.

7 Limitations and future scope

Our proposed approach is limited by its focus on designing games with extrinsic learning elements over intrinsic integration of the subject matter into the game mechanics. Although the extrinsic approach applied here to develop educational games simplifies game design, it may not be effective in enhancing students' conceptual understanding of the subject matter. Our approach may be better suited for reinforcing knowledge and providing engaging practice drills on previously taught topics (Nicholson, 2011). Future research could compare the effects of different game types—trivia-based extrinsic educational games versus intrinsic games with learning elements designed into the game mechanics—on student achievement and comprehension. This comparison would inform which approach best enhances the student learning outcomes. While students responded positively to the GBL sessions, determining whether these games genuinely enhance their outcomes requires further investigation. Future studies could involve comprehensive assessments of student performance, attitudes, and anxiety levels before and after engaging in GBL sessions, providing insights into the effectiveness of this approach in various educational contexts.

Additionally, we acknowledge the importance of considering teacher's perspectives in the implementing GBL sessions. While we have analyzed student feedback and identified design elements for improving future sessions, a comprehensive exploration of teachers' attitudes and challenges toward GBL sessions is equally important. Further, the framework might be strengthened and refined by determining its applicability to schools across diverse contexts, disciplines, age groups, and socioeconomic levels. We plan to address this in future studies for a comprehensive understanding and improvement of GBL sessions.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Philippine Science High School - Academic Research and Ethics Committee. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin. Written informed consent was obtained from the individual(s), and minor(s)' legal guardian/next of kin, for the publication of any potentially identifiable images or data included in this article.

Author contributions

VN: Writing – original draft, Writing – review & editing, Conceptualization, Formal analysis, Methodology, Project administration, Validation, Visualization. SS: Writing – original draft, Writing – review & editing, Formal analysis, Methodology, Project administration, Validation, Visualization, Investigation. ES: Formal analysis, Methodology, Project administration, Validation, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2024.1420515/full#supplementary-material

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