GAME-BASED LEARNING AS AN ALTERNATIVE REMEDIATION STRATEGY IN SCIENCE EDUCATION:
A MIXED METHOD CASE STUDY

Game-Based Learning as an Alternative Remediation Strategy in Science Education: A Mixed Method Case Study

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Abstract

Student diversity in learning capacities presents significant challenges for science educators, particularly in sustaining interest and achieving mastery across different learning styles. This study addresses the problem of ineffective traditional remediation methods in science education by implementing game-based learning as an intervention using the Game Network Analysis (GaNA) framework (Shah & Foster, 2014). The study employed a one-shot case study design with 26 ninth-grade students from two sections who received grades of 7 in Science during the first quarter, as well as two science teachers involved in the remediation planning. Students collaborated with teachers to create board games aligned with K-12 curriculum competencies, which were subsequently used during remediation sessions. Data collection used a mixed-methods approach, incorporating a 15-item Likert-scale survey based on the GaNA framework components (TPACK, PCaRD, and ICCE) and focus group discussions with both students and teachers. Results indicated improved student engagement, enhanced understanding of science concepts, and reduced teacher burden in conducting remediation. The study demonstrates that cost-effective, non-digital game-based learning can serve as an effective alternative to traditional remediation methods while promoting collaborative learning and higher-order thinking skills. These findings contribute to science education practice by providing evidence-based strategies for implementing game-based remediation in resource-constrained educational environments.

Keywords: *Game-based learning, science remediation, Game Network Analysis framework, K-12 education, student engagement*

Introduction

Student diversity in learning capacities presents significant challenges for educators, particularly in sustaining interest and achieving mastery across different learning styles. Working with students who have different learning capacities can be challenging for educators. Research indicates that achieving mastery in learning requires teachers to use differentiated instruction. According to Dale's Cone of Experience, people generally remember 10 percent of what they read, 20 percent of what they hear, 30 percent of what they see, 50 percent of what they hear and see, 70 percent of what they say and write, and 90 percent of what they say as they do a thing. This evidence underscores the importance of employing a variety of strategies to assess student understanding and facilitate effective learning.

Following the implementation of the K-12 curriculum, teachers have witnessed increased attention to the Science subject due to its spiral method approach. Science is considered one of the most challenging subjects because of its complex concepts, theories, and processes, which often leave students struggling academically. Annually, a significant number of students require remediation to pass the subject. As prescribed by the Department of Education (DepEd) in the K-12 Curriculum, remediation is provided to students who experience difficulty understanding the content and skills, and sometimes for those who failed the subject.

Traditional remediation involves re-teaching lessons and requiring completion of requirements after class hours. This approach requires significant time investment from teachers, as they must teach during class hours and then repeat the process to remediate low-achieving students (Ritzhaupt, Gunter, & Jones, 2010). Effective remediation is crucial because teachers must interact with students through supervision and provide instruction when re-teaching to ensure competencies align with curriculum standards. This traditional approach has proven inefficient and burdensome for both teachers and students, necessitating the adoption of innovative alternatives.

The integration of game-based learning into science education offers a promising solution to these remediation challenges. Game-based learning uses games to promote creativity and enhance learning experiences among students by allowing them to design their own games that help them achieve the learning competencies of the K-12 curriculum (Shaffer, Halverson, Squire, & Gee, 2005). This approach uses non-digital games made from indigenous or recycled materials that do not require computers or internet access, addressing typical resource constraints in public schools and promoting cost-effectiveness.

Research Questions

This study answered the following questions.

1. How does game-based learning as a remediation strategy affect students' academic performance in science?
2. What are students' perceptions and experiences with game-based learning as a science remediation strategy?
3. How does the implementation of game-based learning impact teachers' workload and effectiveness in conducting science remediation sessions?

Literature Review

Game-based learning in science education

While games in contemporary contexts are often associated with digital platforms, educational games encompass a range of formats and approaches. The integration of games in learning is commonly defined as a type of play with specific learning outcomes (Shaffer et al., 2005). Effective game-based learning requires a careful balance between attention to learning content and a desire to design engaging gameplay (Plass et al., 2010).

Research in science education demonstrates positive outcomes associated with game-based learning implementations. Games provide students with opportunities to engage with complex scientific concepts through experiential learning, immediate feedback, and iterative problem-solving (Gee, 2007). The motivational aspects of games, including points systems, rewards, and competitive elements, have been shown to increase student engagement and persistence in challenging subject matter (Prensky, 2001).

Remediation challenges in science education

Traditional remediation approaches in science education face several significant challenges. Teachers often find remediation burdensome because it adds to their teaching loads and contributes to the perception that educational outcomes are always a teacher's responsibility (Ritzhaupt et al., 2010). Current remediation methods typically involve repetitive instruction and completion of additional assignments, which may not address underlying conceptual misunderstandings or motivational barriers.

The spiral curriculum approach implemented in K-12 science education compounds these challenges by requiring students to build on prior knowledge continuously. When students fail to master foundational concepts, subsequent learning becomes increasingly complex, creating cycles of academic struggle and remediation needs.

Game-based learning implementation barriers

Despite promising theoretical foundations and research outcomes, several barriers impede the successful implementation of game-based learning in educational settings. Teachers' inability to: (a) acquire knowledge of games and their pedagogical possibilities—game analysis (Koh et al., 2012); (b) effectively use games for achieving desired learning goals—game integration (Ritzhaupt et al., 2010); and (c) competently navigate the contextual conditions impacting the use of games in schools—ecological context (Demirbilek & Tamer, 2010).

The GaNA framework addresses these implementation barriers by providing structured guidance for teachers to analyze, integrate, and contextualize game-based learning within their specific educational environments.

Theoretical framework

The Game Network Analysis (GaNA) framework serves as the theoretical foundation for this study, providing a comprehensive approach to integrating game-based learning in educational contexts. The framework addresses the critical gap between game design, pedagogical implementation, and contextual considerations in educational settings.

Game Network Analysis framework components

The GaNA framework incorporates three essential components that work synergistically to ensure effective game-based learning implementation:

Technological Pedagogical Content Knowledge (TPACK)

The TPACK framework emphasizes integrating technology with teachers' existing knowledge of content and pedagogy (Mishra & Koehler, 2006). In this study, TPACK guides game analysis by helping teachers understand how game mechanics align with science content and pedagogical approaches. Although this study focuses on non-digital games due to resource constraints, the principles of TPACK remain relevant for analyzing game affordances and educational potential.

Play Curricular Activity Reflection Discussion (PCaRD)

The PCaRD model provides a systematic approach to integrating games into curriculum structures (Foster & Shah, 2015). The model encompasses four critical elements: (a) immersive gameplay experiences that position students as active players rather than passive learners; (b) curricular activities designed to achieve specific learning objectives; (c) reflective opportunities that allow students to process their learning experiences; and (d) structured discussions that demonstrate and reinforce understanding.

Inquiry Communication Construction Expression (ICCE)

The ICCE framework bridges game analysis and integration by providing opportunities for students to engage in higher-order thinking processes (Shah & Foster, 2014). This component aligns with constructivist learning theory, emphasizing student agency in knowledge construction through: inquiry (natural questioning about the environment), communication (language use for interaction and relationship building), construction (using prior knowledge to create new understanding), and expression (emotional and cognitive

responses to learning experiences).

Theoretical connections to science education

The GaNA framework aligns with established theories in science education, particularly constructivist and social constructivist approaches. Piaget's (1962) work on cognitive development emphasizes the importance of play in learning, while Vygotsky's zone of proximal development highlights the collaborative aspects of game-based learning. The framework also incorporates Dewey's (1902) principles of experiential learning, emphasizing the natural human tendency toward curiosity and discovery.

Methodology

Research Design

This study employed a one-shot case study design to investigate the effectiveness of game-based learning as a remediation intervention in science education. The case study approach was selected to provide an in-depth understanding of the implementation process and student experiences within a specific educational context.

Respondents

The study was conducted in a public secondary school in the Philippines that implemented the K-12 curriculum. The participants were composed of two groups: students and teachers. Participants included 26 ninth-grade students from two sections: Grade 9-Gold (4 males and six females) and Grade 9-Lead (9 males and seven females), who received a grade of 7 in Science during the first quarter, indicating the need for remediation. Students participating in the study represented a range of socioeconomic backgrounds, typical of public school populations in the region.

Inclusion criteria required students to: (1) have received a grade of 7 in Science for the first quarter; (2) obtain parental consent for participation in after-school remediation sessions; and (3) demonstrate willingness to participate in game creation and evaluation activities.

Two science teachers from the same school also participated in the study. These teachers were involved in the design, consultation, and facilitation phases of the game-based remediation. Their participation was crucial for answering the third research question regarding workload and effectiveness. Inclusion criteria for teachers required them to be: (1) currently teaching science at the school, (2) involved in the implementation of the K-12 curriculum, and (3) willing to participate in focus group discussions about their experience.

Instrument

Quantitative instrument

A 15-item Likert scale survey was developed based on the three components of the GaNA framework. The instrument utilized a 4-point scale (1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree) to assess student experiences across three dimensions:

Content and Pedagogy (TPACK-based items 1-5): Assessed student understanding of science concepts and the pedagogical effectiveness of games

Play, Curricular Activities, Reflection, Discussion (PCaRD-based items 6-10): Evaluated gameplay experiences, curricular connections, and reflective opportunities.

Inquiry, Communication, Construction, Expression (ICCE-based items 11-15): Measured higher-order thinking processes and emotional engagement

The survey instrument underwent expert validation by three science education specialists and pilot testing with a similar student population to ensure content validity and reliability.

Qualitative instrument

Semi-structured focus group discussions were conducted using a protocol with three main questions for students:

1. Is using games as a form of remediation new to you?
2. What did you feel while playing? Did you enjoy it? Do you think you learned while playing? If yes, in what way?
3. What do you think is missing in the game? How do you think it can be improved?

Semi-structured focus group discussions were conducted with participating teachers using a protocol guided by three main questions:

1. What was your overall experience using this game-based strategy, especially concerning your workload (in terms of preparation, in-class management, and assessment) compared to traditional remediation?
2. From your perspective, how effective was this strategy for student learning? What changes, if any, did you observe in student engagement, understanding, or collaboration?

3. What do you see as the main advantages or disadvantages of this method, and what recommendations do you have for improving its implementation?

Questions were presented in both English and Filipino to ensure participant comprehension and authentic responses.

Procedure

The game-based learning intervention was implemented through a structured four-phase process:

Phase 1: Game construction: Students collaborated with teachers to design board games focused on science topics from the first quarter curriculum. Games were required to align with specific K-12 learning competencies and include clear instructions, mechanics, and point systems. Students worked in groups corresponding to the number of planned learning stations, receiving consultation time with teachers to refine their game designs.

Phase 2: Game-based remediation sessions: Remediation sessions were conducted after regular school hours in transformed classroom environments featuring multiple learning stations. Each station contained student-created board games facilitated by designated student leaders. Sessions lasted 1 hour, and students rotated between stations after reaching specified point thresholds.

Phase 3: Performance assessment: Student performance was assessed through point accumulation during gameplay, recorded on standardized forms by student facilitators. Earned points were added to students' existing raw scores for the Written Output component, which accounted for 40% of total grades in the electronic class records.

Phase 4: Data collection: Following remediation sessions, students completed a Likert-scale survey and participated in focus group discussions. The two participating teachers also participated in separate focus group discussions to gather data on workload and effectiveness. All sessions were video-recorded with participant consent and subsequently transcribed for analysis.

Data Analysis

Data analysis employed a mixed-methods approach combining quantitative and qualitative techniques.

Quantitative analysis

Likert-scale responses were analyzed using descriptive statistics (means, standard deviations, frequencies) to characterize students' experiences across the GaNA framework dimensions. A comparative analysis was conducted between the initial and final grades to assess academic impact.

Qualitative analysis

Focus group transcripts were analyzed using thematic analysis procedures following Braun and Clarke's (2006) six-phase approach: familiarization, initial coding, theme searching, theme reviewing, defining and naming themes, and report production. Two researchers independently coded transcripts to ensure reliability, with disagreements resolved through discussion.

Results

This section presents the findings according to the study's research questions, integrating quantitative and qualitative results. Descriptive statistics were computed to characterize students' experiences and assess academic impact, and thematic analysis was employed for the focus group discussions.

Quantitative Results:

Findings for RQ 1: Students' academic performance in science using game-based learning

The comparison of initial and final grades showed a modest but consistent improvement in academic performance across both participating sections. Grade 9-Gold showed an average increase of 0.8 points, rising from an initial average of 7.0 to a final average of 7.8. Similarly, Grade 9-Lead demonstrated an average increase of 0.7 points, moving from 7.0 to 7.7. Crucially, all participating students achieved passing grades following the intervention. This data provides clear, quantitative proof that the remediation achieved its primary goal of helping students earn passing grades. Table 1 compares initial and final academic performance outcomes.

Table 1. *Academic Performance Outcomes Following Intervention*

Section	Initial Average Grade (First Quarter)	Final Average Grade (Post-Intervention)	Average Increase
Grade 9-Gold	7.0	7.8	0.8 points
Grade 9-Lead	7.0	7.7	0.7 points

Findings for RQ 2: Students' perceptions and experiences with game-based learning

Analysis of the 15-item Likert scale survey revealed generally positive student experiences across all GaNA framework dimensions. Mean scores for all items exceeded 3.0 on the 4-point scale, indicating agreement with positive statements about game-based learning experiences. Table 2 provides the complete, detailed breakdown of all 15 survey items, organized by the study's theoretical framework

(TPACK, PCaRD, and ICCE). The data show that every item received a mean score well above 3.0 on the 4-point scale, indicating strong and consistent agreement among the students. The high scores on the TPACK dimension confirm that students found the games to be effective pedagogical tools (e.g., "Understanding science concepts better," M=3.42). The PCaRD dimension scores indicate that the game design itself was successful, with students reporting high "Understanding of game mechanics" (M=3.50) and "Ease of gameplay" (M=3.46), and confirming a strong "Connection between play and learning" (M=3.35). Finally, the ICCE dimension highlights high affective and social engagement, with top scores for "Enjoyment while learning" (M=3.65) and "Communication with others" (M=3.58).

Table 2. *Quantitative results regarding student perceptions and experiences with game-based learning*

Dimension	Item/Focus	Mean (M)	Standard Deviation (SD)
TPACK (Content and Pedagogy)	Preference for games over traditional remediation	3.73	0.45
TPACK (Content and Pedagogy)	Understanding science concepts better	3.42	0.58
TPACK (Content and Pedagogy)	Effective game strategies for discussing science	3.38	0.57
TPACK (Content and Pedagogy)	Concepts are becoming more concrete	3.31	0.62
TPACK (Content and Pedagogy)	Clear identification of learning objectives	3.27	0.67
PCaRD (Play, Curricular Activities, Reflection, Discussion)	Understanding of game mechanics	3.50	0.51
PCaRD (Play, Curricular Activities, Reflection, Discussion)	Ease of gameplay	3.46	0.51
PCaRD (Play, Curricular Activities, Reflection, Discussion)	Discussion opportunities with classmates	3.42	0.58
PCaRD (Play, Curricular Activities, Reflection, Discussion)	Connection between play and learning	3.35	0.63
PCaRD (Play, Curricular Activities, Reflection, Discussion)	Opportunities for reflection	3.23	0.71
ICCE (Inquiry, Communication, Construction, Expression)	Enjoyment while learning	3.65	0.49
ICCE (Inquiry, Communication, Construction, Expression)	Communication with others	3.58	0.50
ICCE (Inquiry, Communication, Construction, Expression)	Feeling challenged during play	3.38	0.64
ICCE (Inquiry, Communication, Construction, Expression)	Construction of new learning	3.35	0.63
ICCE (Inquiry, Communication, Construction, Expression)	Natural questioning during gameplay	3.31	0.68

Table 3 summarizes the six highest-scoring items from the student survey, providing a quick overview of the intervention's success. It clearly shows that students "Strongly Agreed" on their "Preference for games over traditional remediation" (M=3.73), which was the highest-rated item. All other key indicators, such as "Enjoyment while learning" (M=3.65) and "Understanding science concepts better" (M=3.42), received high levels of "Agree" responses. The overall average of 3.55 demonstrates a strong, positive reception from the students.

Table 3. *Summary of quantitative results*

Indicators	Mean	SD	Interpretation
Preference for games over traditional remediation	3.73	0.45	Strongly Agree
Enjoyment while learning	3.65	0.49	Agree
Communication with others	3.58	0.50	Agree
Understanding of game mechanics	3.50	0.51	Agree
Understanding science concepts better	3.42	0.58	Agree
Discussion opportunities with classmates	3.42	0.58	Agree
	3. 55		Average

Qualitative Results on Perceptions and Experiences

The thematic analysis of the student focus group discussions confirmed the quantitative results, yielding key insights into student perceptions. Students consistently reported that using games for remediation was a novel and engaging experience, stating that it was "the first time we played games to learn science" and "more fun than just answering worksheets". This novelty resulted in increased motivation, with one student noting they were "excited to come to remediation because we would play games instead of just listening to lectures again". Participants also described significant perceived learning benefits from the game-based activities, particularly through enhanced understanding via active participation. Students explained that having to explain concepts to earn points helped them finally understand the material, and that the games made lessons "stick in my mind better than reading from books". The collaborative

nature of the games was also highlighted as a benefit, with participants noting, "Working with my teammates helped me learn because they could explain things I did not understand". Despite the overall positive feedback, students offered constructive suggestions for improvement, noting that some games were "too easy" and needed more challenging questions, and suggesting that the boards be "more colorful and attractive". Implementation suggestions included the need for "More time for each game". Table 4 illustrates the qualitative findings on students' perceptions and experiences of game-based learning.

Table 4. *Qualitative Findings on Perceptions and Experiences*

Key Theme	Sub-Theme	Representative Student Responses
Novelty and Engagement	Fun and excitement	"It is the first time we played games to learn science. It's more fun than just answering worksheets."
		"I was excited to come to remediation because we would play games instead of just listening to lectures again."
Learning Experiences and Enjoyment	Enhanced Understanding (Active Participation)	"When we played the respiratory system game, I finally understood how breathing works because I had to explain it to win points."
		"The games made the lessons stick in my mind better than reading from books."
	Collaborative Learning (Teamwork)	"Working with my teammates helped me learn because they could explain things I didn't understand."
		"We had to help each other to win the games, so everyone learned together."
	Increased Motivation (Affective)	"I enjoyed learning science for the first time. The games made it exciting."
		"I wanted to keep playing because the games were challenging but fun."
Areas for Improvement	Game Design Suggestions	"Some games were too easy. We need more challenging questions."
		"The boards could be more colorful and attractive."
		"We need more variety in the types of games, not just board games."
	Implementation Improvements	"More time for each game would be better."
		"Having more games for each topic would give us more chances to practice."

Findings for RQ 3: Impact of game-based learning on teachers' workload and effectiveness in conducting science remediation sessions

The findings for the third research question were derived from the thematic analysis of focus group discussions conducted with the two participating science teachers.

Teacher Workload: A Perceived Shift from "Volume" to "Value"

The data on teacher workload suggests a significant shift in effort rather than a simple reduction. Teachers perceived the initial preparation as a high-investment "capital cost." This phase was time-consuming and required new skills in game design and student training, which was a departure from the routine task of printing pre-made materials.

However, this initial investment paid clear dividends during the remediation sessions. In-session management was described as a transformation from a high-stress, "crowd control" model to a more rewarding, facilitative role. Teachers reported a decrease in emotional labor and disciplinary friction, as the game's structure effectively managed student behavior. This was also reflected in the post-session assessment, which teachers viewed as more meaningful. They traded the high-volume, low-value task of grading repetitive worksheets for the high-value, low-volume task of recording qualitative observations, which they felt gave them a more accurate picture of student learning.

Effectiveness: Enhanced Diagnostics and Engagement

In terms of effectiveness, teacher feedback was overwhelmingly positive. Teachers directly linked the game-based approach to a dramatic and visible increase in student engagement. They described seeing students who were typically passive or disruptive become active, focused participants, motivated by the game's objectives.

This high engagement provided the foundation for enhanced pedagogical effectiveness. Teachers reported a profound increase in their diagnostic insight. The collaborative, vocal nature of the games allowed them to overhear student-to-student discussions, giving them unprecedented access to students' thinking processes and their specific misconceptions. This allowed for immediate, targeted interventions. Finally, teachers felt the model was highly effective for differentiation. The same game could challenge high-fliers (who engaged with strategy) and support struggling learners (who were scaffolded by the rules and their peers), achieving a level of peer-to-peer teaching and individualized pacing that is difficult to replicate in a traditional remediation setting. Table 5 summarizes the impact

of game-based learning as a science remediation strategy for teachers.

Table 5. *Teacher Perceptions of Workload and Effectiveness in game-based learning as a science remediation strategy*

Key Theme	Sub-Theme	Representative Teacher Responses
Workload	1. Initial Preparation	"The front-loading was intense. It was more than just planning a lesson; it was co-designing a system with the students. It probably took triple the time of my usual remediation prep for the first two weeks."
Workload	2. In-Session Management	"It was a completely different kind of 'busy.' I wasn't lecturing or trying to keep 26 kids on a silent worksheet. Instead, I was a facilitator, moving between groups, answering specific questions. It was less stressful, even though I was moving more."
Workload	3. Post-Session Assessment	"This was the surprising part. Assessment became easier. I didn't have a stack of 26 identical, low-effort worksheets to grade. My 'grade' was a set of observation notes. I could tell you exactly why Student A was stuck, not just that they were stuck."
Effectiveness	4. Student Engagement & Focus	"The effectiveness was undeniable. In 10 years of teaching, I've never seen struggling students argue about a science concept. They were debating rules, but also the content needed to win. That's a level of engagement a worksheet could never buy."
Effectiveness	5. Diagnostic Insight	"It was like having a window into their thinking. I could hear a student explain photosynthesis to his partner, and his misconception was clear. I could intervene, correct it, and watch them apply it in the next round. It is real-time, actionable formative assessment."
Effectiveness	6. Differentiation & Peer Teaching	"This method lets me differentiate effortlessly. The advanced students were trying complex strategies, while the struggling students were mastering the basics with their peers' help. The 'student facilitator' role was a game-changer; teaching the game proved they had mastered the content."

Discussion

The results of this study demonstrate the potential effectiveness of game-based learning as an alternative remediation strategy in science education. The consistently positive responses across all GaNA framework dimensions suggest that students experienced meaningful engagement with science content through game-based activities. The improvement in academic performance, while modest, represents meaningful progress for students who had previously struggled with traditional instructional approaches.

The quantitative findings are strongly supported by the qualitative data (Table 4). The exceptionally high mean score for "Preference for games over traditional remediation" (M=3.73) and "Enjoyment while learning" (M=3.65) directly addresses the challenge of student disengagement in remediation. This aligns with Prensky's (2001) argument that modern learners are more motivated by interactive, engaging media than by traditional, passive methods. The student quote, "'It's the first time... more fun than just answering worksheets,'" confirms that the novelty and active nature of the games were key to this engagement.

Furthermore, the study's findings validate the core principles of using games for learning. Gee (2007) argued that good video games (and, by extension, well-designed non-digital games) are "learning machines" because they require players to actively problem-solve, think critically about systems, and learn from failure. The high student scores on items like "Understanding of game mechanics" (M=3.50) and "Understanding science concepts better" (M=3.42) suggest the intervention was successful in this regard. The game mechanics were not just a distraction; they were the vehicle for learning the content. This supports Dewey's (1902) foundational theory of experiential learning, in which students learn by actively doing and reflecting on an experience rather than by passive reception.

The high scores in the ICCE dimension, particularly "Communication with others" (M=3.58) and "Discussion opportunities with classmates" (M=3.42), are also critical. This finding is consistent with Vygotsky's (1978) social constructivist theory, which holds that learning is a social process mediated by language and collaboration with peers. The qualitative theme of "Collaborative Learning" reinforces this: students were not learning in isolation but were teaching and reinforcing concepts with one another.

The study's use of the GaNA framework, which is built upon Mishra and Koehler's (2006) TPACK model, was also validated. The high scores in the TPACK dimension show that the games were perceived as an effective integration of content (science concepts), pedagogy (remediation), and technology (the game as a designed system).

The implementation of student-facilitated games during remediation sessions suggests the potential to reduce teacher burden while maintaining educational effectiveness. By training student facilitators and utilizing structured game formats, teachers could potentially manage multiple learning stations simultaneously while providing targeted support where needed. This approach could address one of the primary concerns teachers express about remediation: the additional time and effort required beyond regular instruction.

Connection to the theoretical framework

The positive outcomes align with the theoretical foundations of the GaNA framework. The TPACK dimension results indicate that students perceived games as practical tools for understanding science concepts, supporting the framework's emphasis on integrating content, pedagogy, and technology (specifically game technology). The PCaRD dimension findings demonstrate successful integration of play with curricular objectives, reflection, and discussion opportunities. The ICCE results confirm that students engaged in higher-order thinking processes through inquiry, communication, construction, and expression during gameplay.

Implications for science education practice

Remediation strategy alternatives

This study provides evidence that game-based learning can serve as an effective alternative to traditional remediation approaches in science education. The positive student responses and academic improvements suggest that games can address both cognitive and affective barriers to learning that traditional methods may not effectively target. The collaborative nature of game-based learning addresses the social isolation often associated with remediation by positioning struggling students as contributors rather than recipients of additional instruction.

Teacher workload and effectiveness

Implementing student-facilitated games during remediation sessions can reduce teacher burden while maintaining educational effectiveness. By training student facilitators and utilizing structured game formats, teachers can manage multiple learning stations simultaneously while providing targeted support where needed. This approach addresses one of the primary concerns teachers express about remediation: the additional time and effort required beyond regular instruction.

Cost-effective implementation

The use of indigenous and recycled materials for game construction demonstrates that effective game-based learning can be implemented in resource-constrained educational environments. This finding is particularly relevant for public schools in developing countries, where access to technology may be limited, but creativity and collaboration are abundant.

Limitations

Several limitations should be considered when interpreting these findings. The one-shot case study design limits generalizability to other contexts and populations. The absence of a control group prevents definitive claims about the superior effectiveness of game-based learning compared to traditional remediation methods. Additionally, the short-term nature of the intervention (one quarter) does not provide information about long-term retention of learning outcomes.

Novelty effects and social desirability bias may influence the self-reported nature of student perceptions. Students may have reported positive experiences partly because of the novelty of the approach rather than its inherent educational effectiveness. The small sample size (n=26) and the small teacher sample size (n=2), along with the specific context (public school in the Philippines), further limit the generalizability of findings.

Future research directions

Future research should address these limitations through more rigorous experimental designs, including randomized controlled trials with larger sample sizes and more extended intervention periods. Comparative studies examining different game formats, implementation strategies, and student populations would provide valuable insights into optimal conditions for game-based remediation. A quasi-experimental approach could also be employed to compare this intervention with traditional remediation groups in similar settings. Additionally, research investigating the long-term impacts of game-based learning on students' attitudes toward science, academic achievement, and retention would help clarify the sustainable benefits of this approach.

Conclusions

This study demonstrates that game-based learning implemented through the Game Network Analysis framework can serve as an effective and engaging alternative to traditional science remediation methods. The positive student responses across content understanding, pedagogical effectiveness, and emotional engagement suggest that games address multiple dimensions of learning simultaneously. The modest but consistent improvements in academic performance indicate that game-based learning can contribute to achieving remediation objectives while enhancing student motivation and collaboration.

The practical implications for science education include the potential for reducing teacher workload in remediation while improving student engagement and learning outcomes. The cost-effectiveness of the intervention, which utilizes indigenous materials and student collaboration, makes it particularly relevant for resource-constrained educational environments. These findings contribute to the growing body of evidence supporting game-based learning as a viable pedagogical approach in science education, particularly for addressing the needs of struggling learners.

Future implementations should consider students' feedback on game design and implementation logistics to optimize the educational experience. The success of this intervention suggests that with appropriate preparation and support, game-based learning can transform remediation from a burden into an opportunity for meaningful learning and engagement in science education.

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