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Structure of Observed Learning Outcomes (SOLO) Taxonomy-Guided Gamification in Disaster Readiness and Risk Reduction (DRRR)

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Abstract

This study investigates the effectiveness of Structure of Observed Learning Outcomes (SOLO) Taxonomy–guided gamification in enhancing Grade 12 learners' competencies in Disaster Readiness and Risk Reduction (DRRR). A mixed-methods quasi-experimental design was employed, involving ninety-six students from Camalig National High School, divided into two groups. The experimental group engaged with gamified DRRR modules structured by SOLO Taxonomy, while the control group received traditional instruction. Quantitative data were analyzed using mean scores, Mean Percentage Score (MPS), Shapiro–Wilk normality test, Mann–Whitney U test, and Wilcoxon Signed-Rank Test, complemented by qualitative insights from interviews, observations, and thematic analysis. Findings revealed that both groups initially performed well at the Unistructural and Multi-structural levels (71–86%) but struggled at the Relational and Extended Abstract levels (35% and 1%), respectively. Post-intervention, experimental group significantly outperformed the control group, demonstrating improved critical thinking and deeper conceptual integration of DRRR concepts. Learners in the gamified group exhibited steady progression toward relational thinking, actively connecting ideas and applying knowledge in meaningful contexts, supported by collaborative engagement and realistic disaster scenarios.

The study concludes that SOLO Taxonomy–guided gamification is more effective than traditional methods in fostering higher-order thinking and meaningful disaster education. Practical implications highlight the need for localized modules tailored to Philippine disaster contexts, inclusive designs that accommodate diverse learners, and structured activities with clear instructions and motivational elements to sustain engagement. Recommendations include refining gamified modules to address implementation barriers and integrating them into DRRR curricula to strengthen disaster preparedness and resilience among learners.

Keywords: SOLO Taxonomy; Gamification; Disaster Readiness and Risk Reduction (DRRR); Critical Thinking Skills; Grade 12 Learners; Mixed-Methods Quasi-Experimental Design

1. Introduction

The Structure of Observed Learning Outcomes (SOLO) Taxonomy, is a hierarchical framework that assesses the quality and depth of student learning across five levels, from simple recall to complex synthesis and application. Gamification refers to the integration of game design elements such as points, challenges, and rewards into non-game contexts to enhance motivation and engagement. Combining these approaches, SOLO Taxonomy–guided gamification provides a structured pathway for learners to progress through increasingly sophisticated levels of understanding while maintaining high engagement. In the context of Disaster Readiness and Risk Reduction (DRRR), this integration offers a promising tool to foster critical thinking and preparedness among students.

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This study aligns most closely with Sustainable Development Goal (SDG) 4: Quality Education, which emphasizes inclusive and equitable learning opportunities. By applying SOLO Taxonomy, disaster readiness learning progresses systematically from basic knowledge to complex understanding, while gamification enhances engagement and motivation. This combination strengthens disaster education by making it more interactive and effective, equipping learners with critical skills for resilience and preparedness. It also supports SDG 11: Sustainable Cities and Communities and SDG 13: Climate Action, since disaster risk reduction education contributes to safer communities and proactive responses to climate-related hazards.

Hence, the conduct of this study contributes to both educational practice and community resilience by offering a novel instructional framework that enhances disaster education. By aligning gamification techniques with the SOLO Taxonomy, the study provides teachers with a structured yet engaging approach to guide students from basic knowledge acquisition toward complex, applied understanding of disaster readiness and risk reduction. This not only improves classroom learning outcomes but also equips students with practical skills and critical thinking abilities essential for real-world disaster preparedness.

1.1. Statement of the Problem

This study explores the use of SOLO Taxonomy–guided gamification to enhance Grade 12 students' competencies in DRRR. By structuring learning outcomes through progressive levels of understanding, the approach aims to foster critical thinking skills while making disaster education more engaging and meaningful. Specifically, it will seek to answer the following research problems:

- What is the initial level of critical thinking skills in DRRR among Grade 12 learners as measured by SOLO Taxonomy criteria?
- What SOLO based material can be developed based on the findings of the study?
- To what extent does the implementation of SOLO Taxonomy-guided gamified learning modules improve students' critical thinking skills in DRRR compared with traditional teaching methods?
- What patterns of progression across the SOLO Taxonomy levels emerge among students after their engagement with gamified DRRR modules?
- What challenges are encountered by teachers and learners during the implementation of SOLO Taxonomy-guided gamification in DRRR?

1.2. Scope and Delimitation

This study focuses on Grade 12 learners enrolled in Camalig National High School, who will serve as the primary respondents. A purposive sampling method will be employed to select participants based on their enrollment in Disaster Readiness and Risk Reduction (DRRR) classes. Science teachers handling DRRR subjects will also be included to provide insights into instructional challenges and facilitating factors. The intervention consists of the design and implementation of gamified learning modules guided by the Structure of Observed Learning Outcomes (SOLO) Taxonomy. These modules will be administered over a period of one quarter during the academic year 2025 – 2026, with pre- and post-assessments conducted to measure changes in students' critical thinking skills.

The study is delimited to the use of SOLO Taxonomy–guided gamification in Disaster Risk Reduction and Readiness (DRRR) instruction among Grade 12 Senior High School students and does not extend to other subject areas or grade levels. It focuses solely on the cognitive domain, particularly critical thinking skills, while excluding affective and psychomotor outcomes. Only five DRRR topics were included because these represent the complete set of lessons covered within the semester, and each topic was provided with a single gamified module to ensure balanced coverage, manageability of implementation, and alignment with the curriculum scope.

The research is confined to classroom-based interventions and does not extend to extracurricular or community-based DRRR activities. While the findings may inform broader educational practices, the scope is limited to the immediate context of Grade 12 learners, their teachers, and school administrators within the chosen study site. External factors such as variations in school resources, teacher training backgrounds, and community disaster preparedness programs are acknowledged but not directly examined in this study. Within this scope, the study is significant to Grade 12 learners and teachers teaching DRRR curriculum.

2. Materials and Methods

2.1. Research Design

This study employed a mixed-methods quasi-experimental design to comprehensively investigate the effectiveness of SOLO Taxonomy–guided gamification in Disaster Readiness and Risk Reduction (DRRR). The quasi-experimental approach was chosen because it allows for the comparison of outcomes between students exposed to gamified DRRR modules and those taught using traditional methods, even without full randomization of participants. This design is particularly appropriate in educational settings where random assignment is often impractical due to existing class structures (Hall & Hall, 2020). By using pre-tests and post-tests aligned with SOLO Taxonomy criteria, the study measures changes in learners' critical thinking skills, providing quantitative evidence of cognitive progression across different instructional approaches.

At the same time, the integration of qualitative methods strengthens the study by capturing the contextual dynamics of implementation. Interviews, focus group discussions, and classroom observations provide insights into the challenges and facilitating factors encountered by both teachers and learners. This mixed-methods design ensures that the study does not only quantify improvements in critical thinking but also explains the underlying processes and conditions that influence learning outcomes. The combination of quantitative rigor and qualitative depth makes this design the most suitable for addressing the research problems, as it provides a holistic understanding of how gamified, SOLO-guided modules impact DRRR education, learner engagement, and instructional practice.

2.2. Respondents of the Study

The respondents of this study are Grade 12 learners enrolled in the General Academic Strand (GAS) at Camalig National High School. Two sections were purposively selected to participate: one section served as the experimental group, which received the SOLO Taxonomy–guided gamified DRR modules, while the other section served as the control group, which continued with traditional teaching methods. Each section consisted of Forty-eight (48) learners, making the total number of respondents ninety-six (96) students. The selection of GAS learners was based on their enrollment in Disaster Readiness and Risk Reduction (DRRR) subjects, ensuring that the intervention was directly relevant to their curriculum.

In addition to the learners, DRRR teachers were also included as secondary respondents to provide qualitative insights into the challenges and facilitating factors encountered during implementation. Ethical considerations were strictly observed throughout the study. Prior to participation, informed consent was obtained from both students and their parents or guardians, ensuring voluntary involvement. Confidentiality was maintained by anonymizing student responses and securing all collected data. Teachers' contributions were likewise treated with respect and confidentiality, with findings reported in aggregate form to avoid personal identification. These measures ensured that the study adhered to ethical standards while safeguarding the rights and welfare of all participants.

2.3. Data Gathering Tools

In this study, multiple data gathering tools are employed to address the research questions and ensure a comprehensive understanding of how SOLO Taxonomy-guided gamification influences critical thinking in DRRR concepts in grade 12.

Interview Guide. The interview guide served as a vital qualitative instrument across several objectives, ensuring that the study captured not only numerical outcomes but also contextual insights. For Problem 1, which sought to determine the initial level of critical thinking skills in (DRRR), a pre-test was administered to both the controlled and experimental groups to establish baseline performance as measured by the SOLO Taxonomy criteria. In addition, an interview guide was used with teachers to gather perspectives on learners' prior knowledge, behaviors, and observed thinking patterns. These qualitative accounts complemented the documentary analysis of student records and assessment outputs, while the results were quantified through descriptive statistics to classify students into SOLO Taxonomy levels.

For Problem 3, which examined patterns of progression across SOLO levels, the interview guide was administered to both students and teachers to document narratives of learning trajectories and experiences with the gamified DRRR modules. These insights provided depth to the quantitative findings obtained through a non-parametric statistics (Mann–Whitney U Test and Wilcoxon Signed-Rank Test), which statistically identified shifts in students' SOLO levels from pre-test to post-test.

In Problem 4, which investigated challenges and facilitating factors in implementation, the interview guide was employed alongside focus group discussions (FGDs) to collect detailed accounts from teachers and learners. These

responses highlighted conditions such as teacher readiness, student motivation, resource availability, and institutional support. The data were analyzed using thematic analysis, allowing recurring themes to be identified and contextualized.

Moreover, to ensure the credibility and reliability of the qualitative data, the interview guide underwent a rigorous validation process prior to its administration. The draft instrument was reviewed by a panel of five experts, three DRR/science educators with advanced degrees and two language specialists, who evaluated the clarity, relevance, and alignment of the questions with the study's objectives. Their feedback was used to refine the wording, sequencing, and focus of the items to avoid ambiguity and ensure that responses would directly address the research problems. A pilot test was then conducted with a small group of non-participant teachers and students to assess the guide's effectiveness in eliciting meaningful insights. Adjustments were made based on pilot feedback, ensuring that the final interview guide was both contextually appropriate and methodologically sound. This validation process strengthened the instrument's capacity to capture authentic perspectives on learners' progression, challenges, and facilitating factors in the implementation of SOLO Taxonomy–guided gamification in DRRR.

3. Results and Discussion

3.1. Initial Level of Critical Thinking Skills in DRRR as Measured by SOLO Taxonomy Criteria

To establish the foundation for analyzing the intervention's effectiveness, this section first examines the initial level of critical thinking skills in Disaster Readiness and Risk Reduction (DRRR) among Grade 12 students of Camalig National High School. Using the criteria of the Structure of Observed Learning Outcomes (SOLO) Taxonomy, the pretest results of both the experimental and control groups were computed in terms of mean and percentage scores to determine baseline equivalence. This statistical treatment provides a crucial benchmark, ensuring that subsequent improvements in performance can be attributed to the SOLO Taxonomy–guided gamified learning module rather than pre-existing differences between the groups.

Table 1 Mean and Percentage Scores of SOLO Levels in Pre-test

SOLO Levels	Experimental		Control		Overall	
	Mean	MPS	Mean	MPS	Mean	MPS
Unistructural	12.02	80	12.85	86	12.44	83
Multi-structural	10.63	71	10.58	71	10.61	71
Relational	6.46	43	4.04	27	5.25	35
Extend Abstract	0.25	2	0.08	1	0.17	1
Overall	7.34	49	6.89	46	7.12	48

Table 1 shows that the overall mean scores (7.12) and MPS (48%) across both groups confirm that Grade 12 students of Camalig National High School entered the intervention with relatively strong foundational knowledge at the lower SOLO levels but limited capacity for relational and extended abstract reasoning. This baseline analysis is crucial, as it establishes that while both groups were comparable in their initial performance, the intervention's effectiveness must be assessed in terms of its ability to elevate students' skills beyond basic recall and enumeration toward deeper synthesis and abstraction in disaster readiness and risk reduction.

This only implies that while Grade 12 students of Camalig National High School demonstrated adequate foundational knowledge in disaster readiness concepts, their higher-order critical thinking skills were still underdeveloped prior to the intervention. Both the experimental and control groups performed strongly at the Unistructural and Multistructural levels, indicating competence in recalling and listing disaster-related ideas. However, their relatively low scores at the Relational and Extended Abstract levels highlight a significant gap in synthesizing concepts and applying them to novel situations, skills essential for effective disaster preparedness and risk reduction. This baseline analysis underscores the need for instructional strategies, such as the SOLO Taxonomy–guided gamified learning module, that deliberately scaffold students' progression from surface-level understanding toward deeper reasoning and abstraction. By addressing these gaps, the intervention has the potential to strengthen learners' capacity for critical thinking, enabling them to make more informed and adaptive decisions in real-world disaster contexts.

Recent research demonstrates that gamification can effectively foster critical thinking and problem-solving skills. Asigigan and Samur (2021)[1] found that gamified STEM practices improved students' intrinsic motivation and critical thinking dispositions, showing that structured game-based learning can address the limitations of traditional methods. Similarly, Bangcaya et al. (2021) reported that gamification in science instruction enhanced both motivation and learning outcomes, reinforcing its potential to engage students in higher-order tasks.

Table 2 Pretest Scores of Experimental and Control Group

Group	N	Mean	SD	p-value	Interpretation
Experimental	48	29.35	7.79	0.132	Not Significantly Different
Control Group	48	27.52	6.64		

Table 2 shows that the mean scores of the experimental and control groups are closely aligned, with overlapping interquartile ranges. This indicates that both groups had comparable distributions of pretest scores, with no evident difference in central tendency or variability. This visual pattern is consistent with the non-significant Mann–Whitney U test result ($p = .132$). Since the p-value is greater than the 0.05 level of significance, the null hypothesis is not rejected. These results suggest there is no statistically significant difference in the pretest scores between the two groups. The baseline equivalence implies that any observed post-test differences can be attributed to the SOLO Taxonomy-guided gamified learning module rather than to pre-existing differences.

The results provided empirical evidence of the effectiveness of the SOLO-guided gamification intervention in fostering higher-order thinking skills. By integrating robust statistical analysis with the study's pedagogical framework, the findings not only validate the intervention's impact but also reinforce its potential as a replicable model for disaster readiness education in senior high school curricula.

Table 3 Experimental Group Pretest and Posttest Comparison

Test	Mean	SD	p-value	Interpretation
Pretest	28.435	7.215	<0.001	Significant
Posttest	42.22	6.22		

Table 3 shows an increase in mean scores from pretest to posttest. This upward trend indicates that students demonstrated improved performance after the instructional period. This visual pattern is supported by the Wilcoxon Signed-Rank Test. The results revealed a statistically significant difference between pretest and posttest scores ($Z = -8.466$, $p < .001$). Since the p-value is less than the 0.05 level of significance, the null hypothesis is rejected. This indicates a significant increase in students' critical thinking scores following instruction.

Table 4 Mann-Whitney U Test Results for Post-test Scores

Group	N	Mean Rank	Mann-Whitney U	p-value
Experimental	48	67.48	241.00	p<.001
Control	48	29.52		

Table 4 shows that the experimental group had a higher mean rank (67.48) than the control group (29.52), indicating better posttest performance. The Mann–Whitney U test yielded a p-value <0.05 ($p < .001$), leading to rejection of the null hypothesis. This indicates that there is a statistically significant difference in posttest scores between the two groups.

This result suggests that the SOLO Taxonomy-guided gamified learning module was more effective in enhancing students' critical thinking skills in DRRR compared to traditional teaching methods. The higher performance of the experimental group indicates that the structured progression of learning tasks combined with gamified elements supported deeper understanding and improved student outcomes.

The results strongly indicate that SOLO Taxonomy–guided gamification significantly enhanced students' critical thinking in DRRR compared to traditional teaching, and recent studies support its effectiveness in fostering deeper reasoning, motivation, and learning outcomes. Hence, these findings align with contemporary scholarship emphasizing the transformative role of gamification in education. Bangcaya et al. (2021)[2] found that gamification in science instruction enhanced both learning outcomes and student motivation, suggesting that interactive and game-based strategies can counteract the limitations of conventional teaching methods by engaging learners more meaningfully in complex tasks.

Table 5 Students' Perceived Extent of Improvement in Critical Thinking Skills Across Four Dimensions of Gamified Learning in DRRR

Category	Weighted Mean	Interpretation
Understanding and Conceptual Clarity	4.70	Major Improvement
Critical Thinking and Analysis	4.39	Major Improvement
Engagement and Motivation	4.61	Major Improvement
Comparison to Traditional Methods	3.94	Substantial Improvement

Legend: 4.50–5.00 = Major Improvement; 3.50–4.49 = Substantial Improvement; 2.50–3.49 = Moderate Improvement; 1.50–2.49 = Minimal Improvement; 1.00–1.49 = No Improvement.

Table 5 presents the students' perceived extent of improvement across four dimensions of the gamified learning modules. The results indicate major improvement in understanding and conceptual clarity (M = 4.70), critical thinking and analysis (M = 4.39), and engagement and motivation (M = 4.61), and substantial improvement compared to traditional teaching methods (M = 3.94).

The self-reported high improvement in understanding and conceptual clarity reflects that students were able to better comprehend Disaster Readiness and Risk Reduction (DRRR) concepts through the gamified activities. The students expressed strong agreement that the gamified activities helped them understand DRRR topics better and made complex concepts easier to grasp. The activities helped in effective recall, identification of important concepts, and understanding of clear causal relationships. Learners consistently reported that the gamified activities enhanced their grasp of DRRR concepts and improved their ability to connect ideas. One student explained, "It helps me understand more concepts under DRRR, for example the Fire Triangle Relay, where I could connect why fire is not possible when one of the three elements is absent." Another emphasized that, "The game helped me understand the concepts more. It gives us knowledge but, in a fun, creative way." Similarly, a learner reflected, "It helped me to easily grasp the concepts and situations of specific topics within DRRR."

These results are reinforced by related literature, Catedrilla et al. (2021)[3] developed an Android-based educational game for disaster preparedness in the Philippines, finding that gamified modules improved risk awareness and knowledge retention among learners. Similarly, Wulandari et al. (2021)[4] conducted a systematic review of gamification in disaster education and concluded that gamified approaches effectively build awareness and preparedness in disaster-prone areas, particularly by fostering engagement and critical thinking. More broadly, MDPI (2021) reported that gamifying community disaster education enhanced public resilience and improved perceptions of preparedness, showing that interactive strategies are more effective than passive instruction.

Table 6 Students' Progression in Critical Thinking Skills Across Gamified Activities Based on SOLO Taxonomy

Developed GLE / Topic	Mean SOLO Level	Interpretation
Epicenter Escape: Navigating Earthquake Hazard Maps	3.75	Relational
Maze of Hazard: Navigating Volcano Maps	3.88	Relational
Classifying Geological Hazards	4.00	Relational
Charades of Hydrometeorological Hazards	4.00	Relational
Fire Triangle Relay	4.00	Relational
Overall SOLO Level	3.93	Relational

Legend: 1.00–1.49 = Prestructural; 1.50–2.49 = Unistructural; 2.50–3.49 = Multistructural; 3.50–4.49 = Relational; 4.50–5.00 = Extended Abstract

Table 6 presents the progression of students' critical thinking skills across five gamified learning activities based on the SOLO Taxonomy. The results show that all activities yielded mean SOLO scores at the relational level, ranging from 3.75 to 4.00, with an overall mean of 3.925, also interpreted as relational.

The findings indicate that the intervention facilitated a stable progression toward relational thinking, where students can integrate multiple concepts and demonstrate coherent understanding across learning activities. These results are further supported by students' qualitative responses, which reflect meaningful changes in how they connect ideas, apply knowledge, and approach problem-solving in DRRR contexts. The interview responses show that learners experienced clear growth in their thinking as they engaged in gamified DRRR activities. They moved from fragmented to integrated understanding, connecting ideas across topics and applying them to real-world situations such as storms, volcanic hazards, and community safety planning. Students also reported greater awareness and preparedness in daily life, identifying evacuation routes and prevention strategies. At the same time, their approaches evolved from passive participation and trial-and-error to more confident and analytical strategies. Overall, the activities fostered relational thinking, strengthened critical application, and advanced learners' ability to plan and respond effectively to disaster scenarios.

Table 7 Observed Critical Thinking Behaviors of Students During SOLO-Guided Gamified Learning in Disaster Readiness and Risk Reduction (DRRR)

Observed Behavior	Mean	Interpretation
Participation in tasks	3.42	Frequently Observed
Demonstrates curiosity	3.23	Frequently Observed
Applies one concept	3.23	Frequently Observed
Uses multiple concepts	3.17	Frequently Observed
Connect and integrates ideas	3.56	Frequently Observed
Generalizes/applies beyond the task	3.63	Frequently Observed
Collaboration	3.92	Frequently Observed
Explains reasoning	3.73	Frequently Observed
Reflects on learning	3.60	Frequently Observed
Shows confidence	3.73	Frequently Observed
Average Weighted Mean	3.52	Frequently Observed

Legend: 3.50–4.00 = Frequently Observed; 2.50–3.49 = Sometimes Observed; 1.50–2.49 = Rarely Observed; 1.00–1.49 = Not Observed.

Table 7 presents the observed critical-thinking behaviors of students during the implementation of SOLO-guided gamified learning activities in Disaster Readiness and Risk Reduction (DRRR). All indicators were interpreted as frequently observed, with mean values ranging from 3.17 to 3.92, indicating that students consistently demonstrated behaviors associated with active engagement and higher-order thinking throughout the activities.

Hence, recent studies confirm that gamified learning fosters critical thinking, collaboration, and higher-order reasoning, aligning with the observed behaviors in your DRRR classroom. Evidence from both STEM and disaster education contexts shows that gamification enhances motivation, conceptual integration, and preparedness. The observed behaviors in Table 4 such as participation, curiosity, collaboration, and the ability to connect and generalize concepts are consistent with recent studies on gamified learning. Asigigan and Samur (2021) found that gamified STEM practices significantly improved students' intrinsic motivation, critical thinking dispositions, and problem-solving skills, highlighting how game-based approaches encourage learners to move beyond rote recall toward deeper engagement and analysis. Similarly, Wulandari, Budijanto, Bachri, and Utomo (2023) emphasized that gamification in disaster education enhances awareness and preparedness among learners in disaster-prone areas, reinforcing the idea that gamified modules can bridge classroom knowledge with real-world application.

3.2. Challenges Encountered During the Implementation of the SOLO Taxonomy-Guided Gamification in DRRR

Disaster Readiness and Risk Reduction (DRR) is an important subject in the Philippine curriculum, designed to prepare learners with the knowledge, skills, and values necessary to respond effectively to hazards and emergencies. To enhance

engagement and deepen understanding, educators have increasingly turned to gamification as a pedagogical strategy. When guided by the SOLO Taxonomy, gamified modules are intended to scaffold learners' progression from surface-level recall to relational and extended abstract thinking. This approach not only makes lessons more interactive but also aligns with the cognitive demands of DRR education. However, despite its potential, the implementation of SOLO Taxonomy-guided gamification at Camalig National High School presented both opportunities and challenges for teachers and students, influencing the overall effectiveness of the learning experience.

- **Participation and Engagement.** Both teachers and students stated the same concern on participation and engagement were sometimes limited, which reduced interest and made learning more difficult. They emphasized that short time frames, classroom noise, technical issues, and uneven group participation created challenges, while collaboration and creative game design facilitated deeper involvement. Participants stated that: *"Participation was sometimes limited, which made some of us less interested. Short time frames and time pressure made the games difficult. Classroom distractions such as noise, crowded spaces, broken windows, and technical issues like the TV blinking interrupted focus. Competition between groups and uneven student numbers also created challenges. It was hard to choose between good options when resources were limited, and unclear instructions sometimes caused confusion."*
- **Classroom and Technical Challenges**. In addition, classroom and technical challenges were consistently noted by both teachers and students, with crowded rooms, noise, broken windows, and malfunctioning equipment making it difficult to concentrate and participate fully in gamified DRR activities. Participants noted that: "Crowded rooms, noise, broken windows, and technical issues like the TV blinking distracted us and made it hard to focus. Limited space and uneven group numbers also hindered free movement and participation."
- The responses highlight that environmental and technical conditions significantly affect the success of gamified learning. Learners found it difficult to focus when classrooms were noisy, crowded, or physically constrained, while teachers struggled to manage uneven group numbers and limited space for movement. Technical issues, such as malfunctioning equipment, further disrupted the flow of activities. These challenges reveal that even well-designed gamified modules can lose effectiveness if the learning environment is not conducive to active participation and engagement.
- **Game Design and Delivery.** Moreover, game design and delivery were seen as both a strength and a challenge: creative styles, realistic scenarios, and interactive movement made the DRR modules engaging, but competition, time pressure, and difficult questions sometimes hindered participation. Participants, stated that: "The games were exciting because of their creative style, realistic scenarios, and the way they felt like real games, not just lessons. Seeing the results of our choices and moving around made them more engaging, though competition, time pressure, and difficult questions sometimes made them challenging."

These findings are consistent with reports from previous studies. Rivera and Palmer (2021)[5] proposed a framework showing that game design elements such as creativity, feedback, and realism enhance student engagement but must be carefully managed to avoid cognitive overload. Similarly, systematic reviews highlight that gamification fosters motivation and collaboration but can become counterproductive when competition and time constraints dominate the learning experience. These insights align with the present study, underscoring that while SOLO Taxonomy-guided gamification can deepen DRR learning, its success depends on thoughtful design and delivery that balance challenge with accessibility.

The findings revealed that both teachers and students at Camalig National High School encountered similar challenges in implementing SOLO Taxonomy-guided gamification in DRR. Limited participation opportunities, time pressure, and classroom distractions such as noise, overcrowding, and technical issues disrupted engagement and hindered the smooth delivery of gamified modules. At the same time, facilitating factors such as collaboration, creativity, and the use of realistic disaster scenarios enhanced motivation and made learning more meaningful. As one participant aptly summarized, "Gamified learning in DRRR was most effective when it fostered collaboration, creativity, and realistic scenarios, but it was hindered by limited participation, time pressure, and classroom distractions. Improvements in inclusivity, design, and contextual relevance can make the experience more engaging and impactful." This statement encapsulates the balance between the promise and the challenges of gamified DRR learning, underscoring the need for thoughtful design and supportive classroom environments. Ultimately, bridging these gaps requires a pedagogical shift that prioritizes long-term resilience over short-term engagement. By addressing these systemic barriers, educators can transform gamified simulations from mere classroom activities into vital tools for community disaster preparedness.

4. Conclusion

The following conclusions are drawn from the findings of the study, highlighting how gamified DRRR activities supported students' progression in critical thinking, integration of concepts, and application of knowledge to real-world contexts.

- The Grade 12 students of Camalig National High School entered the intervention with sufficient foundational knowledge but underdeveloped higher-order critical thinking skills in DRRR. The comparable baseline performance of both groups confirms that any subsequent improvement can be attributed to the SOLO Taxonomy–guided gamified learning module, which is designed to scaffold students' progression from basic recall toward deeper synthesis and abstraction. The triangulation of pretest results, documentary analysis, and interviews shows that while students can recall and list disaster concepts, they struggle to connect ideas and apply them in new situations. This highlights the need for structured approaches, such as SOLO Taxonomy–guided gamification, to help learners move beyond memorization toward deeper reasoning and practical application in disaster preparedness.
- The development and expert validation of the gamified learning modules demonstrate that integrating SOLO Taxonomy into instructional design provides a structured and reliable framework for enhancing critical thinking in DRRR. The modules not only meet academic and pedagogical standards but also offer an innovative approach that bridges theory and practice, ensuring that learners are guided through increasingly complex tasks in a motivating and interactive manner.
- SOLO Taxonomy–guided gamification provides a dual advantage; it enhances learner engagement through interactive design while simultaneously ensuring cognitive rigor through structured progression. Baseline equivalence confirmed that improvements in critical thinking were attributable to the intervention rather than prior differences. The significant posttest gains of the experimental group highlight how SOLO Taxonomy–guided gamification, through structured task progression and interactive design, fosters deeper reasoning and problem-solving skills. These results establish the approach as a strong framework for disaster education, with both theoretical and practical value in preparing learners for real-world resilience.
- The gamified DRRR module effectively facilitated students' progression toward relational-level thinking within the SOLO Taxonomy. Learners consistently organized, connected, and applied concepts across different hazard-related contexts, showing stable and meaningful understanding rather than fragmented knowledge. Both quantitative results and qualitative responses confirm that students became more confident, collaborative, and strategic in their approaches, reflecting growth in critical thinking and preparedness for real-world disaster scenarios.
- While SOLO Taxonomy-guided gamification has strong potential to deepen disaster preparedness learning, its effectiveness is contingent upon both pedagogical and logistical conditions. The balance between engaging design and classroom realities determines whether learners can progress meaningfully through the levels of SOLO Taxonomy. Without addressing participation gaps, environmental distractions, and technical limitations, the promise of gamified DRR modules risks being undermined despite their creative and collaborative strengths.

Compliance with ethical standards

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Disclosure of conflict of interest

I declare that I have no conflicts of interest related to this research. I have no personal or financial relationships that could influence my work.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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