Development of GeoHazard Cube Games as Supplementary Material to Enhance Student Geologic Hazard Literacy

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ABSTRACT

This study aims to enhance student geologic hazard literacy by developing and implementing GeoHazard Cube Games as supplementary educational materials. Employing a mixed-method research design, the study involved a pretest and posttest methodology to assess the impact of the games on student literacy of geological hazards. Conducted at Hinatuan National Comprehensive High School, permissions were obtained from school authorities, and informed consent was secured from participants. A pretest was administered to establish baseline knowledge, followed by introducing the GeoHazard Cube Games into classroom routines for a specified duration. After the intervention, a posttest was conducted to evaluate changes in student knowledge and engagement levels. The analysis involved statistical methods, including paired t-tests to compare pretest and posttest results, revealing a significant increase in mean scores, indicating a statistically significant difference. Additionally, qualitative data were gathered through focus group discussions and interviews to gain insights into student perceptions of the games. The findings demonstrated the effectiveness of game-based learning in educational settings, contributing to the growing body of literature on gamification in education and highlighting the potential of interactive learning tools to foster a deeper understanding of critical subjects such as geological hazards, ultimately promoting preparedness and resilience among students in the face of natural disasters.

Keyword: - *Geologic Hazards, Game-Based Learning, Student Literacy, Normalized Gain, Educational Intervention.*

1. INTRODUCTION

Geological hazards are the result of geological occurrences that adversely affect human lives, property, and the natural environment. They arise from the earth's intrinsic and extrinsic dynamic processes or from anthropogenic environmental deterioration (Cheng Y, et al. 2024 & Luo, Y et al. 1998). These catastrophic disasters happen rapidly and drastically affect the nation's risk perception. Geologic hazards pose significant threats to communities worldwide, particularly within educational institutions. Recognizing the adverse impacts of these hazards, it becomes crucial to implement proactive measures that enhance preparedness and resilience in these settings. Given the increasing frequency and severity of natural disasters in the Philippines, especially in areas like Hinatuan and Surigao del Sur, students must develop a comprehensive understanding of geologic hazards.

Education is essential in equipping students with the knowledge and skills necessary to comprehend and effectively address geologic dangers. Conventional pedagogical approaches, however, do not inherently engage learners in a meaningful manner or promote profound understanding. Huda, Putriani C., et al. (2024), and Sunarto (2012) assert that children are particularly susceptible to disasters, which may be exacerbated by their surroundings, rendering them ill-prepared when such events transpire. Furthermore, disaster education is deemed crucial for psychological preparedness. Disaster literacy enhances community preparedness, including among students, for effectively managing calamities. Noor (2014) asserts that mitigation activities are designed to enhance community readiness, diminish long-term disaster risk, decrease victim numbers, and be executed extensively to mitigate damages.

Al-Azawi R. et al. (2016) characterize an educational game as one specifically created for pedagogical purposes, integrating enjoyable features with instructional principles to enhance student motivation and engagement. Allery, L. (2014) defines an educational game as a unique learning tool that requires learner engagement in competitive activities regulated by specific rules. Rouse, K.E. (2013) defines an educational game as a competitive activity governed by rules that promote a unified experience and understanding, allowing students to achieve a more profound comprehension of the world. These games can be categorized as either physical or digital. Research indicates that game-based learning significantly improves student motivation and engagement, thereby enhancing educational outcomes (Buckley & Doyle, 2016).

The integration of gaming into educational frameworks has gained significant traction in recent years, particularly within science and environmental education. One innovative approach is the development of GeoHazard Cube Games, which aim to enhance student engagement and improve geologic hazard literacy. These games serve as interactive tools that make learning about geohazards enjoyable and provide students with essential knowledge about the risks associated with natural disasters. GeoHazard cube games are designed to engage students through interactive gameplay that simulates real-world geological scenarios. Incorporating aspects like challenges, rewards, and collaborative gameplay enhances the immersive learning experience of these games (Zainuddin et al., 2020).

Students' engagement significantly influences their academic performance. When involved, students typically achieve higher grades, perform better on exams, and are less prone to drop out of school prematurely (Ali & Hassan, 2018, p. 2167). Engaged students excel academically and profoundly comprehend the material they study, acquiring skills that will benefit them throughout their lives. Conversely, students who lack engagement tend to face difficulties in school, skip classes, and may even drop out before completing their education. Thus, ensuring students are involved is crucial to aiding them in succeeding in school and life.

2. RESEARCH QUESTIONS

1. What is the level of geologic hazard literacy among Grade 11 students at HNCHS, as assessed through the pretest and posttest?
2. What is the level of improvement in students' geologic hazard literacy as indicated by the normalized gain score?
3. Is there a statistically significant difference between the pretest and posttest mean scores in geologic hazard literacy?
4. Based on the findings, what specific interventions can be proposed to enhance geologic hazard literacy among students further?

3. RESEARCH METHODOLOGY

3.1 RESEARCH DESIGN

This research employed a mixed-method design approach for developing and evaluating GeoHazard Cube Games as supplementary materials to enhance student geologic hazard literacy. The quantitative method, through pretests and posttests, is designed to measure how student awareness of geologic hazards has changed. Additionally, qualitative data is gathered through focus group discussions (FGDs) and interviews to assess how students engage and their perceptions of GeoHazard Cube Games. These combined methods allow a comprehensive assessment of both the cognitive improvements and the interactive, engaging attributes of the game in promoting geologic hazard literacy among Grade 11 students at Hinatuan National Comprehensive High School.

3.1 RESEARCH LOCALE

The study was conducted in Hinatuan National Comprehensive High School, Senior High School Department, Hinatuan, Surigao del Sur Philippines. It is a central institution for secondary education in the area and caters to a very diverse group of students coming from both urban and rural communities. It was selected as the research site because of its relevance to the goal of the study of enhancing geologic hazard literacy among Grade 11 students, which falls within the target population of the intervention.

3.2 RESEARCH PARTICIPANTS

The participants are 40 Grade 11 students from Hinatuan National Comprehensive High School. They were selected because they are currently taking up the Earth and Life Science subject, which includes topics on geologic hazards.

3.3 RESEARCH INSTRUMENT

The researchers crafted the research instruments aimed to evaluate student engagement and geologic hazard literacy. To analyze geologic hazard literacy, a 50-item test was crafted by the researchers for both the pretest and posttest. These tools underwent validation by experts in education and disaster risk reduction. The reliability of the instruments was substantiated, showing a Cronbach's alpha score of 93%.

3.4 DATA GATHERING PROCEDURE

The data collection process encompassed multiple stages. Initially, permissions were obtained from the school administration to facilitate the study. Subsequently, a pretest was conducted to assess the baseline levels of student engagement and geologic hazard literacy. The GeoHazard Cube Games were introduced into classroom routines for a designated duration. Upon completion of the activities, a posttest was administered, and participant feedback was gathered. Ultimately, the data obtained from both the pretest and posttest were scrutinized to evaluate the efficacy of the GeoHazard Cube Games. Focus group discussions (FGDs) and interviews were conducted to gather qualitative insights into student engagement and perceptions of the GeoHazard Cube Games.

3.5 ETHICAL CONSIDERATIONS

The study adhered to ethical guidelines to safeguard the rights and well-being of the participants. Prior permissions were secured from the school administration and the student's parents or guardians. Participants were duly informed about the study's objectives and their option to withdraw at any point without facing repercussions. Moreover, strict confidentiality and anonymity concerning the participants' information were upheld throughout the study.

3.6 SCOPE AND LIMITATION

.The scope of the study focused on implementing GeoHazard Cube Games to enhance geologic hazard literacy, hence allowing the generalizability of findings only to similar contexts. The study's limitations included variance in student engagement, resulting from the differences in their levels of technology and geologic hazard knowledge. Other variables include the time allotted for the intervention and, most interestingly, the demographic makeup of the students involved in the sample.

4. RESULTS

Table 1. Mean Percentage Scores and Mastery Levels in Pretest and Posttest Assessments

Assessment	Percentage (%)	Mastery Level
Pretest	59. 66%	Near Mastery
Posttest	79.78%	Mastery

Table 1 shows the comparison between the pretest and posttest results, and it reveals a notable enhancement in students' geologic hazard literacy after the implementation of GeoHazard Cube Games. Initially, students exhibited a moderate level of comprehension, denoted by a pretest mean percentage score of 59.11%, categorizing their understanding as "Near Mastery", indicating a foundational grasp with some knowledge gaps. However, the posttest means percentage score surged to 79.78%, signifying a transition to "Mastery" level comprehension. This progression underscores the efficacy of GeoHazard Cube Games in improving students' understanding and retention of geologic hazard concepts. The transformation highlights the positive impact of incorporating interactive learning

approaches, like game-based education, in teaching complex scientific subjects. Furthermore, scholarly research, exemplified by Hamari J. et al. (2014), confirm the benefits of gamification in enhancing student engagement and academic performance across diverse educational settings, emphasizing the importance of innovative educational tools in addressing knowledge deficiencies and promoting deeper involvement in the learning process.

Table 2. Normalized Gain Results

Assessment	Percentage (%)	Normalized Gain (g)
Pretest	59. 66%	0.505
Posttest	79.78%	

Table 2 reveals the normalized Gain calculated from the pretest and posttest scores, which is approximately 0.505, suggesting a medium level of improvement in students' understanding of geologic hazards. This value falls within the moderate range of gains (between 0.3 and 0.7), as Hake (1998) outlined. The outcome implies that the utilization of GeoHazard Cube Games successfully fostered learning, enabling students to enrich their knowledge throughout the intervention phase notably.

Table 3. Statistical Analysis of Geologic Hazard Literacy: Pretest vs. Posttest Results

	Pretest	*Posttest*
Mean	17.96666667	24.4
Variance	9.757471264	7.351724
Observations	30	30
Pearson Correlation	0.534975786	
Hypothesized Mean Difference	0	
df	29	
t Stat	-12.42156365	
P(T<=t) one-tail	0.000000000000195	
t Critical one-tail	1.699127027	
P(T<=t) two-tail	0.000000000000390	
t Critical two-tail	2.045229642	

Table 3, on the other hand, reveals the analysis of pretests and posttests, which explicitly indicates that there is a significant increase in geological hazard literacy among students of grade 11 at the Hinatuan National Comprehensive High School. The additional means were 17.97 for the pretest and 24.4 for the posttest, marking a more significant development in student performance post-intervention. Hence, slight variations were observed in the pretest score of 9.76 and the posttest score of 7.35. Hence, the deviation from the score of pretests indicated a more significant variation, which means the performance level is substituted with higher conformity during the posttest. The Pearson correlation coefficient of 0.535 indicates moderate positive relationships between the pre-and posttest results, which means that students who scored higher in the pretest tended to continue doing so. Hypothesis testing resulted in a very small p-value (one-tail = 0.000000000000195, two-tail = 0.000000000000390). Thus, it is far below the usual .05 significance level, which implies that pre-test-post-test score comparisons are significantly different. Further, the t-statistics of -12.42 would provide definite evidence to reject the null hypothesis, especially because it was still far more significant than the critical t-values for one and two-tail tests (1.699 and 2.045, respectively). Further proves the vast effect of GeoHazard cube games on students' geological hazard literacy development.

Table 4. Thematic Analysis Based on Focus Group Discussions

Theme	Description	Key Findings
Increased Awareness of Geologic Hazards	Students better understood geologic hazards like earthquakes, landslides, and volcanic eruptions.	Recognized risks and impacts of hazards in their communities through interactive learning.
Enhanced Engagement and Motivation	The interactive nature of the GeoHazard Cube Game increased student interest and participation.	Students were more motivated and excited to learn through hands-on, game-based activities.
Improved Critical Thinking and Decision-Making Skills	The game encouraged students to think critically about hazard responses and preparedness strategies.	Greater confidence in applying knowledge to real-life situations, like creating safety plans and identifying safe locations.
Collaboration and Peer Learning	Group-based activities within the game promoted teamwork and collaborative problem-solving.	Students benefited from sharing ideas and working together, which enhanced their understanding of geologic hazards.
Limitations in Prior Knowledge and Awareness	Initial understanding of hazards was limited; the game helped fill knowledge gaps.	Suggested adding more localized content to improve relevance and comprehension.
Positive Impact on Preparedness	The game strengthened students' preparedness for geologic hazards through safety measures and emergency planning.	Increased confidence in handling emergencies with the knowledge gained from the game.

Table 4 gives the thematic analysis of students' experiences with GeoHazard Cube Games and presents various important results. First, concerning awareness, students became increasingly aware of geologic hazards like earthquakes, landslides, and volcanic eruptions, understanding the association of risks and potential impacts facing their communities. Increased engagement and motivation to participate were apparent when the interactions afforded by the game created interest and prompted involvement through hands-on learning. Research conducted by Moradian MJ & Mehraein Nazdik Z. (2019), indicates that interactive educational methods, such as games, significantly enhance students' knowledge of disaster risks compared to traditional lecture methods, leading to increased awareness of hazards and their implications in real-world contexts. Also, game-based learning has been shown to foster greater engagement among students, as it promotes active participation and enthusiasm for learning (Wang, C. Et., al 2023). Cojocariu et al. (2014) and Miller (2014) noted that game-based learning seeks to impart knowledge and skills through games, positively influencing problem-solving and critical reasoning. This approach fosters enjoyable experiences, engagement, motivation, self-satisfaction, creativity, social interaction, and emotional stimulation (Shute & Ke, 2012; Prensky, 2001).

Moreover, there were enhanced critical faculties and decision-making skills on the students' part as they acted on their knowledge to make safety plans and identify safe spots. The game also encouraged teamwork through collaboration and shared learning, thus adding to an even greater appreciation of geologic hazards. However, there were gaps in prior knowledge that existed from the very beginning which highlight the need for more localized content to increase relevance and understanding. Studies have shown that many students enter educational programs with minimal prior knowledge about disasters, highlighting the need for tailored educational interventions that address these gaps effectively (Moradian MJ & Mehraein Nazdik Z. 2019). Eventually, the GeoHazard Cube Games promoted the preparedness of students and made them feel competent in emergency preparedness by way of willingness to face various kinds of geologic hazards through safety measures and contingency planning.

The findings from the GeoHazard Cube Games activities are supported by various studies highlighting the positive impact of game-based learning on student engagement, enjoyment, motivation, and perceived learning. According to Kapp (2012), games promote collaborative learning, enhancing students' ability to work together effectively, corroborating the effective collaboration noted during the GeoHazard Cube Games. Additionally, Barata et al. (2013) found that educational games improve students' understanding of complex subjects and enhance critical thinking skills, consistent with the results showing that students felt they learned significantly from the games. Lastly, Surendeleg et al. (2020) discuss how serious games can boost student motivation and enjoyment in learning

environments, reflecting the high levels of enjoyment and eagerness for future participation expressed by students in your findings.

5. CONCLUSIONS

GeoHazard Cube Games have successfully improved geological hazard literacy among the students of Grade 11 at Hinatuan National Comprehensive High School, as evidenced by the significant increase in the scores after the posttest compared to the pretest. Their average Gain moved from 59.66% during the pretest to 79.78% during the posttest, classified as "Near Mastery" to "Mastery." Thus, a medium normalized gain of 0.505 once again proved this to be moderate knowledge improvement, while t analysis confirmed that a significant difference exists between the pre-and posttest scores with a t stat of -12.42 and a p-set far below 0.05. The thematic analysis found increased awareness, engagement, critical thinking, and collaborative learning among students, bridging gaps in prior knowledge through localized content and interactive learning means. Thus, these findings show the GeoHazard Cube Games' potential as an innovative pedagogical tool for fostering one country's preparedness, critical judgment, and group decision-making with practical strategies to combat geological hazard literacy in similar educational contexts.

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