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The impact of contextual problem-based materials on students' disaster mitigation concept mastery and critical thinking

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Abstract

This study aims to enhance students' disaster mitigation concept mastery and critical thinking through problem-based contextual teaching materials. The research employed a quasi-experimental one-group pretest-posttest design. Participants consisted of thirty undergraduate students randomly selected from the student population at Universitas Pendidikan Ganesha using simple random sampling techniques. The instruments used included a Critical Thinking Skills test and a Concept Mastery test, which underwent reliability testing. Data analysis was conducted descriptively and further examined using the Wilcoxon test at a significance level of 0.05 to determine the significance of differences before and after the intervention. The research findings indicate that: (1) Critical thinking skills ($p < 0.05$, $\langle g \rangle = 50\%$) showed improvement and were categorized as medium; (2) students' disaster mitigation concept mastery ($p < 0.05$, $\langle g \rangle = 40\%$) also showed improvement and was categorized as medium; (3) the Wilcoxon test analysis revealed a significant difference before and after the intervention ($p < 0.05$); (4) student responses to the teaching materials indicated a positive response. In conclusion, contextual problem-based disaster mitigation teaching materials can enhance students' disaster mitigation concept mastery and critical thinking. The practical implications of this study recommend integrating contextual problem-based materials into school curricula to enhance disaster preparedness.

Keywords: Critical thinking skills, Disaster mitigation, Students' concept mastery, Teaching materials.

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1. Introduction

Indonesia, as an archipelagic country, has a high potential for various types of natural disasters. Based on the National Agency for Disaster Countermeasure (Badan Nasional Penanggulangan Bencana, BNPB), the most frequent disasters occurring between 2009 and 2018 were floods (35%), tornadoes (30%), and landslides (23%). From January to July 14, 2019, more than 98% of disasters were classified as hydrometeorological disasters (e.g., floods, landslides, droughts, and storms), while only 2% were geological disasters (e.g., earthquakes, tsunamis, and volcanic eruptions) [1].

Based on this, to mitigate the negative impact of natural disasters on the Indonesian population, disaster education must be integrated into the learning curriculum so that effective mitigation efforts can be understood from an early age and reinforced in higher education. This is especially important for university students, who serve as agents of change in society. However, in reality, disaster mitigation courses are still not optimally implemented.

Disaster mitigation refers to proactive actions taken before a disaster occurs to eliminate or reduce risks and hazards [2]. The primary goal of disaster mitigation is to minimize injuries and fatalities, while its secondary goal is to reduce economic losses and infrastructure damage. Therefore, students must enhance their critical thinking skills and Concept Mastery of disaster mitigation to effectively reduce disaster risks and contribute to a safer community environment.

Previous studies have shown that problem-based electronics modules can improve students' critical thinking skills and students' disaster mitigation Concept Mastery across various disciplines, including physics education [3]. However, research specifically integrating problem-based learning with local disaster contexts in Indonesia to enhance disaster mitigation Concept Mastery remains limited. Additionally, conventional teaching materials tend to be less engaging and do not adequately facilitate the development of analytical skills necessary for solving complex disaster mitigation problems [4].

The preliminary observation was conducted at Ganesha University of Education, as this institution is located in Bali. Bali is one of Indonesia's most disaster-prone regions, making it an ideal research location. Additionally, Bali's education system uniquely emphasizes the preservation of local wisdom, which presents distinct challenges in implementing contextual teaching materials. Observations on the Disaster Mitigation course in the Science Education Program at Ganesha University of Education revealed that problem-based contextual teaching materials and learning tools for disaster mitigation are not yet available. Problem-based contextual teaching materials are more meaningful for students as they are closely related to real-life situations [5]. Learning with contextual problem-based teaching materials addresses issues in students' disaster mitigation, Concept Mastery of disasters, and enhances their critical thinking skills, particularly in responding to frequent natural disasters in Indonesia. This statement is supported by Winarso and Haqq [6], who found that contextual learning improves learning outcomes more effectively in enhancing students' critical thinking skills than expository learning.

According to Banda and Nzabahimana [7], Students' disaster mitigation Concept Mastery is insufficient to equip individuals for solving real-world problems; individuals need critical thinking skills to make well-considered decisions. In this context, a major challenge Indonesian society faces is the threat of natural disasters. Critical thinking is the ability to analyze, evaluate, and solve problems logically and systematically [8]. So, critical thinking is crucial for formulating effective solutions and making informed decisions when facing disaster threats.

Research trends on the importance of critical thinking skills were evident in national and international studies. Pujani et al. [9] found that using the Collaborative Ranking Task method and lesson study in learning can improve students' disaster mitigation Concept Mastery and critical thinking skills. Chusni et al. [10] emphasized that critical thinking involves various cognitive components and activities aligned with modern educational directions. Furthermore, Pujani et al. [9] demonstrated that astronomy teaching materials and inquiry-based learning models can enhance students' critical thinking skills, particularly through integration with observational activities such as night-sky observations.

So, this study has novelty to explore the intersection of Problem-Based Learning (PBL), Contextual Teaching, and Disaster Mitigation Education to enhance students' concept mastery and critical thinking skills. By blending these three approaches, we investigate how they create a transformative learning experience that is both relevant and actionable, particularly in disaster-prone communities. The findings are expected to not only advance pedagogical innovation but also provide a practical framework for educators and policymakers to foster community resilience through education. The framework of this research is visualized in Figure 1.

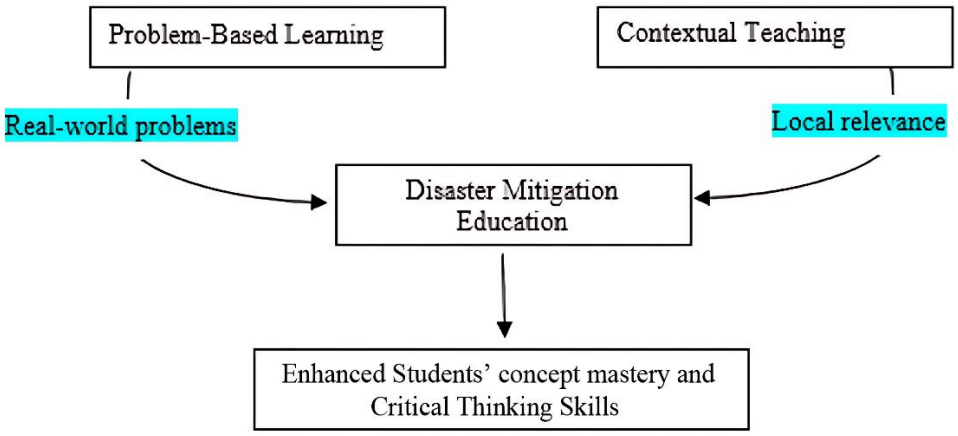

Figure 1.
Research framework.

Thus, providing contextual problem-based disaster mitigation teaching materials is academically relevant and applicable to real-life situations. This approach prepares students to face disaster mitigation challenges by optimizing their critical thinking skills and students' disaster mitigation concept mastery. This research presents a novelty by integrating problem-based contextual teaching materials. Unlike traditional textbook-based learning, this study incorporates interactive elements such as pocketbooks and multimedia resources, including videos, to engage students in real-world disaster scenarios. The unique aspect of this research lies in its use of local context and the development of materials that encourage active participation, collaboration, and independent learning, providing a dynamic and engaging learning environment for students.

Based on the discussion above, this study aims to determine the effectiveness of contextual problem-based disaster mitigation teaching materials in enhancing students' disaster mitigation Concept Mastery and critical thinking skills

2. Method

This study employs a quasi-experimental design with a one-group pretest-posttest research design. The focus of this research is to test the contextual problem-based disaster mitigation teaching materials, which were developed by the researcher through a design and validation process, to assess their effectiveness in improving students' concept mastery and critical thinking skills. This one-group pretest-posttest design can be described as follows.

Sample Group	:	O_1	X_1	O_2

Figure 2.
Pre-test post-test group design.

Figure 1 describes the treatment during the research at the beginning of the study. The group was given a pretest (O_1). The group used an implementation of contextual problem-based teaching materials. The implementation procedure for learning using contextual problem-based disaster mitigation teaching materials is divided into three stages. Firstly, students take a diagnostic assessment of their concept mastery and critical thinking skills related to disaster mitigation content. Subsequently, students are divided into study groups consisting of 3-4 members. Secondly, this stage begins with an in-depth discussion of topics presented in the contextual problem-based disaster mitigation textbook, ensuring students gain a proper understanding of the material. Students then summarize the discussion. The final step of the in-class stage involves students presenting their findings using a disaster mitigation pocketbook as their learning product. At the end, students take a posttest assessing their concept mastery and critical thinking skills related to disaster mitigation content. Additionally, they complete a questionnaire to provide feedback on the learning process. At the end of the study, a post-test was administered (O_2).

This study population consists of science education bachelor's degree students from Ganesha University of Education, Indonesia. The sample group subjects consisted of thirty students in the third semester selected through simple random sampling. Informed consent was obtained from all participants. This class received instruction using contextual problem-based disaster mitigation teaching materials covering ten main topics, including: 1) Earthquakes; 2) Tsunamis; 3) Volcanic Eruptions; 4) Thunderstorms; 5) Tropical Cyclones; 6) El Niño and La Niña; 7) Floods; 8) Landslides; 9) Drought; and 10) Forest Fires.

The students' mastery concept instrument consists of 20 multiple-choice questions that are modified based on Bloom's taxonomy C2-C4. The second instrument is a critical thinking skills test. The test was an essay test consisting of 10 questions modified based on the critical thinking indicators: Interpretation, Analysis, Evaluation, Inference, and Explanation. All research instruments used in this study have undergone reliability testing and met the required standards. The reliability testing result showed a value greater than 0.4, indicating that the instrument was reliable. The test grid for measuring students' mastery of concepts is presented in Table 1, and the test grid for measuring critical thinking skills is presented in Table 2.

Table 1.
The students' concept mastery test grid.

Topic	Learning Indicator	Indicator (Concept Mastery)					
		C1	C2	C3	C4	C5	C6
Earthquake	Analyze the causes of earthquakes				V		
	Explain the impacts of earthquakes		V				
Tsunami	Explain the causes of tsunamis		V				
	Analyze the process of tsunami formation				V		
Volcanic Eruption	Explain pre-volcanic symptoms		V				
	Explain post-volcanic symptoms		V				
Thunderstorm	Explain the causes of thunderstorms		V				
	Explain the classification of thunderstorms		V				
Tropical Cyclone	Explain the definition of tropical cyclones		V				
	Explain the causes of tropical cyclones		V				
El Niño & La Niña	Analyze the impacts of ENSO and El Niño				V		
	Analyze the impacts of ENSO on La Niña				V		
Flood	Explain the definition of convective rain		V				
	Investigate flood mitigation efforts			V			
Landslide	Investigate the causes of landslides			V			
	Determine mitigation efforts to minimize landslide risks			V			
Drought	Predict the causes of drought		V				
	Investigate the relationship between drought and monsoon			V			
Forest Fire	Explain the recapitulation of forest/land fire areas in Indonesia		V				
	Investigate forest fire mitigation			V			
Total		-	11	5	4	-	-

Table 2.
The students' critical thinking test grid.

Topic	Learning Indicator	Interpretation	Analysis	Evaluation	Inference	Explanation
Earthquake	Determine earthquake mitigation steps	V				
Tsunami	Analyze the tsunami formation process	V				
Volcanic Eruption	Explain the impacts of volcanic eruptions			V		
Thunderstorm	Explain thundercloud formation stages				V	
Tropical Cyclone	Describe the impacts of tropical cyclones					V
El Niño & La Niña	Examine the El Niño formation mechanism	V				
Flood	Explain flood disaster mechanisms		V			
Landslide	Determine mitigation efforts to minimize landslide risks			V		
Drought	Describe global arid regions				V	
Forest Fire	Explain the impacts of forest fires					V
Total		3	1	2	2	2

The improvement in Students' Concept Mastery and critical thinking skills was analyze using the normalized gain percentage, calculated using the following formula:

$$\%\, g = \frac{(S_{post}) - (S_{pre})}{(S_{\max}) - (S_{pre})} x100$$

Figure 3.
The Normalized Gain Percentage Formula.

The % g value is then converted based on the following normalized gain criteria. The criteria of %g values are shown in Table 3.

Table 3.
Criteria of N-Gain values.

Interval	Criteria
71 - 100	High
31 - 70	Medium
0 - 30	Low

Source: Sesmiyanti, et al. [11].

The analysis of students' concept mastery and critical thinking skills was then subjected to a Kolmogorov-Smirnov normality test as a prerequisite test. The results indicated that the pretest and posttest data were not normally distributed ($p < 0.05$). Therefore, the non-parametric Wilcoxon test was used to determine the significance of differences before and after the treatment. Data analysis in this study was conducted using Minitab version 19.0, with a 5% significance level.

3. Results

3.1. Students' Disaster Mitigation Concept Mastery

The improvement in Students' Concept Mastery of disaster mitigation was measured using the normalized gain percentage (%g). The concept mastery scoring ranged from 0 to 100, with n = 30. The pretest, posttest, and normalized gain percentage (% g) scores for concept mastery of disaster mitigation in this study are presented in Table 4.

Table 4.
The frequency distribution and percentage of pretest and posttest scores for concept mastery of disaster mitigation.

		Students' Concept Mastery			
		Pre-test		Post test	
Interval	Criteria	f	%	f	%
85 – 100	Excellent	0	0.0	9	30.0
70 – 84.9	Good	4	13.3	13	43.3
55.0–69.9	Fair	13	43.3	6	20.0
40.0-54.9	Low	11	36.7	2	6.7
0 – 39.9	Very Low	2	6.7	0	0.0
Sum		30	100	30	100
Mean		55.3		75.6	
Std.dev		10.99		13.5	
%(g)	40% (Medium)				

Based on Table 4, the pretest score distribution ranged from Very Poor to Good, while the posttest score distribution ranged from Poor to Excellent. The normalized gain percentage for concept mastery was 40%, which falls into the medium category. This indicates that there was a notable improvement after learning with the teaching materials and the disaster mitigation pocketbook. In other words, the average posttest score was higher than the average pretest score.

Then, a follow-up analysis test was conducted to determine the significance of the increase in the mean pretest and posttest scores. Before this, a prerequisite test was performed using the Kolmogorov-Smirnov (KS) normality test for the pretest and posttest data. The normality tests are visualized in Table 5.

Table 5.
Result of Normality tests for concept mastery

Data	n	Mean	SD	P-value	Conclusion
Pre-test	30	55.33	10.99	0.010	Not normally ($p<0.05$)
Post-test		75.67	13.50	0.010	Not Normally ($p<0.05$)

The normality test results indicated that students' scores were fairly distributed, but the distribution was not normal. This was shown by a p-value of 0.010 ($p < 0.05$), concluding that the data were not normally distributed.

Therefore, based on the normality test result of the Students' Concept Mastery of disaster mitigation data, which was concluded not normally distributed, the Wilcoxon Signed Rank Test, a non-parametric statistical test for paired data, was used to analyze the significance of the improvement before and after treatment. The Wilcoxon test results are presented in Table 6.

Table 6.
Result of the Wilcoxon Test for students' concept mastery.

Sample	N for Test	Wilcoxon Statistic	P-Value
Data Wilcoxon	30	0.00	0.000

Table 6 shows that the P-value is 0.000 (< 0.05), indicating a significant difference between students' scores before and after the learning intervention. This confirms that implementing contextual problem-based disaster mitigation teaching materials effectively enhances students' concept mastery

3.2. Critical Thinking Skills

The improvement of students' Critical Thinking Skills with $n = 30$ is demonstrated through the calculation of the normalized gain percentage (%g). The pre-test and post-test scores, and the normalized gain percentage (%g) of Critical Thinking Skills in the field of disaster mitigation obtained in this study are presented in Table 7.

Table 7.
The frequency distribution and percentage of pretest and posttest scores for Critical thinking skills.

		Critical Thinking Skills			
		Pre-test		Post-test	
Interval	Criteria	f	%	f	%
85 – 100	Excellent	0	0.0	10	33.3
70 – 84,9	Good	0	0.0	16	53.3
55,0–69,9	Fair	18	60.0	4	13.3
40,0-54,9	Low	12	40.0	0	0.0
0 – 39,9	Very Low	0	0.0	0	0.0
Sum		30	100	30	100
Mean		56.4		79.5	
Std.Dev		7.5		7.3	
%(g)	50% (Medium)				

Based on Table 7, the distribution of pre-test scores falls within the categories of low and moderate, while the distribution of post-test scores ranges from moderate to good and very good. The normalized gain percentage of students' critical thinking skills is 50%, classified as moderate. This indicates an improvement after the learning process using the teaching materials and the disaster mitigation pocketbook. In other words, the average score of students' critical thinking skills in the post-test is higher than the average score in the pre-test. These findings suggest that implementing mitigation teaching materials in learning can help students master several indicators of critical thinking skills.

The data were then further analyzed using inferential statistical analysis to determine the significance of the difference in students' critical thinking skills before and after the intervention. Before this, a normality test for pre-test and post-test data was conducted using the Kolmogorov-Smirnov (KS) test. The normality test results are shown in Table 8.

Table 8.
Result of Normality Test for Critical Thinking Skills.

Data	n	Mean	SD	p-value	Conclusion
Pretest	30	56.4	7.5	0.150	normal (p>0.05)
Posttest		79.3	7.3	0.010	Not normally (p<0.05)

Based on Table 8, the pre-test data had a *p*-value of 0.15 ($p > 0.05$), indicating that students' initial critical thinking ability was normally distributed. However, the post-test data exhibited a non-normal distribution with a *p*-value of 0.01 ($p < 0.05$). Therefore, the appropriate follow-up test was the non-parametric Wilcoxon test to analyze the significance of the difference in students' initial critical thinking skills before and after the intervention. The Wilcoxon test results for students' critical thinking skills are presented in Table 9.

Table 9.
Result of Wilcoxon Test for students' critical thinking skills.

Sample	N for Test	Wilcoxon Statistic	P-Value
Data Wilcoxon	30	0.00	0.000

Based on Table 9, the obtained *p*-value is 0.000 (< 0.05), indicating a significant difference between students' scores before and after the learning process. These follow-up test results suggest that the use of problem-based contextual disaster mitigation teaching materials is effective in enhancing students' critical thinking skills.

4. Discussion

The significant difference between pretest and post-test results proves that implementing contextual problem-based mitigation materials provides an innovation, especially in improving students' knowledge of disaster mitigation concepts through problem-solving activities. Väisänen and Hirsto [12] support this result by stating that concept mastery improves when students are given time for independent learning at their own pace. This finding aligns with previous research by Akben [13] and Suarlin et al. [14], which concluded that problem-posing learning is highly effective in enhancing students' concept mastery, as seen in learning outcomes, metacognitive skills, and problem-solving abilities. This finding supports previous research by Dita et al. [15] and which states that integrating problem-solving activities into learning media or teaching materials has also been proven to positively impact concept mastery.

The comparison of pre-test and post-test scores for concept mastery shows that the average improvement in concept mastery is medium. This result is related to concept mastery. Students who learn with contextual teaching materials show greater improvement in concept mastery than those who learn with a conventional textbook, Khaldun [16]. Jdaitawi [17] found that students who learn before class have better concept mastery than those in the conventional class. Better concept mastery indicates a better knowledge structure, which positively impacts disaster mitigation in real life [18].

The core of this teaching material can affect students' cognitive processes in solving disaster-related problems rooted in their local context by analyzing landslide risks in their village. Contextual PBL teaching material has a specific syntax to focus on mitigation strategies, such as designing early warning systems and creating a tsunami drill protocol. The intersection of contextual and mitigation lessons is shown in the use of local disaster history/data to teach mitigation, studying past volcanic eruptions in Indonesia.

The difference analysis results on students' critical thinking skills demonstrate that disaster mitigation learning, incorporating problem-based contextual teaching materials, can improve both students' concept mastery and critical thinking skills. The 50% increase in critical thinking ability further supports the effectiveness of problem-based contextual disaster mitigation teaching materials in developing students' critical thinking skills.

This improvement is attributed to the reading and summarizing activities conducted during the pre-class stage. The pre-class stage, assigning students to summarize the problem-based contextual disaster mitigation teaching materials, fosters reading literacy. Kusumoto [19] supports this statement with their research findings, which indicate that students engaged in problem-based reading activities or discussion texts exhibit higher critical thinking skills compared to those who engage in passive reading. Thus, promoting deep and analytical reading literacy can directly enhance critical thinking skills, ultimately strengthening students' reasoning and decision-making abilities in a disaster.

Students were also allowed to present their work by creating a pocketbook, which further motivated them to engage in the disaster mitigation course. This approach supports students in problem-solving, logical reasoning, and effectively communicating their ideas through problem-based contextual learning [20]. The improvement in critical thinking skills, as a positive impact of students' increased interest in disaster mitigation learning using mitigation teaching materials, is supported by several studies. Consistent with Harefa et al. [21]. These studies highlight a correlation between learning interest and academic achievement, creative thinking ability, and critical thinking skills. Furthermore, our findings about the positive impact of disaster mitigation teaching materials are consistent with the findings of other researchers, by Kwangmuang et al. [22] and [23]

These findings indicate that learning with mitigation teaching materials and pocketbook media fosters students' ability to interpret, analyze, conclude, evaluate, and self-regulate, which are essential critical thinking skills [24]. The development of these skills requires attention to several factors, such as providing students with broad opportunities to acquire information and apply it in learning, selecting appropriate learning targets, objectives, and content, as well as continuously improving and evaluating the learning process [25].

These results align with the findings of Khoiri et al. [26], which states that teaching materials enable students to learn independently by controlling their learning pace and reading speed while also supporting discussions that promote collaboration and critical thinking development. Discussion forums in learning that utilize contextual teaching materials or media can enhance students' critical thinking by engaging them in activities such as identifying patterns, formulating hypotheses, and effectively communicating information. This argument is consistent with the findings by Loveys and Riggs [27] and Yu et al. [28].

Student responses to learning using the Problem-Based Contextual Disaster Mitigation Teaching Material were collected through a response questionnaire. The results showed that students had a positive perception, with 95% selecting "Agree" (S) and "Strongly Agree" (SS). However, a small percentage (5%) of students disagreed, primarily due to the high variability in students' abilities. These responses show that learning through contextual teaching materials requires self-motivation from learners. This learning motivation plays a crucial role in the diverse abilities of students in utilizing the teaching materials.

The positive student responses were supported by the advantages of the teaching materials, which were enhanced with pocketbook media and educational videos related to disaster topics. These additions made the learning process more engaging and interactive. This finding aligns with the study by Zulfiya et al. [29] which states that interactive teaching materials have been proven to introduce innovative learning approaches that are more appealing to students, especially those classified as digital natives.

5. Conclusion

The Problem-Based Contextual Disaster Mitigation Teaching Material has been proven effective in enhancing students' concept mastery and critical thinking skills. This teaching material received positive responses from students, indicating its potential as an effective learning resource. This study recommends that educational practitioners implement Problem-Based Contextual Disaster Mitigation Teaching Materials in schools to provide early knowledge of disaster mitigation and to enhance students' concept mastery and critical thinking skills.

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