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Application of Science Concepts and Disaster Preparedness Capability in Sustainability Learning Oriented by Science Issues Integrated Natural Disaster Mitigation

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Abstract: Education for Sustainable Development (ESD) emphasizes the integration of economic, ecological, and social aspects, and has gained global recognition. Science education supports ESD by embedding sustainability issues into scientific content and using sustainability-based learning strategies. This study aimed to design and evaluate the effectiveness of sustainability-oriented science learning integrated with disaster mitigation to improve disaster preparedness among prospective elementary school teachers. A quasi-experimental design was used, involving two PGSD student groups in the Basic Concepts of Science course. The experimental class received instruction integrating sustainability issues related to tsunami mitigation, while the control class did not. Preparedness was measured using pretest and posttest questionnaires based on LIPI-UNESCO indicators. Data were analyzed using n-gain, t-test, and effect size. Results showed a significant improvement in disaster preparedness in the experimental class. Concepts such as fluid statics, hydrology, sedimentation, and river silting were relevant to local flooding issues in South Sumatra. This study contributes to science education by highlighting the value of incorporating local disaster contexts into sustainability-focused learning to enhance resilience among pre-service teachers.

Keywords: Education for Sustainability Development (ESD), Disaster preparedness capabilities, Disaster mitigation.

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1. Introduction

Education for Sustainability Development (ESD) has become a hot topic in the world, especially in the field of Education, where since the beginning of national and international policies regarding sustainable development. *ESD* in relation to science education becomes an important potential in contributing to all three relevant learning domains (Eilks & Hofstein, 2014). This is relevant because it involves natural resources, community participation in resources and community participation in sustainable development issues, or related to sustainability in science and technology (For, 2015). Based on the UN declaration in the 2005-2014 period, it is stated that sustainability development emphasizes the importance of education to improve world sustainability (Wals et al., 2014).

ESD is the key to sustainability in building solid education for sustainable development *UNESCO* (2020). Therefore, in practice, *ESD* Not being able to stand alone must involve many dimensions such as education, economy, technology, social, religion, culture and also science content that are related to each other. The role of science education in answering this sustainability issue can be in the form of integrating the issue of sutainability in science content and using sustainability strategies in science education where science education is part of developing ESD (Burmeister & Eilks, 2014)(Education, 2014).

The role of science from time to time is undeniable to answer problems that exist in the world, be it in technology, social, culture and others, science can answer these problems. The contribution of science in learning can be made such as reducing greenhouse emissions, increasing biodiversity, efficient use of energy and reducing ecological footprint, disaster mitigation and others. Indirectly, the many positive contributions made from science also have a negative impact that is felt. Therefore, it is important to teach the concept of science to students or students, that science is a value, an absolute truth, and an objective that is rejected by itself (Birdsall, 2013).

Most science-oriented issues *ESD* is interdisciplinary learning, *greenchemistry*, natural resources, environmental Sciences, dan *socio scientific issue (SSI)* (Žalėnienė & Pereira, 2021) (Gao, 2021) (Yang, Yang, & Xia, 2021) (Zhai et al., 2021) (Mallick, 2021) (Fu et al., 2021). Based on some of these studies, there are still few studies related to ESD in the field of natural disaster mitigation. Therefore, in this study, an interesting issue related to the three pillars of ESD was chosen, namely ecology, economics and society, namely natural disaster mitigation to provide disaster preparedness capabilities to students.

The results of a search of 593 articles in the Google Scholar database from 2014 to 2024 with the keywords "disaster mitigation" and "education" were obtained from the distribution of research opportunities regarding research related to disaster mitigation which was analyzed using the vosviewer application presented in Figure 1

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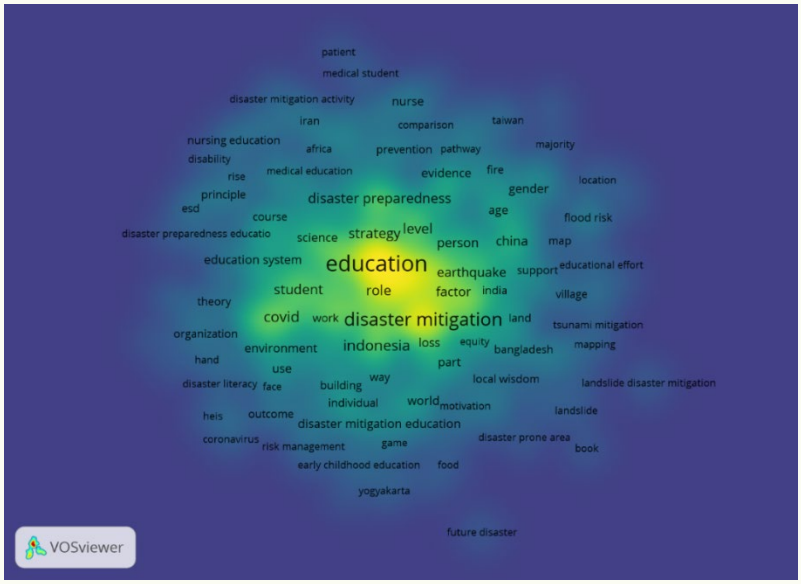

Figure 1. Mitigation and education research opportunities

Figure 1 shows that disaster mitigation research opportunities on the keywords "education" and "mitigation" refer to these opportunities, so the research was conducted on education disawareness mitigation to provide floods disaster preparedness capabilities to students.

Based on geographical conditions, Indonesia has a high potential for disasters, especially in coastal areas that face the open sea. The activity of 3 tectonic plates also causes an increasing potential for disasters where Indonesia is located in the subduction zone of the Indo, Australian and Eurasian plates with a plate shift of 4-6 cm/year (Akbar et al., 2020) (Irwanto, 2015). The meeting of these plates often causes earthquakes. If an earthquake occurs on the seabed, with a scale of more than 7.0 on the Richter scale with a shallow depth and a thrust fault mechanism, it will potentially cause a tsunami (Cahyaningsih et al., 2021) (Ilyas, 2018) (Mustafa, 2020). In addition, the increase in sea level caused by high waves causes the phenomenon of tidal water where sea water overflows towards the land (Ningsih et al., 2019). One of the natural disasters that often occurs is flooding, where flooding is a disaster that often occurs and has a detrimental impact on the surrounding community. The impacts caused by various disasters are very numerous, such as social, economic, educational, psychological for the community and others (Fitri et al., 2023) (Fauzi & Mussadun, 2021).

However, most science learning in educational institutions still focuses on conceptual aspects and has not integrated much into the local context of disasters, especially in the form of a sustainability approach that can provide disaster preparedness. This is important so that it can answer the research objective, namely how to design science learning that not only teaches concepts, but also equips students with awareness and skills to deal with disasters based on local contexts.

In order to minimize the risk of disasters, it is necessary to introduce and instill awareness and preparedness for natural disasters from an early age to students, students and the community in order to minimize the impacts caused (Husna, 2019) (Wulandari & Purnomo, 2020). Based on this, a mitigation effort is needed to deal with the possibility of such a disaster, one of which can be realized through school or college-based disaster mitigation. Where disaster mitigation education in schools has a good impact on students and students in areas prone to natural disasters (Soffer et al., 2018) (Shoji et al., 2020). The integration process in learning is expected to improve disaster preparedness skills in students and students both in terms of affective, psychomotor and cognitive (Rohana et al., 2025). Referring to the ESD pillars and the issue of natural disaster mitigation as science learning, research analyzing sustainability learning oriented to integrated science issues of natural disaster mitigation needs to be carried out. Therefore, this research is important to fill the gap in the literature regarding how sustainability-based and local contextual science learning strategies can be used to improve disaster preparedness for prospective teacher students, as future education agents. In addition, the ability to prepare for natural disasters in this study was also measured in order to minimize the risks posed by natural disasters.

2. Method

This study used a quasi-experimental design to analyze the effectiveness of sustainability learning strategies based on disaster preparedness. The subjects of the study were elementary school teacher education students at Universitas PGRI Palembang who took the Basic Concepts of Elementary School Science course. Data collection techniques were carried out through pretest and posttest questionnaires referring to disaster preparedness indicators from LIPI-UNESCO (2006), namely knowledge and attitudes, emergency policies, early warning systems, and resource mobilization. The instrument has been validated and used in various previous studies that prove its validity in the context of disaster education (Paton & Johnston, 2017). To measure the increase in preparedness skills, data were analyzed using normalized gain (n-gain) values. The n-gain results can show the effectiveness of intervention learning compared to control classes, with low, medium, or high gain classifications (Hake, 1999).

In addition, the effect size test was conducted to determine how much impact the sustainability learning strategy applied had on disaster preparedness skills. Cohen's d is used as a measure of effect, with interpretations of small (0.2), medium (0.5), and large (≥0.8) categories as explained by Cohen (1988). This test is important to ensure that the changes that occur are not only statistically significant but also practically meaningful. Research conducted by (Basri, 2021; Waked & Jaime, 2025) shows that disaster preparedness-based learning linked to the local context can significantly improve students' understanding of risk and emergency response skills. Thus, the use of a quasi-experimental approach in this study is not only based on

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theory, but also refers to practices that have been proven effective in previous studies internationally.

3. Result and Discussion

Results

They should be combined. Based on the results of the analysis, the concept of science is integrated into natural disasters, namely floods. The flood disaster was chosen because the South Sumatra region, especially the city of Palembang, is an area that is often affected by floods almost every year. Thus, science learning that integrates these concepts can provide a deeper understanding of the causes and effective solutions for flood mitigation. The following is an analysis of the concept of integrated science for flood disaster mitigation:

Table 1. Analysis of the Concept of Integrated Science for Natural Disaster Mitigation

Science Concepts	Analysis of Disaster Mitigation Concept Material	Sub Material	Learning Objectives	Learning Activities
Fluida Statis	Impact of Hydrostatic Pressure in Flood Mitigation	Hydrostatic pressure	Understand the role of hydrostatic pressure in river water flow as well as its use in the design of dams or embankments to prevent flooding.	Using a perforated plastic bottle filled with water to demonstrate the principle of hydrostatic pressure.
		Pascal's Law		Create a simple simulation using balloons and water to explain Pascal's laws.
		Archimedes' Law		
		Phenomena in static fluids		
Hydrology	The Water Cycle and Its Role in Reducing Flood Risk	Hydrological cycle	Understanding the hydrological cycle and how it can be managed can reduce flood risk through	Draw a diagram of the water cycle on large paper in batches.

Science Concepts	Analysis of Disaster Mitigation Concept Material	Sub Material	Learning Objectives	Learning Activities
		Benefits of the hydrological cycle	drainage planning and conservation of water catchment areas.	Creating a simple simulation of the water cycle using a bowl filled with water, transparent plastic, and a lamp to demonstrate the evaporation and condensation process.
		Water cycle using diagrams or drawings		
Sedimentation and Siltation	Impact of River Siltation on Flood Risk	Waste and garbage	Understand how sedimentation and siltation affect river capacity, as well as the importance of waste control and river cleanup for flood mitigation.	-Create a demonstration using a small sandbox to show how sedimentation occurs when a stream of water carries solid material.
		Sedimentation and siltation processes		Use images or photos of silted rivers for class discussions.

The analysis of the concept of integrated science of natural disaster mitigation, where the integrated materials are static fluids, hydrology, sedimentation, and river siltation, are very relevant to the issue of floods that often occur in the South Sumatra region. These materials provide a scientific foundation that allows students to understand the complex factors that affect flood risk, including water pressure, hydrological flow, and sedimentation impacts.

In addition, disaster preparedness capabilities are also considered in this study where the results of flood disaster preparedness capabilities are as shown in the table below:

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Table 2. N-Gain analysis of disaster preparedness capabilities

Class Name	Pretest (Nilai Awal)	Posttest (Final Grade)	N-Gain	Categories N-Gain
Experimental Classes	45.8	56	0,8	Tall
Control Classes	45.7	52	0,5	Keep

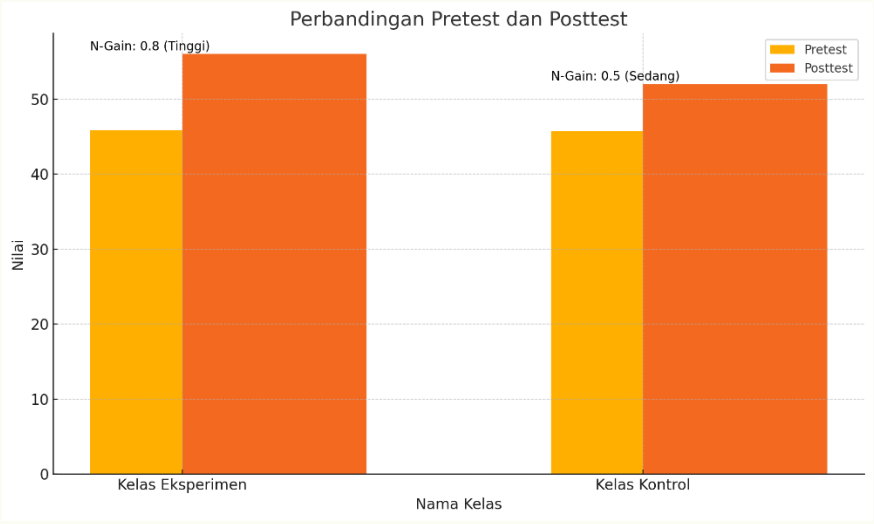

Figure 2. N-Gain Analysis on Flood Disaster Preparedness Capability

Based on the results listed in the table above, it can be concluded that sustainability issue-based learning integrated with natural disaster mitigation has a significant influence on improving students' disaster preparedness capabilities.

After the N-Gain test was carried out to see the improvement of disaster preparedness capabilities between the two groups, then the analysis was carried out using the effect size, as shown in the table below:

Table 3. Effect size results of natural disaster preparedness capabilities

	N (Number of participants)	SD	Cohen's d
Experimental Classes	40	0,4	0,54
Control Classes	40	0,3	

Furthermore, an effect size test was carried out on both classes, where the results can be seen in the table above. Cohen's d value of 0.54 is included in the medium category, indicating that there is a significant difference in disaster preparedness between the two groups. This study supports the finding that sustainability-based learning integrated with floods disaster mitigation has a significant impact on student disaster preparedness. This is in line with Burmeister's research and (Burmeister & Eilks, 2014) which shows that a sustainability issue-based learning approach can improve students' understanding and practical skills in facing real-world challenges.

Discussion

The relationship between the concept of static fluid and flood mitigation is one of the main points in this learning. Static fluids, which study the properties of fluids at rest, can be used to explain how hydrostatic pressure and river surface water level affect the likelihood of water overflow during flooding. This learning helps students understand the basic principles of fluid pressure, which can be used to design more efficient drainage systems, as suggested by (Burmeister & Eilks, 2014), where a sustainability-based approach encourages the application of scientific theory to real-world problems.

Hydrological concepts also make an important contribution to flood mitigation, especially in understanding how surface flows, extreme precipitation, and suboptimal management of water resources can exacerbate flood risk. In this regard, (Sakurai, 2022) suggests that education that integrates sustainable water resource management and climate change can increase awareness of disaster risk. Students are taught to understand the water cycle and its impact on increased flood risk, as well as the importance of infrastructure such as reservoirs and drainage channels to mitigate their impacts. River sedimentation and siltation are also important focuses in this learning. The process of excessive sedimentation can lead to a decrease in the capacity of waterways, which ultimately increases the risk of flooding. This reflects the importance of river maintenance and waste management to maintain the optimal capacity of waterways, as explained by (Ernst, 2013), who states that sustainability-based environmental management can help reduce disaster risk and improve community well-being.

This sustainability-issue-based learning provides significant benefits to students. By understanding the interconnectedness between static fluids, hydrology, sedimentation, and river siltation, they can design natural disaster mitigation strategies that not only help today's communities, but also educate future generations. As proposed by (Žalėnienė & Pereira, 2021), the integration of sustainability education in the higher education curriculum can prepare students to reduce their impacts, prevent disasters from occurring and face global challenges, including the risk of natural disasters. Overall, this approach makes a major contribution to the development of sustainability-based education that not only

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enhances students' academic knowledge, but also provides practical skills to deal with real-world disasters. By integrating the concepts of science and flood disaster mitigation in education, students can develop an understanding of science concepts, foster better disaster preparedness, and directly contribute to sustainable development goals (Ali, 2021; Talan, 2020).

In the experimental class that used the tsunami disaster mitigation issue-based learning, there was a greater increase in preparedness skills compared to the control class that did not use the issue in learning. Higher n-gain values in the experimental class showed that students who studied with this approach experienced a more significant improvement in knowledge and skills related to disaster preparedness, such as the ability to plan disaster responses, mitigate and manage communication during disasters. This issue-based learning is in line with the concept of problem-based teaching that focuses on the application of knowledge in a real context, which has been proven to be effective in improving disaster preparedness (Suarmika, 2022). This also strengthens findings that show that issue-based learning is able to increase students' awareness and understanding of disaster risks that are more contextual and relevant (Hamid, 2023).

The results of the t-test conducted to compare the two classes also showed a significant difference (p-value < 0.05), which indicates that the application of integrated sustainability issue-based learning for disaster mitigation does have a greater impact on improving disaster preparedness. The increase that occurred in the experimental class shows that issue-based learning is able to encourage students to better understand and apply their knowledge related to disaster mitigation in a real context. This kind of learning not only enriches students' theoretical knowledge of disasters, but also develops practical skills that are essential in dealing with disasters. For example, in a study conducted by (Li, 2022), the use of technology and web-based learning for disaster education has been shown to accelerate students' understanding and preparedness for natural disasters. Issue-based learning has also been shown to be effective in increasing community participation in disaster mitigation activities, especially when based on local needs and contexts (Que, 2022; Zhang et al., 2021).

Meanwhile, the control class that did not use integrated sustainability issues for disaster mitigation experienced a lower ability increase, with a much smaller n-gain value. Although there has been an increase in disaster preparedness knowledge and skills, it is not comparable to the experimental class. This shows that without the integration of issues related to disaster mitigation in learning, students do not get the opportunity to learn contextually and applicatively about how to deal with natural disasters. This non-issue-based learning tends to be more theoretical and does not connect science knowledge with the reality of the disasters that surround them. In this case, issue-based approaches can be more effective in connecting theoretical knowledge to real-world situations faced by communities, as described by (Hamid, 2023) in a community-based disaster mitigation training model that

focuses on practical skills to mitigate the impact of disasters. Other research also shows that more practical and problem-based disaster mitigation education improves community preparedness in dealing with disasters (Christian, 2021; Sanabria-Z, 2022).

Overall, the results of this study emphasize the importance of integrating sustainability and disaster mitigation issues in science learning. By linking learning materials to real issues around students, this approach not only improves theoretical knowledge but also prepares students to face future disaster challenges. This is relevant to findings showing that a sustainability-based approach can strengthen disaster resilience and make a positive contribution to sustainable natural resource management (Islam, 2022; Rangel-Buitrago, 2023). On the other hand, it is also important to note that in the context of science education, community involvement in disaster mitigation management must pay attention to the relationship between scientific knowledge and local policies (Que, 2022; Suarmika, 2022). This integration is key to building an education system that not only prepares students theoretically but also practically in facing the challenges faced by communities in managing disaster risks. This issue-based learning not only introduces theory but also connects knowledge to real-world situations, allowing students to be better prepared in dealing with disasters. In addition, this issue-based learning is effective in changing students' attitudes and behaviors towards disaster preparedness and mitigation, as stated by (Ernst, 2013), who emphasized the importance of sustainability-oriented pedagogy in reducing disaster risk. With the significant difference in the results between the experimental and control classes, it can be concluded that tsunami disaster mitigation issue-based learning is very effective in improving students' disaster preparedness skills. The moderate Cohen's d value indicates that the effect of this learning is quite large, and this issue-based learning model can be applied more widely in the education curriculum. This supports the idea (Hemmati, 2021) that learning that integrates sustainability with disaster mitigation can provide practical skills that are relevant to real-world challenges, such as flood or tsunami preparedness. This issue-based learning helps students develop a better and more applicable understanding of disaster preparedness, as stated by (Hung et al., 2021), who show that risk-based education can increase awareness and preparedness for disasters.

Overall, the results of this study indicate that the integration of sustainability issues in science learning can have a significant positive impact on students' disaster preparedness. This is in line with research (Yang et al., 2021), which shows that a sustainability-oriented approach provides a deeper understanding of environmental challenges and disaster mitigation. This issue-based learning not only enriches students' academic knowledge but also improves students' preparedness attitudes in dealing with natural disasters. Therefore, as recommended by (Suarmika, 2022), this learning approach is recommended to be applied more widely in the teacher education curriculum, to equip prospective teachers with better competencies in

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preparing future generations to face disasters. Based on the results of the ngain test and the effect size test, it can be compared between the two classes where there is a significant difference in terms of students' disaster preparedness abilities. The experimental class using integrated sustainability issue-based learning with disaster mitigation showed a greater increase in disaster preparedness compared to the control class. This can be seen from the higher n-gain value in the experimental class, indicating that students who participated in the issue-based learning experienced more significant development in their knowledge and skills related to disaster mitigation. Issue-based learning of tsunami disaster mitigation allows students to relate the science concepts they learn to real-world situations, making them better prepared for natural disasters. On the other hand, the control class, which did not integrate disaster mitigation issues, showed a lower increase in disaster preparedness skills. Learning in the control class tended to be theoretical without direct links to real issues faced by the community, so that the increase in disaster preparedness skills achieved by students was not as good as in the experimental class. This shows that issue-based learning of disaster mitigation not only enriches students' academic understanding but also strengthens their readiness to face disaster situations.

4. Conclusion

The results of the study show that sustainability-based learning integrated with natural disaster mitigation, especially floods, has a significant influence on improving student disaster preparedness. The integration of science concepts into learning provides a deep understanding of the causes and mitigation solutions of natural disasters, especially floods and tsunami. The analysis shows that the experimental class that uses a sustainability issue-based approach recorded a higher increase in disaster preparedness ability compared to the control class. This is evidenced by a larger n-gain value and an effect size test with a Cohen's d value of 0.54, which is included in the medium category. Students who learn with this approach not only experience an increase in theoretical knowledge, but are also able to apply science concepts in real contexts for disaster mitigation. Sustainability issue-based learning has also proven to be effective in improving student attitudes and behaviors related to disaster preparedness. By linking learning materials to real-world issues, this approach helps students develop the practical skills essential to face future disaster challenges. In addition, this approach supports the three pillars of *ESD* economy, ecology, and society so as to contribute to sustainable development.

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