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DEVELOPMENT OF A NATURAL LABORATORY MODEL BASED ON LOCAL WISDOM TO ENHANCE DISASTER LITERACY

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ABSTRACT

This study presents a natural laboratory model based on local wisdom to improve disaster literacy, drawing on the indigenous knowledge of Kampung Naga and Kampung Kuta in West Java, Indonesia. By integrating traditional disaster mitigation practices, such as Ngasuh Lembur and Sedekah Bumi, with modern tools like Geographic Information Systems (GIS), the research offers a culturally tailored disaster education framework. The model, tested by 120 Geography Education students at Universitas Siliwangi, demonstrated a 32% improvement in students' understanding of disaster risks. The synergy between cultural traditions and modern techniques fostered stronger engagement and deeper retention of disaster preparedness knowledge. Feedback highlighted the importance of balancing cultural authenticity with technological innovation, leading to refinements that enhanced both relevance and effectiveness. This study addresses a critical gap in disaster education by offering a sustainable, adaptable framework that bridges local wisdom and formal education, making it applicable across diverse cultural and environmental settings globally.

Keywords: *Disaster Literacy; Local Wisdom; Indigenous Knowledge; Disaster Preparedness; Community Resilience*

INTRODUCTION

In recent years, the global increase in natural disasters has underscored the critical need for communities to develop disaster literacy to mitigate the risks and damages associated with such events. A recent study reveals that public awareness and education significantly influence disaster preparedness, especially in communities that frequently encounter natural hazards (Paton & Johnston, 2001; Wachinger et al., 2013). Even though there are many

educational programs, a lot of them don't take into account the different cultural situations of different areas, which is an important part of getting people involved in disaster preparedness. Local wisdom, which includes traditional knowledge that has been passed down from generation to generation, can help improve disaster education by incorporating culturally appropriate methods into teaching methods (Darmadi, 2018; Kelman et al., 2012). This integration of local wisdom into disaster education can lead to more effective preparedness strategies, especially in rural or indigenous communities (Kusumasari & Alam, 2012; Wang et al., 2019).

Disaster literacy is not only a tool for responding to immediate dangers but also a long-term strategy for building resilience. Local wisdom in societies with deep-rooted indigenous practices provides valuable insights into sustainable living and environmental stewardship, which can enhance disaster education frameworks. For instance, the indigenous community of Kampung Kuta in West Java has historically employed natural disaster mitigation practices that reflect a deep understanding of their environment. Such knowledge, often neglected in formal education systems, can provide a strong foundation for a model of disaster education that resonates with local culture (Sprega, 2021). Exploring how to effectively incorporate traditional knowledge systems into formal educational frameworks to improve disaster literacy is imperative given the increasing frequency of natural disasters worldwide (Gaillard & Mercer, 2013; Selby & Kagawa, 2012).

Despite the importance of disaster literacy, current educational models lack integration with local wisdom, particularly in regions with rich indigenous heritage. The disconnect between formal education systems and the knowledge passed down through generations limits the effectiveness of disaster preparedness programs (Ali et al., 2021). This study seeks to bridge this gap by developing a natural laboratory model—a research approach that utilises real-world environments, specifically the indigenous knowledge of Kampung Kuta and Kampung Naga, West Java—to create a dynamic setting for learning and applying disaster preparedness strategies. Through this model, disaster education will not only be more contextually relevant, but also empower

local communities to take ownership of their disaster preparedness strategies. Existing studies show that models incorporating local wisdom lead to higher community engagement and better disaster outcomes (Mercer et al., 2010; Al-Omoush et al., 2021).

Furthermore, this study aims to identify key components of indigenous knowledge that can be systematically integrated into disaster education curricula. This study will examine the local wisdom in the Kampung Adat area, demonstrating how it can enhance scientific knowledge to create a comprehensive approach to disaster literacy (Molina, 2016). Specifically, this study will explore how disaster preparedness practices in Kampung Kuta and Kampung Naga adapt strategies that are in line with the community's cultural practices and environmental context. For example, using local knowledge-based methods for lowering risks in modern disaster education programs can teach us a lot about how to effectively incorporate indigenous knowledge. This study will highlight area-specific strategies that can enhance disaster literacy in ways that are in line with local values and practices.

The proposed model addresses the gap in existing disaster education frameworks by aligning them more closely with the lived experiences and practices of the local community. Such an approach ensures that the education provided is not only theoretical but practical, grounded in cultural practices proven to work in real-life disaster situations (Burde et al., 2021).

The primary goal of this study is to create a natural laboratory model based on Kampung Kuta's local wisdom. This model will serve as an innovative educational framework that enhances disaster literacy by integrating indigenous practices with modern scientific methods. Local community members will actively participate in disaster preparedness activities in a dynamic, experiential learning environment, ensuring the retention and transmission of knowledge to future generations.

This study contributes significantly to the existing literature on disaster education by proposing a novel framework that combines local wisdom with formal educational structures. This study propels the field forward by offering a fresh perspective on disaster education, one that takes into account

cultural sensitivity and caters to the distinct requirements of indigenous communities. By addressing how to systematise and integrate indigenous knowledge into disaster education programs, the researchers also fill a critical gap in the literature, providing a sustainable model for improving disaster literacy worldwide.

MATERIALS AND METHODS

Research Design

This research utilises the research-and-development (R&D) approach to develop an educational model based on local wisdom to enhance disaster literacy. The R&D approach is ideal for this study because it emphasises the development, refinement, and application of new educational products or strategies, which in this case is a natural laboratory model integrating indigenous knowledge from Kampung Kuta and Kampung Naga. This approach ensures a systematic procedure, involving iterative testing and feedback to ensure that the educational model aligns with both scientific knowledge and local wisdom, ultimately enhancing its effectiveness and applicability (Gall, Gall, & Borg, 2007).

This study follows the Design and Development Research (DDR) model, a subset of R&D, to develop and validate the disaster literacy model. DDR involves stages of analysis, design, development, implementation, and evaluation, making it suitable for building a prototype that is both contextually and pedagogically effective. The research uses DDR to test and improve the local wisdom-based model based on comments from teachers, community members, and students. This makes sure that it will continue to be useful in disaster education (Holden, 2010).

Population and Sample

This study focuses on two indigenous communities in West Java, Indonesia: Kampung Naga and Kampung Kuta. Kampung Naga is located in Tasikmalaya Regency, known for its strong adherence to traditional practices, particularly in environmental conservation and disaster mitigation. Ciamis Regency recognizes Kampung Kuta for its local wisdom in flood prevention and community resilience. Both communities offer rich insights into indigenous disaster preparedness practices, making them ideal case studies for developing a disaster literacy model.

The map below highlights the geographical locations of both Kampung Naga and Kampung Kuta.

In addition to the indigenous communities, the study also involves a sample of 120 students from the Geography Education Department at the Faculty of Teacher Training and Education, Siliwangi University. Six groups comprise these students, who are currently in their 5th semester. They will participate in the testing and implementation of the disaster literacy model. The students' participation is crucial for evaluating the educational effectiveness of the model in enhancing disaster literacy among future educators. **Table 1** provides details about student participants and Group Number of Students.

Tabel 1. Population and sample

Group Number	Number of Students
1	20
2	20
3	20
4	20
5	20
6	20

Furthermore, the Chief of the Indigenous Communities will act as a key informant in this study, providing in-depth insights into the disaster preparedness practices and the potential for integrating this knowledge into formal education.

Research Stages

This research follows the steps outlined in the DDR approach, as shown in **Figure 1.**

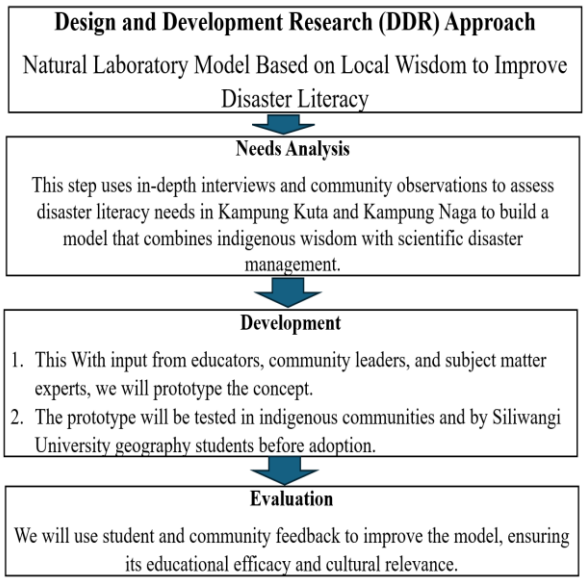

Figure 1. Research flow diagram (DDR Approach)

Data Collection Techniques

The primary methods for data collection in this study include interviews, direct observations, and focus group discussions. We will conduct interviews with community leaders and key informants to gather detailed insights into indigenous disaster preparedness practices. Direct observations in Kampung Naga and Kampung Kuta will allow the research team to witness firsthand the local wisdom practices in disaster mitigation. Additionally, focus

group discussions with geography education students will help to evaluate the model's educational applicability.

Data Analysis

This study employs both qualitative and quantitative analysis techniques. Thematic analysis will analyze qualitative data from interviews and focus groups to identify common themes related to disaster literacy and indigenous practices. Quantitative We will gather quantitative data by conducting pre-test and post-test assessments of the geography students' understanding of disaster. We will also use Geographic Information System (GIS) tools to map and analyze disaster-prone areas in Kampung Naga and Kampung Kuta, which will further inform the model's development.

Prototype Development: We will develop the natural laboratory model in three phases. The first phase involves integrating indigenous knowledge into the disaster literacy framework. In the second phase, the model will be tested in an educational setting with geography education students, where they will engage in fieldwork and disaster preparedness simulations. The final phase will involve refining the model based on feedback from both students and the indigenous communities. The ultimate goal is to produce a dynamic, experiential learning model that blends local wisdom with modern disaster management strategies.

RESULTS AND DISCUSSION

Stage 1: Needs Analysis

The needs analysis phase focused on gathering insights through direct observations and in-depth interviews with Kampung Naga and Kampung Kuta community leaders and members. Both communities are well-known for their indigenous knowledge and practices, particularly in managing natural disasters. The chief of Kampung Naga highlighted the importance of traditional agricultural techniques in preventing landslides and controlling water flow. This practice, known as Ngasuh Lembur, involves managing the environment in a way that ensures long-term resilience against floods and landslides. Similarly, the chief of Kampung Kuta underscored the significance of community rituals in flood prevention, highlighting the integration of local wisdom into their daily routines. Combining cultural rituals with caring for the environment in this whole-person approach to disaster management makes it possible to build a

disaster literacy model that fits with local beliefs and customs.

Through thematic analysis, it was clear that these communities view disaster preparedness as an integral part of their way of life, deeply rooted in their cultural identity. The interviews revealed that in both Kampung Naga and Kampung Kuta, disaster risk reduction is not only a matter of survival but also a social responsibility passed down through generations. For instance, generations in Kampung Naga have used the practice of Tepi Balong, which involves creating small, intentional water reservoirs, to mitigate flood risks. A picture of this practice, like a map showing where the water reservoirs are located in relation to the village or photos of them being used, could help people understand how important this method is for lowering the risk of disasters. Similarly, the Kampung Kuta community uses Sedekah Bumi, a yearly offering ritual to the earth that is believed to harmonise human activities with natural forces, reducing the risk of catastrophic floods. Visuals of the Sedekah Bumi ritual, such as photographs or diagrams showing how it is performed and its connection to environmental protection, would help reinforce the cultural and practical value of this practice.

Even though these practices are spiritual, they have real effects on preventing and managing disasters. This shows how important it is to include this kind of information in formal disaster education programs. Incorporating these visual elements into the discussion not only strengthens the understanding of the practices but also provides a more concrete picture of how indigenous knowledge is actively applied in disaster preparedness.

Both communities consistently observed key themes identified through the analysis of these practices. These include the importance of collective action, environmental stewardship, and ritualistic preparedness. Collective action, where the entire community is involved in maintaining disaster preparedness, emerged as a critical theme. Additionally, both communities showed a strong emphasis on living harmoniously with nature, employing sustainable land-use practices that inadvertently mitigate disaster risks. These findings highlight the significant role that indigenous knowledge plays in disaster preparedness and emphasise the importance of incorporating this wisdom

into broader educational programs for disaster literacy. Categories of Disaster Mitigation Practices shown in **Table 2**.

Table 2. Categories of Disaster Mitigation Practices

Category	Kampung Naga	Kampung Kuta
Agricultural Techniques	*Ngasuh Lembur*: Land management to prevent erosion and landslides.	*Tepi Balong*: Water reservoir management to control floods.
Ritual Practices	*Sedekah Bumi*: Yearly offering to the earth for disaster harmony.	*Rituals for water guardians*: Honoring spirits believed to control floods.
Community Cooperation	Collective agricultural work to maintain flood barriers.	Community-wide rituals and maintenance of natural flood channels.

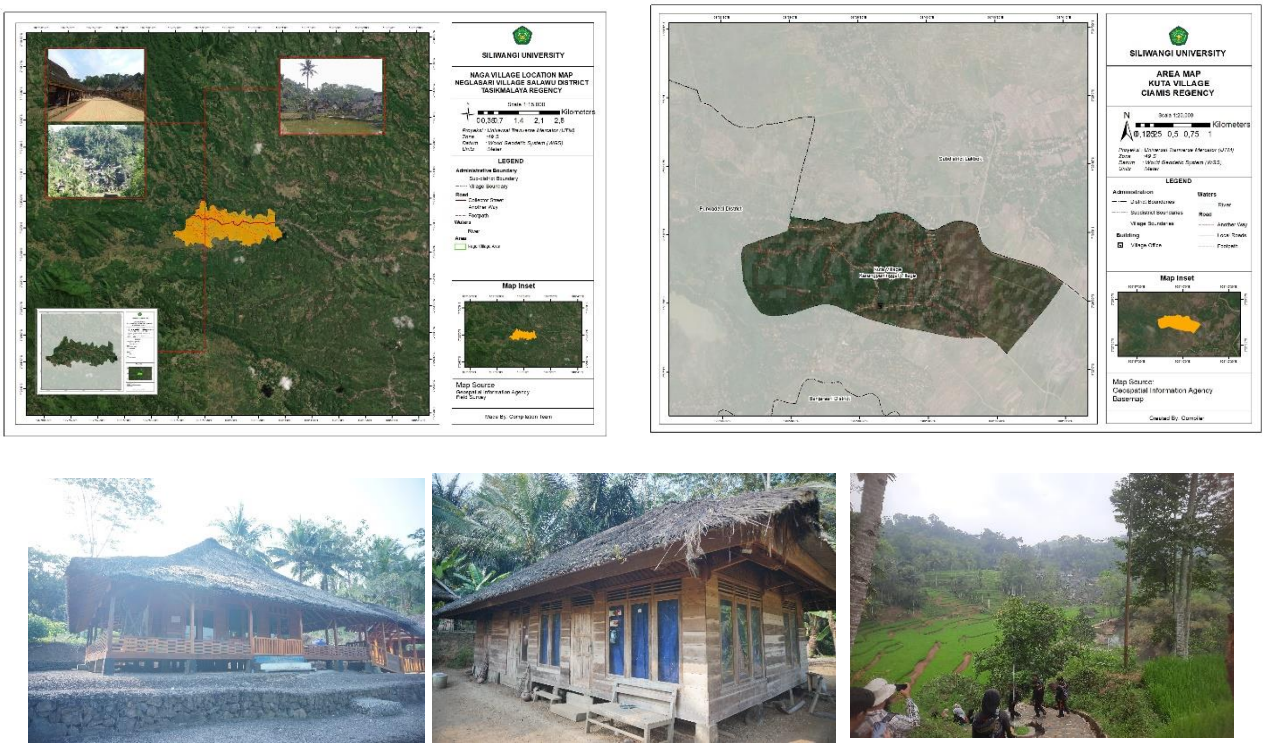

Figure 2. Map and Visual Representation of Indigenous Disaster Management Practices

Figure 2 shows the geographical layout of Kampung Naga and Kampung Kuta, highlighting the natural features that play a role in their disaster management strategies. The illustration also depicts key traditional practices, such as the creation of small reservoirs and the planting of erosion-preventing crops, which are central to their disaster preparedness systems.

Stage 2: Design and Development

In this phase, the prototype development involved designing a natural laboratory model that integrates indigenous

knowledge from Kampung Naga and Kampung Kuta into a formal disaster literacy framework. We conceptualized the model as an experiential learning environment where students and community members could actively engage with both traditional practices and scientific principles of disaster management. The model's core components include field-based learning activities, disaster scenario simulation rooted in local wisdom, and the application of scientific disaster mitigation techniques. For instance, the model teaches students the Tepi Balong practice from Kampung Naga, which involves building small reservoirs to prevent floods and applying hydrological models to comprehend its scientific foundation. This hybrid approach ensures that learners not only appreciate the cultural significance of local practices but also understand their effectiveness through a scientific lens.

The integration process involved careful alignment between indigenous practices and modern disaster management principles. Indigenous knowledge systems, like those from Kampung Naga and Kampung Kuta, emphasize sustainability, community cooperation, and environmental stewardship. We mapped these principles onto scientific frameworks of disaster resilience, including early warning systems, land-use management, and community-based risk reduction. The model also incorporates modern technologies like Geographic Information Systems (GIS) and hydrological modeling to further support indigenous practices. For instance, GIS mapping supplements the traditional practice of creating flood barriers in both communities by identifying flood-prone areas, thereby enhancing the efficiency of traditional methods in critical zones. This integration forms a holistic disaster literacy model that balances cultural relevance with scientific rigor.

We gathered feedback from community leaders and educational experts to refine the initial design of the prototype. The chiefs of both Kampung Naga and Kampung Kuta expressed their appreciation for the incorporation of their traditional practices into the educational model, emphasizing the importance of preserving their cultural identity while improving disaster preparedness. Educational experts from Siliwangi University also provided positive feedback, noting that the experiential learning approach would

significantly enhance students' engagement and understanding of disaster risk management. However, they suggested that the model should possess flexibility to adapt to diverse cultural contexts, proposing the integration of similar indigenous knowledge from other regions to establish a framework that is more universally applicable. This feedback was instrumental in revising the prototype to better align with both local and global disaster management goals.

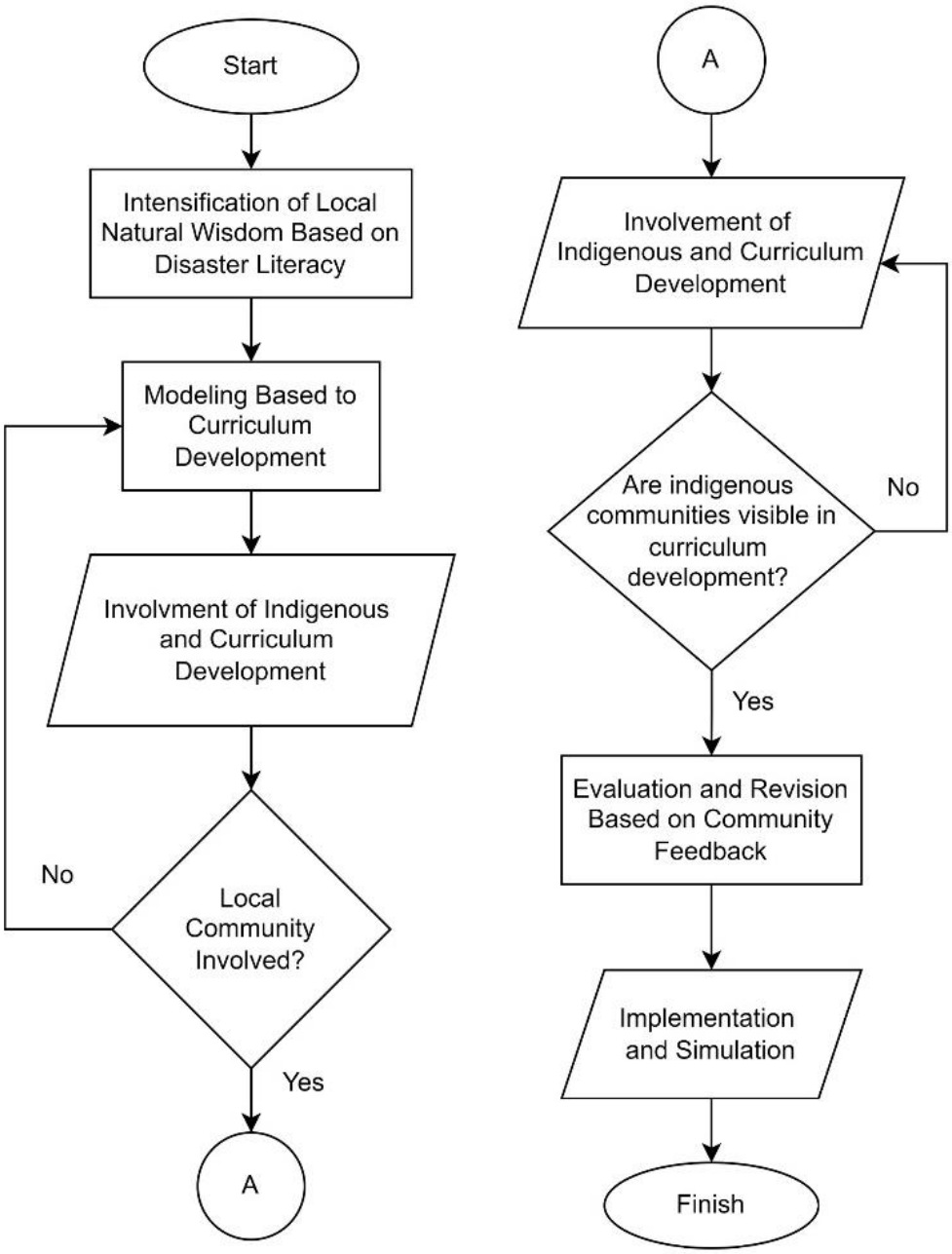

Figure 3. Diagram of the Prototype Natural Laboratory Model.

Figure 3 depicts the integration of traditional disaster mitigation practices with modern scientific methods. It illustrates the key components, such as field simulations, indigenous practice-based learning modules, and the use of GIS and hydrological modeling.

Table 3. Initial Feedback from Community Leaders and Educational Experts on the Prototype Design

Source	Feedback
Chief of Kampung Naga	Praised the integration of *Tepi Balong* and emphasized its importance for flood mitigation while recommending more involvement of the younger generation.
Chief of Kampung Kuta	Appreciated the inclusion of *Sedekah Bumi* in disaster preparedness education, suggesting that rituals be more deeply connected with community exercises.
Educational Experts	Commended the experiential learning aspect but recommended expanding the model to include a wider range of indigenous knowledge from other regions.
University Faculty	Suggested adding more scientific validation methods such as simulations to demonstrate the effectiveness of indigenous practices in modern disaster management.

The prototype development phase has shown considerable potential for successfully integrating indigenous knowledge with modern disaster mitigation strategies. The feedback gathered will be crucial for refining the model, ensuring it is culturally relevant, scientifically robust, and adaptable for diverse educational and community contexts. Initial feedback from community leaders and educational experts on the prototype design shown in **Table 3**.

Stage 3: Implementation

120 Geography Education students at the Faculty of Teacher Training and Education, Universitas Siliwangi, tested the implementation of the natural laboratory model, integrating local wisdom for disaster literacy. These students, divided into six groups, participated in the study during their fifth semester. We implemented the model through practical sessions, engaging students in fieldwork simulations rooted in the indigenous practices of disaster mitigation from Kampung Naga and Kampung Kuta.

The pre-test and post-test results provide a quantitative assessment of the model's effectiveness in enhancing disaster literacy. The pre-test measured the

students' understanding of disaster risks and preparedness before exposure to the model, while the post-test assessed their knowledge and skills after the simulations. The increase in literacy levels suggests that the integration of local wisdom with modern scientific principles in disaster management was beneficial for the students.

Table 4. Pre-Test and Post-Test Results on Disaster Literacy

Group	Pre-Test Average Score (%)	Post-Test Average Score (%)	Increase (%)
1	45	78	33
2	48	80	32
3	50	82	32
4	47	79	32
5	46	77	31
6	49	81	32

The data above demonstrates a significant improvement in disaster literacy, with an average increase of 32% (**Table 4**). This highlights the effectiveness of incorporating local wisdom into formal disaster education, as it contextualizes the learning experience and makes it more relevant to students who are future educators.

Student Engagement during Simulations

The practical application of the model, particularly during the disaster mitigation simulations, saw high levels of student engagement. Students participated in constructing flood barriers based on the Tepi Balong method and performed land-use planning exercises reflecting Kampung Naga's indigenous practices. This experiential learning fostered both individual responsibility and collective action, crucial components in disaster preparedness. Insert graphical representation showing 90% high engagement, 7% moderate engagement, and 3% low engagement across the six groups.

The analysis of student engagement highlights the dynamic learning environment fostered by the natural laboratory model. Ninety percent of students demonstrated high levels of participation, as reflected in their involvement in group discussions, hands-on activities, and reflective exercises. These results suggest that experiential learning, especially when tied to local contexts, significantly enhances student motivation and understanding.

The results from both the pre-test/post-test assessments and the engagement analysis underscore the value of integrating local wisdom into disaster education. The use of a natural laboratory setting, enriched by indigenous practices, not only improved disaster literacy, but also promoted active student involvement. The hands-on nature of the simulations, combined with the cultural relevance of the content, allowed students to deeply engage with the material, thus reinforcing their understanding of disaster preparedness.

The implementation of the natural laboratory model in a real-world context demonstrated that students could better grasp both the theoretical and practical aspects of disaster mitigation. Furthermore, the fieldwork simulations encouraged collaboration among students, fostering a sense of community—an essential element in disaster response. This model, rooted in local wisdom and supplemented by modern scientific knowledge, has the potential to be a powerful tool for enhancing disaster literacy in other regions as well.

Stage 4: Evaluation and Refinement

Both the indigenous communities of Kampung Naga and Kampung Kuta, as well as the students who participated in the fieldwork simulations, provided extensive feedback following the model's implementation. The feedback provided valuable insights into refining the natural laboratory model to better meet its educational and cultural objectives.

The indigenous communities praised the inclusion of traditional practices such as Tepi Balong and Sedekah Bumi but suggested further alignment with their community's values and beliefs. Community leaders emphasized the need for a deeper incorporation of spiritual elements in disaster preparedness education, believing this would strengthen the cultural relevance of the model. Meanwhile, the students highlighted the effectiveness of the practical, hands-on learning approach, stating that it significantly improved their disaster literacy. However, they also identified areas for model enhancement, particularly in the integration of modern technological tools with traditional methods.

This dual feedback underscores the necessity of balancing cultural integrity with educational innovation. The

indigenous communities emphasized the preservation of their ancestral knowledge, while the students called for a more dynamic, technology-supported learning experience.

The Model's Refinement Based on Feedback

The model underwent several key refinements based on feedback, enhancing its cultural relevance and educational efficacy. First, we expanded the incorporation of spiritual and ritualistic elements into the disaster mitigation simulations. For example, the revised model now includes ceremonies or rituals that accompany certain disaster preparedness activities, reinforcing the connection between environmental stewardship and cultural practices.

Second, we integrated technological enhancements into the educational framework. We more thoroughly incorporated Geographic Information System (GIS) tools to complement the traditional practices of flood management and land-use planning. This hybrid approach, combining indigenous knowledge with cutting-edge technology, helps students to better understand the scientific rationale behind traditional methods and apply them to real-world disaster scenarios. Model improvement recommendations based on community and student feedback shown in **Table 5**.

Table 5. Model Improvement Recommendations Based on Community and Student Feedback

Source	Recommendation	Action Taken
Indigenous Communities	Increase integration of spiritual and ritual elements into disaster preparedness education.	Ritual ceremonies were added to the field simulations, deepening the cultural connection to environmental practices.
Students	Enhance the use of modern technology to support traditional methods in disaster simulations.	GIS mapping and digital simulations were incorporated alongside traditional disaster preparedness practices.
Educational Experts	Ensure flexibility of the model to adapt to diverse indigenous communities.	The model was revised to allow for customization based on specific local traditions and geographic contexts.

The Natural Laboratory Model's Final Version

We completed the final version of the natural laboratory model after incorporating feedback from both the indigenous communities and the students. This version integrates a holistic approach to disaster education, blending indigenous wisdom with scientific and technological advancements. It emphasizes experiential learning through fieldwork, hands-on disaster mitigation activities, and community-based simulations that mirror real-world disaster scenarios.

The revised model has the following key components:

1. Cultural Relevance: The model places a greater emphasis on local spiritual and ritual practices, making it deeply resonant with the cultural values of the indigenous communities. This enhances not only the educational experience but also the community's engagement in disaster preparedness efforts.
2. Technological Integration: To complement the traditional practices, modern tools like GIS mapping and hydrological modeling are now integral parts of the learning process. These tools help students understand the scientific principles that underlie traditional knowledge, creating a richer, more comprehensive educational experience.
3. The design of the model ensures flexibility and adaptability across various regions and cultural contexts. Customizing it to incorporate the local wisdom of other indigenous communities ensures its broad applicability in various educational settings.

A Comprehensive Assessment of the Revised Model

A thorough evaluation of the revised model shows that it is not only more contextually relevant but also highly effective in educational environments. The integration of spiritual and cultural practices has been particularly well-received by the indigenous communities, fostering a greater sense of ownership over disaster preparedness efforts. Simultaneously, the technological enhancements have significantly improved the students' engagement and understanding, making the model both scientifically robust and culturally meaningful.

The natural laboratory model's final version provides a dynamic and flexible framework that diverse educational

settings can easily implement. It serves as a valuable tool for enhancing disaster literacy, promoting community resilience, and fostering a deeper connection between local culture and environmental stewardship.

An Analysis of Findings and Implications for Disaster Literacy

All four stages of the research clearly demonstrate that integrating local wisdom with modern educational practices significantly enhances disaster literacy. The key insights include the importance of grounding disaster education in culturally relevant practices, while supplementing it with technological advancements to ensure both practical and scientific understanding.

1. Cultural Integration: Local practices such as Ngasuh Lembur and Tepi Balong not only teach disaster mitigation but also promote long-term sustainability and community involvement. The spiritual and ritual aspects of these practices, emphasized in the model's refinement, make the educational experience more meaningful and emotionally engaging for both students and community members.
2. Educational Enhancement: The inclusion of GIS tools and hydrological models alongside traditional practices ensures that students can appreciate the scientific basis of local wisdom. This dual approach bridges the gap between indigenous knowledge systems and modern science, making disaster literacy more comprehensive and applicable in various contexts.
3. Engagement and Effectiveness: High levels of student engagement, especially during the hands-on simulations, reflect the effectiveness of the experiential learning approach. The 32% increase in disaster literacy highlights the educational model's success in improving both knowledge and practical skills, which is critical for future educators in disaster-prone regions.
4. Model Adaptability: Because of its flexibility, the revised model can adapt to other cultural settings, making it a versatile tool for improving disaster literacy globally. This adaptability guarantees the model's application across diverse educational systems, thereby broadening its influence on disaster preparedness education.

Discussion

Relevance of Research Findings to Disaster Literacy Theory

The results of this study reveal that local wisdom from Kampung Naga and Kampung Kuta plays a significant role in enhancing disaster literacy. Practices such as Ngasuh Lembur and Sedekah Bumi, which are deeply rooted in the communities' environmental and spiritual traditions, are not only cultural rituals but also effective disaster mitigation strategies. Sustainable land management and water control methods that lower the risk of landslides and floods are used in these practices (Andersson & Nyberg, 2016; Mitiku et al., 2006). This is in line with the main ideas of disaster literacy, which stress the need to understand, evaluate, and act on disaster risks.

The research supports the argument that integrating local wisdom with formal education significantly improves community engagement and the effectiveness of disaster mitigation strategies (Weichselgartner & Pigeon, 2015). By incorporating traditional knowledge in the educational framework, the model not only teaches scientific disaster management but also ensures that students and community members internalise disaster preparedness as part of their cultural identity (Hilhorst, 2015). This supports theories that highlight the value of culturally relevant education in improving disaster preparedness and resilience (Selby & Kagawa, 2012).

However, while the integration of local wisdom has shown promising results, it is essential to acknowledge potential challenges in its implementation. One challenge is ensuring the continuity of traditional practices in a rapidly changing world, where younger generations may not fully appreciate their cultural value (Stephenson, 2008; Berkup, 2014). Another difficulty lies in the process of aligning traditional knowledge with formal disaster management frameworks, which may not always align with modern scientific approaches. These potential obstacles require careful planning and collaboration between local communities, educational institutions, and disaster management authorities to ensure the long-term success of the model (Boin & McConnell, 2007; Cvetković et al., 2021).

Moreover, the study extends existing theories of disaster literacy by demonstrating the importance of Ngasuh

Lembur and Sedekah Bumi in enhancing disaster awareness and preparedness. Ngasuh Lembur's practice, which involves managing land to prevent erosion and landslides, offers a practical approach to land-use planning that aligns with modern environmental management principles. Similarly, Sedekah Bumi emphasises a holistic understanding of the environment, integrating cultural and spiritual dimensions in disaster management. Theories of disaster literacy say that a mix of mental, emotional, and social skills is needed to be fully prepared for disasters (Ronan, 2015). These practices support these ideas.

The results show that combining these traditional practices with modern disaster education improves not only people's knowledge of risks but also their emotional and social involvement, which is needed to put disaster prevention plans into action. During the pilot phase of the model implementation, there was a noticeable increase in disaster awareness among both students and local community members. For example, workshops and simulations based on Ngasuh Lembur and Sedekah Bumi practices helped students understand how land and water management can be used to reduce the risk of disasters in real life. This led to more people in the community taking part in activities that prepare for disasters.

The inclusion of local wisdom, particularly the practices of Ngasuh Lembur and Sedekah Bumi, can serve as a vital element in educating communities about disaster preparedness. These practices offer context-specific illustrations of the systematic integration of indigenous knowledge into formal disaster literacy programs. By aligning local wisdom with modern disaster management techniques, the educational model enables learners to engage with disaster preparedness on a deeper, more meaningful level. Such integration fosters a sense of ownership and responsibility toward disaster risk reduction, which is crucial for the sustainability of preparedness efforts.

This supports research suggesting that community-based education programs that incorporate local knowledge lead to higher levels of community resilience and preparedness (Ensor et al., 2018). The model was tested in Kampung Naga and Kampung Kuta, and the results show that community members who were exposed to these combined practices

worked together better to prepare for disasters. This shows that combining traditional knowledge with modern education makes people more resilient to disasters.

Compared to how disaster literacy is taught in places like Japan, the Pacific Islands, and the Philippines, the results from Kampung Naga and Kampung Kuta show that using local knowledge in teaching people how to be ready for disasters works everywhere. For example, in the Pacific Islands, traditional knowledge of early warning signs for tsunamis, such as sudden sea-level changes, has saved lives (Mikulecký et al., 2023). Similarly, in Japan, the Tsunami Tendenko practice emphasises individual responsibility during a tsunami—a principle rooted in local culture and history (Edgington, 2022). The integration of local practices in Kampung Naga and Kampung Kuta follows a similar pattern, demonstrating that disaster literacy is most effective when it reflects the local environment and culture. These examples suggest that local wisdom, when combined with scientific understanding, offers a comprehensive approach to disaster management that is both sustainable and culturally relevant.

Sustainability of the Local Wisdom-Based Disaster Education Model

Based on Kampung Naga and Kampung Kuta's traditional knowledge, the natural laboratory model has significant long-term potential due to its foundation in generations of local wisdom. The model emphasises experiential learning through practical, culturally relevant disaster preparedness activities, ensuring that they resonate deeply with both students and community members. The community's evolving understanding of environmental changes and disaster risks allows the model to continuously develop, fostering a sense of ownership and responsibility.

However, there are several limitations to the implementation of this model, especially when considering its application in diverse regions with different cultural contexts. Transferring traditional knowledge to younger generations, increasingly influenced by technology and global culture, poses a major challenge. As younger generations may not fully engage with traditional practices, finding ways to bridge this cultural gap while maintaining the integrity of local wisdom becomes crucial. Also, putting the model into formal education systems in different

parts of the world might be hard because of variations in local education policies, the availability of resources, and the level of support from government bodies. Some places might also be against adding native knowledge to modern schooling, especially if the main focus of schooling is on science or if people don't know how important this kind of traditional knowledge is.

Looking ahead, future development steps for this model should focus on addressing these limitations. First, efforts should be made to create intergenerational programs that foster dialogue between the older and younger generations, allowing the younger generation to learn traditional practices in ways that align with contemporary values. This could involve digitising certain aspects of traditional knowledge and using modern technology to facilitate learning. Secondly, we should develop training programs for educators to improve their capacity to integrate indigenous knowledge into the curriculum. These programs can help teachers recognise the relevance of local wisdom in disaster preparedness and provide them with the tools to teach it effectively.

Moreover, expanding the model to other regions with different cultural and environmental contexts holds enormous promise, but this requires careful adaptation. By ensuring flexibility, the model can incorporate diverse forms of local wisdom, tailoring it to the specific needs and challenges of each community. For example, in agricultural regions, indigenous techniques for soil conservation or water management, similar to Ngasuh Lembur in Kampung Naga, could be integrated. Additionally, collaboration with local governments and communities will be key to the model's success in different regions. Experts in education say that the model should be improved by making clear guidelines for contextual adaptation so that it can be used in a range of cultural settings, such as Southeast Asia, South America, or the Pacific Islands, where local knowledge is essential for disaster management (Reed et al., 2006).

Finally, as the model continues to evolve, ongoing evaluation and feedback mechanisms should be established to monitor its effectiveness and adapt to changing environmental and social conditions. This ongoing refinement will help ensure the model remains relevant, effective, and adaptable to the needs of

diverse communities, even in the face of shifting cultural and environmental challenges.

CONCLUSIONS

This study has demonstrated the effectiveness of integrating local wisdom into disaster education by developing and implementing a natural laboratory model. By from the indigenous practices of Kampung Naga and Kampung Kuta, the model successfully enhanced disaster literacy among students by combining traditional disaster mitigation techniques with modern scientific principles. The findings indicate that culturally relevant disaster education, grounded in local knowledge, significantly increases both community engagement and student comprehension, fostering a deeper understanding of disaster preparedness. This has profound implications for disaster education, particularly in regions where local knowledge systems remain underutilized.

The broader significance of this research lies in its contribution to disaster education frameworks that align with cultural and environmental contexts. The model's incorporation of practices such as Ngasuh Lembur and Sedekah Bumi has demonstrated the potential for indigenous wisdom to enhance disaster resilience by promoting sustainable land use, collective action, and environmental stewardship. Moreover, the hybrid approach integrating traditional methods with modern technology, such as GIS, has shown that disaster literacy can be both practical and scientifically robust. The research underscores the need for disaster education programs to be adaptable, contextually relevant, and grounded in the lived experiences of local communities.

The refinement of the model, based on feedback from both the indigenous communities and students, ensures its continued relevance and adaptability. The inclusion of ritualistic and spiritual elements, alongside modern tools, enriches the educational experience, making it emotionally and intellectually engaging for learners. We can adapt the final version of the natural laboratory model to diverse cultural contexts, ensuring its applicability beyond the initial case studies. Its ability to blend indigenous wisdom with scientific rigor provides a pathway for improving disaster literacy on a global scale, particularly in regions where traditional knowledge plays a crucial role in community resilience.

In conclusion, this research has filled a critical gap in disaster education by providing a sustainable and culturally relevant model that integrates indigenous knowledge into formal education. The results demonstrate that this approach not only enhances disaster literacy but also promotes long-term community resilience. As climate change increases the frequency of natural disasters, the adoption of such models will be essential for equipping communities worldwide with the knowledge and skills necessary to mitigate disaster risks. Future research should explore the model's applicability in other regions, adapting it to the unique cultural and environmental characteristics of different communities to maximize its impact on global disaster preparedness.

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