

FROM ORAL FOLKLORE TO DIGITAL DISASTER LITERACY: DEVELOPING AN INDIGENOUS LEARNING MODEL FOR DISASTER PREPAREDNESS IN PRIMARY SCHOOLS MEDAN CITY- NORTH SUMATRA

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Abstract

Natural disasters increasingly threaten children's safety and educational continuity, underscoring the urgent need for culturally responsive disaster education that extends beyond procedural preparedness toward the development of comprehensive disaster literacy. This study developed an Indigenous Digital Disaster Literacy Model by systematically transforming educational values embedded in 34 North Sumatran oral folklore narratives into interactive digital learning resources for primary school students. Employing a Research and Development (R&D) approach based on the ADDIE instructional design framework, the study integrated qualitative content analysis, expert validation, and a one group pretest posttest evaluation implemented in Muhammadiyah primary schools in Medan City, North Sumatra. The findings identified four core disaster literacy dimensions environmental awareness, hazard recognition, preparedness behavior, and community resilience which were operationalized through digital storytelling, multimedia animation, hazard simulations, and interactive assessments. The intervention significantly enhanced students' disaster literacy, with mean scores increasing from 63.2 to 85.7 ($t = 15.08$, $p < .001$; Cohen's $d = 1.82$), indicating a substantial educational effect. The study extends Indigenous Knowledge Theory by advancing a conceptual shift from knowledge integration to knowledge transformation, demonstrating that oral folklore can be systematically reconstructed into evidence based digital learning resources that simultaneously strengthen disaster preparedness, promote culturally responsive education, and preserve indigenous cultural heritage.

Keywords: Disaster literacy; Indigenous knowledge; Oral folklore; Digital learning; ADDIE; Primary education.

1. Introduction

Natural disasters have become increasingly frequent and severe due to climate change, rapid urbanization, environmental degradation, and unsustainable land use practices, posing significant challenges to sustainable development. Besides causing economic losses and infrastructure damage, disasters disrupt education, threaten children's well-being, and reduce community resilience. As one of the most vulnerable groups, children often have

limited capacity to recognize hazards, assess risks, and respond appropriately during emergencies. Consequently, disaster education has become a global priority under the Sendai Framework for Disaster Risk Reduction (2015-2030) and UNESCO's disaster risk reduction agenda, both of which emphasize developing disaster-resilient communities through education that promotes risk awareness, adaptive capacity, and sustainable behaviour from an early age (UNDRR, 2023; UNESCO, 2023; Kelman et al., 2022).

Accordingly, disaster education has evolved from teaching emergency procedures to fostering disaster literacy, a multidimensional competence integrating hazard recognition, environmental awareness, risk communication, critical thinking, and adaptive decision making. Disaster literacy enables students not only to understand disaster risks but also to interpret environmental information and actively participate in preparedness activities. Previous studies consistently show that structured disaster education enhances preparedness, environmental responsibility, and resilience more effectively than conventional evacuation-based instruction (Ronan et al., 2021; Kitagawa, 2022; Gowan et al., 2021). Nevertheless, disaster education in many schools remains largely procedural, emphasizing emergency drills while providing limited opportunities for culturally meaningful and context-specific learning.

Digital technologies have transformed education through interactive and learner-centred approaches. Digital storytelling, animation, multimedia applications, and mobile learning improve student engagement, conceptual understanding, and long-term knowledge retention (Bond et al., 2024; Crompton & Burke, 2023). However, most digital disaster education programs still rely on standardized scientific content, with limited incorporation of local cultural knowledge. Consequently, technology often serves merely as a delivery medium rather than a culturally responsive learning environment capable of strengthening contextual understanding (OECD, 2023).

Recent scholarship increasingly recognizes Indigenous Ecological Knowledge (IEK) as an essential component of disaster risk reduction because it embodies generations of ecological observation, environmental adaptation, and community resilience. Oral folklore preserves collective memories of environmental warning signs, ecological ethics, and adaptive strategies developed through long-term interactions between communities and their environments. Integrating indigenous knowledge into formal education has been shown to strengthen environmental awareness, cultural identity, and sustainability-oriented learning (Mercer et al., 2010; Hiwasaki et al., 2014; McMillen et al., 2022). However, previous studies have mainly focused on documenting oral traditions, whereas their transformation into structured digital disaster-learning resources for primary education remains limited.

Indonesia provides an important context because it is among the world's most disaster-prone countries, frequently experiencing floods, earthquakes, landslides, volcanic eruptions, and hydrometeorological hazards. Flooding is particularly recurrent in Medan City, North Sumatra, where rapid urbanization, inadequate drainage, river overflow, and increasing rainfall regularly disrupt schools and public services. Meanwhile, North Sumatra possesses rich oral traditions from the Batak Toba, Mandailing, Karo, Simalungun, and Malay communities, whose folklore preserves ecological knowledge, environmental ethics, collective responsibility, and adaptive strategies. This study systematically analysed 34 oral folklore narratives representing these five ethnic groups as the cultural foundation for developing digital disaster literacy for primary school students (BNPB, 2023; UNESCO, 2023).

Despite growing interest in disaster education, indigenous knowledge, and digital learning, important gaps remain. First, disaster education research continues to prioritize

procedural preparedness while paying limited attention to culturally grounded disaster literacy (Ronan et al., 2021; Kitagawa, 2022). Second, indigenous knowledge studies primarily emphasize documentation and preservation without demonstrating how traditional ecological knowledge can be transformed into structured instructional resources (Mercer et al., 2010; Hiwasaki et al., 2014). Third, digital learning research largely focuses on technological innovation while overlooking local cultural representation in instructional design (Bond et al., 2024; Crompton & Burke, 2023). Consequently, no validated instructional framework systematically integrates oral folklore, Indigenous Ecological Knowledge, disaster literacy, and digital pedagogy into a coherent primary-school learning model.

To address these gaps, this study develops an Indigenous Digital Disaster Literacy Model using the ADDIE instructional design framework. Unlike previous studies that examined disaster education, folklore, or digital learning separately, the proposed model transforms disaster related educational values embedded in North Sumatran folklore into interactive digital learning resources through systematic needs analysis, instructional design, expert validation, classroom implementation, and effectiveness evaluation involving Muhammadiyah primary schools in Medan City (Branch, 2009).

Accordingly, this study aims to identify disaster-related educational values embedded in North Sumatran oral folklore, evaluate their contribution to strengthening disaster literacy among primary school students, and develop an evidence-based Indigenous Digital Disaster Literacy Model. The study extends Indigenous Knowledge Theory from knowledge preservation to knowledge transformation, demonstrating how oral folklore can function as a dynamic educational resource. Methodologically, it integrates qualitative cultural analysis, instructional design, and empirical evaluation within the ADDIE framework. Practically, the proposed model offers educators and policymakers a culturally responsive strategy for strengthening disaster preparedness while preserving indigenous cultural heritage through digital education, thereby promoting resilient, environmentally responsible, and culturally grounded future generations.

2. Literature Review

2.1 Disaster Literacy and Culturally Responsive Disaster Education

Over the past two decades, disaster literacy has evolved from a narrow emphasis on emergency response into a comprehensive educational framework supporting disaster risk reduction (DRR). Earlier approaches primarily focused on evacuation procedures, hazard awareness, and emergency protocols, whereas contemporary scholarship conceptualizes disaster literacy as a multidimensional competence encompassing hazard recognition, environmental awareness, risk perception, critical thinking, communication, adaptive decision-making, and community resilience (Ronan et al., 2021; Kitagawa, 2022). This theoretical shift reflects the transition from reactive disaster management toward proactive DRR, positioning education as a strategic mechanism for strengthening long-term societal resilience rather than merely preparing individuals to respond during emergencies (UNDRR, 2023).

Current research consistently demonstrates that effective disaster education should extend beyond procedural preparedness to foster adaptive capacities that enable learners to interpret environmental risks and participate actively in community resilience. Empirical evidence from disaster-prone regions shows that comprehensive disaster literacy enhances preparedness behaviour, environmental responsibility, and risk awareness while strengthening resilience through intergenerational knowledge transmission (Ronan et al.,

2021; Gowan et al., 2021). UNESCO (2023) further positions disaster literacy as a key component of Education for Sustainable Development (ESD), emphasizing its role in equipping learners with the competencies required to anticipate, understand, and respond to increasingly complex environmental challenges. Collectively, these studies establish disaster literacy as a multidisciplinary construct integrating cognitive, behavioural, environmental, and social dimensions.

Despite these advances, important theoretical limitations remain. Existing disaster literacy frameworks continue to privilege scientific, institutional, and technological perspectives, assuming that preparedness can be achieved primarily through standardized scientific knowledge and emergency procedures. Such approaches pay comparatively little attention to the socio-cultural contexts through which communities perceive environmental risks and develop adaptive responses. Mercer et al. (2010) argue that disaster preparedness is shaped not only by scientific information but also by local ecological experience, traditional environmental knowledge, and culturally embedded interpretations of natural hazards. Nevertheless, these dimensions remain marginal within many contemporary disaster literacy models, creating a persistent disconnect between formal disaster education and community-based environmental knowledge.

A further limitation concerns the insufficient integration of Indigenous Ecological Knowledge (IEK). Although previous studies acknowledge the value of indigenous environmental knowledge accumulated through long term interaction with local ecosystems, this knowledge is generally treated as complementary rather than foundational to disaster literacy (Kelman et al., 2012; Hiwasaki et al., 2014). Consequently, existing frameworks remain insufficiently responsive to culturally diverse educational settings where indigenous ecological knowledge continues to influence environmental decision making and community resilience. Addressing this limitation requires reconceptualizing disaster literacy as a culturally situated educational process in which indigenous ecological knowledge functions as an integral epistemological resource rather than supplementary contextual information.

2.2 Indigenous Knowledge Theory and Disaster Education

The growing recognition of Indigenous Knowledge (IK) has significantly reshaped contemporary perspectives on disaster risk reduction, environmental sustainability, and culturally responsive education. Rather than viewing indigenous knowledge as traditional belief or local custom, recent scholarship recognizes it as a legitimate epistemological system generated through long-term interaction between communities and their environments (Mercer et al., 2010). Likewise, Kelman et al. (2012) emphasize that effective disaster risk reduction depends on reciprocal interaction between scientific knowledge and indigenous ecological knowledge because both contribute complementary understandings of environmental uncertainty.

One of the major strengths of Indigenous Knowledge Theory lies in its recognition that environmental adaptation is embedded within cultural practices, oral traditions, collective memory, and everyday social interaction. Studies conducted across Asia, Oceania, Africa, and Latin America consistently demonstrate that indigenous communities possess sophisticated knowledge of seasonal change, biodiversity, hydrological systems, ecosystem management, and natural warning signs, enabling them to anticipate and respond effectively to environmental hazards (Hiwasaki et al., 2014; McMillen et al., 2022). These findings confirm

that indigenous knowledge contributes not only to cultural continuity but also to environmental sustainability and community resilience.

Nevertheless, an important methodological gap persists. While previous research has successfully documented indigenous ecological knowledge and advocated its inclusion in disaster risk reduction, most studies remain descriptive and ethnographic. Relatively few demonstrate how indigenous knowledge can be transformed into structured instructional resources suitable for formal education, particularly within digital learning environments for children. Consequently, Indigenous Knowledge Theory has advanced conceptually but remains underdeveloped in instructional implementation. Responding to this limitation, the present study extends the theory from knowledge preservation toward knowledge transformation, proposing that indigenous ecological knowledge embedded in North Sumatran oral folklore can be systematically reconstructed into interactive digital learning resources that strengthen disaster literacy among primary school students. This perspective positions indigenous knowledge as the primary epistemological foundation of culturally responsive disaster education rather than as complementary cultural content.

2.3 Digital Learning, Oral Folklore, and Theoretical Positioning

The rapid advancement of digital technology has transformed educational practice, positioning digital learning as a central paradigm in twenty first century education. Digital storytelling, multimedia applications, educational animation, virtual simulations, and mobile learning have consistently been shown to enhance learner engagement, conceptual understanding, collaborative learning, and long-term knowledge retention (Mayer, 2021; Bond et al., 2024; Crompton & Burke, 2023). Within disaster education, these technologies extend learning opportunities beyond conventional classrooms by enabling flexible dissemination of preparedness knowledge before, during, and after hazardous events. Consequently, digital learning has become an important pedagogical strategy for strengthening disaster awareness among children.

Despite these advantages, current scholarship reveals a significant conceptual imbalance. Most digital disaster education studies evaluate technological effectiveness primarily through usability, multimedia quality, interface design, or learning outcomes, while giving comparatively little attention to cultural relevance. Technological innovation frequently becomes the primary objective, whereas indigenous perspectives, local ecological knowledge, and learners' socio-cultural experiences remain peripheral. This orientation implicitly assumes that standardized scientific knowledge can be universally transferred across diverse educational settings, despite evidence that meaningful learning is strengthened when instructional content reflects learners' cultural identities and lived experiences (Mayer, 2021; Bond et al., 2024). From a constructivist perspective, knowledge is most effectively developed when new concepts are connected to learners' prior experiences and familiar cultural contexts (Vygotsky, 1978). Nevertheless, relatively few digital disaster education models position indigenous ecological knowledge as the epistemological foundation of instructional design, leaving an important gap in culturally responsive digital pedagogy.

Oral folklore offers considerable potential for addressing this limitation. Traditionally examined within anthropology, linguistics, literature, and cultural studies, folklore has long been recognized as an important component of intangible cultural heritage that supports literacy, language learning, moral education, character formation, and cultural identity by transmitting collective experience and social values across generations (Sibarani, 2018;

UNESCO, 2023). However, its educational role has largely been confined to cultural preservation and language education. Comparatively little attention has been devoted to the ecological intelligence embedded within oral narratives, including environmental stewardship, hazard recognition, adaptive decision-making, collective preparedness, and community resilience. As a result, folklore is often treated as a cultural artifact rather than as an evolving educational knowledge system capable of addressing contemporary environmental challenges.

This limitation is particularly important in light of Education for Sustainable Development (ESD), which emphasizes balancing scientific innovation with local knowledge systems to promote sustainable learning (UNESCO, 2023). Although previous studies advocate preserving folklore, few explain how it can be systematically transformed into interactive digital learning resources while maintaining its cultural authenticity. Consequently, a substantial theoretical gap remains concerning the pedagogical transformation of folklore into disaster education. The present study addresses this gap by conceptualizing North Sumatran oral folklore as the principal source of disaster literacy competencies rather than merely supplementary instructional content.

The preceding review demonstrates that disaster literacy, Indigenous Knowledge Theory, digital learning, and folklore have evolved as important yet largely independent research domains. Disaster literacy research has expanded beyond emergency preparedness but continues to privilege scientific and institutional perspectives. Indigenous Knowledge Theory has successfully legitimized local ecological knowledge, yet its instructional transformation remains insufficiently explored. Digital learning research has generated substantial technological innovation but frequently neglects cultural authenticity, while folklore studies continue to emphasize linguistic and cultural preservation rather than ecological knowledge and disaster education. This theoretical fragmentation limits the development of culturally responsive disaster education.

To address these limitations, the present study proposes an Indigenous Digital Disaster Literacy Model integrating Disaster Literacy Theory, Indigenous Knowledge Theory, Constructivist Learning Theory, and the ADDIE instructional design framework within a unified conceptual model. Unlike previous studies that position folklore as complementary instructional material, this study conceptualizes North Sumatran oral folklore as a repository of indigenous ecological intelligence capable of generating measurable disaster literacy competencies through systematic instructional transformation. In doing so, it extends the framework of Mercer et al. (2010) by moving beyond knowledge integration toward knowledge transformation, whereby indigenous ecological knowledge is reconstructed into interactive digital pedagogical resources for primary education. Accordingly, the proposed model advances a culturally responsive paradigm that integrates scientific knowledge, indigenous wisdom, and digital pedagogy, offering a more comprehensive framework for disaster education in multicultural and disaster-prone societies.

3. Research Method

This study adopted a Research and Development (R&D) approach using the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) instructional design model to develop an Indigenous Digital Disaster Literacy Model grounded in North Sumatran oral folklore for primary school students. The ADDIE framework was selected because it provides a systematic process for designing, validating, implementing, and refining educational

products while ensuring alignment among learners' needs, instructional objectives, learning content, and evaluation (Branch, 2009; Borg & Gall, 2003; Sugiyono, 2022).

The research was conducted from January to July 2025 in Muhammadiyah primary schools in Medan City, North Sumatra, an area frequently affected by flooding and other hydrometeorological hazards. Four participant groups were involved: Grade IV and V students who participated in model implementation; classroom teachers who provided information on instructional practices and disaster education needs; experts in folklore, disaster risk reduction, educational technology, and primary education who validated the instructional product; and documentary sources comprising 34 North Sumatran oral folklore narratives, regional cultural archives, and disaster management documents from BNPB and BPBD. These multiple data sources enhanced research credibility through methodological triangulation (Lincoln & Guba, 1985; Creswell & Creswell, 2023).

Data collection integrated qualitative and quantitative techniques across the ADDIE phases. The Analysis phase employed interviews, classroom observations, questionnaires, and document analysis to identify disaster-related educational values and learners' needs. The Design and Development phases produced and validated interactive digital learning materials integrating indigenous ecological knowledge with disaster mitigation concepts through iterative expert review (Branch, 2009). During Implementation, the revised prototype was evaluated using a one-group pretest posttest design. Students' mean disaster literacy score increased from 63.2 to 85.7, demonstrating the effectiveness of the developed model. Finally, the Evaluation phase integrated descriptive quantitative analysis with thematic analysis of interviews, observations, validation sheets, and open ended responses following Braun and Clarke (2022). Research rigor was ensured through triangulation, expert validation, iterative revision, informed consent, confidentiality, and institutional ethical approval (Lincoln & Guba, 1985).

4. Result and Discussion

4.1 Identification of Disaster Educational Values Embedded in North Sumatran Oral Folklore

The first stage of this study examined disaster related educational values embedded in 34 oral folklore narratives representing five major ethnic communities in North Sumatra Batak Toba, Mandailing, Karo, Simalungun, and Malay to establish the conceptual foundation for the proposed Indigenous Digital Disaster Literacy Model. Using qualitative content analysis, the narratives were systematically analyzed to identify ecological knowledge, environmental ethics, hazard awareness, collective preparedness, and adaptive behaviors relevant to disaster education in primary schools. Rather than viewing folklore solely as intangible cultural heritage, this study conceptualizes oral traditions as repositories of Indigenous Ecological Knowledge (IEK) that can be transformed into culturally responsive digital learning resources.

Table 1. Distribution of North Sumatran Oral Folklore and Disaster Related Educational Values

Ethnic Group	Number of Folklore Narratives	Dominant Educational Values	Disaster Literacy Dimension
Batak Toba	8	Environmental stewardship, respect for nature	Environmental awareness
Mandailing	9	Collective cooperation, responsibility	Preparedness behavior
Karo	6	Ecological balance, natural signs	Hazard recognition
Simalungun	6	Mutual assistance, community resilience	Community preparedness
Malay	5	River ecology, environmental adaptation	Environmental adaptation
Total	34	Indigenous ecological knowledge	Integrated disaster literacy

Table 1 demonstrates that the 34 folklore narratives collectively represent an integrated system of Indigenous Ecological Knowledge rather than isolated cultural expressions. Although each ethnic tradition reflects distinct socio-cultural perspectives, all narratives consistently converge around four fundamental educational values: environmental stewardship, recognition of natural warning signs, collective responsibility, and adaptive responses to environmental change. These findings indicate that disaster preparedness has long been embedded in local cultural memory and transmitted intergenerationally through oral traditions, reinforcing the view that indigenous knowledge functions as a dynamic epistemological resource for disaster risk reduction rather than merely as cultural heritage (Mercer et al., 2010; Kelman et al., 2012; UNESCO, 2023). Cross-ethnic comparison further highlights complementary ecological emphases. Batak Toba and Malay narratives prioritize environmental ethics and harmonious human nature relationships; Mandailing and Simalungun folklore emphasizes cooperation, mutual responsibility, and collective resilience; whereas Karo narratives foreground ecological indicators as informal early warning systems. Collectively, these culturally grounded values align closely with contemporary disaster literacy, environmental monitoring, and community resilience, providing the conceptual basis for developing culturally responsive digital learning materials (Hiwasaki et al., 2014; Gaillard & Mercer, 2013; Ronan et al., 2021).

4.2 Mapping Indigenous Educational Values into the Digital Disaster Literacy Framework

Following the identification of indigenous educational values, the second stage translated these findings into a structured disaster literacy framework suitable for digital instruction. The objective was to establish explicit relationships between folklore-derived values and measurable disaster literacy competencies while preserving the cultural authenticity of the narratives. This transformation ensured that indigenous knowledge became pedagogically meaningful learning outcomes rather than remaining descriptive cultural content.

Table 2. Mapping Indigenous Educational Values to Disaster Literacy Competencies

Indigenous Educational Value	Disaster Literacy Competency	Expected Student Outcome	Digital Learning Feature
Respect for nature	Environmental awareness	Understand human environment relationships	Interactive storytelling
Natural warning signs	Hazard recognition	Identify early disaster indicators	Animated simulation
Collective cooperation	Preparedness behavior	Participate in evacuation and teamwork	Scenario-based activities
Mutual assistance	Community resilience	Develop collaborative problem-solving	Collaborative learning tasks
Ecological responsibility	Sustainable behavior	Practice environmentally responsible actions	Reflection and digital portfolio

Table 2 demonstrates that each indigenous educational value can be translated into observable learning competencies without losing its original cultural meaning. Instead of presenting folklore merely as narrative content, the instructional framework reconstructs indigenous ecological knowledge into competency-based disaster education aligned with twenty first century learning principles.

The mapping also reveals that disaster literacy should be understood as an interdisciplinary construct integrating cognitive, affective, behavioral, and socio-cultural

dimensions. Environmental awareness provides foundational ecological understanding; hazard recognition develops students' ability to interpret disaster risks; preparedness behavior encourages appropriate action during emergencies; while community resilience strengthens collaboration and collective responsibility. Collectively, these dimensions support the development of comprehensive disaster literacy rather than isolated procedural knowledge.

4.3 Development of the Indigenous Digital Disaster Literacy Model

Following the identification of disaster-related educational values embedded in 34 North Sumatran oral folklore narratives, the study proceeded to develop the Indigenous Digital Disaster Literacy Model using the ADDIE instructional design framework (Branch, 2009). The development phase translated qualitative findings into an interactive digital learning prototype for Grade IV-V primary school students by integrating indigenous ecological knowledge with contemporary disaster mitigation concepts through digital storytelling, multimedia animation, hazard simulations, interactive quizzes, and child centered learning activities. The instructional design prioritized pedagogical relevance, cultural authenticity, technological usability, and age-appropriate learning experiences. Unlike conventional disaster education modules that primarily emphasize procedural preparedness, the proposed model contextualizes disaster literacy through culturally familiar narratives adapted from North Sumatran oral traditions. Disaster mitigation messages related to floods, earthquakes, landslides, and fires are presented through animated storytelling and the educational mascot “Si Sigap,” enabling students to connect scientific disaster concepts with their local cultural experiences. This culturally responsive approach strengthens meaningful learning while simultaneously supporting the preservation of indigenous cultural heritage and fostering disaster resilience among young learners (Mayer, 2021; Mercer et al., 2010; UNESCO, 2023).

Table 3. Main Components of the Indigenous Digital Disaster Literacy Model

Component	Description	Educational Purpose
Digital storytelling	Adaptation of North Sumatran oral folklore into animated narratives	Contextual understanding of disaster concepts
Multimedia animation	Interactive visual explanations of disaster events	Improve conceptual understanding
Hazard simulation	Flood, earthquake, landslide, and fire scenarios	Develop preparedness behavior
Interactive quizzes	Scenario-based assessment	Evaluate disaster literacy competencies
Reflection activities	Environmental and cultural reflection	Strengthen ecological responsibility

Table 3 demonstrates that the developed model integrates cognitive, affective, behavioral, and cultural dimensions into a single instructional framework. Rather than functioning merely as digital media, the learning model serves as a pedagogical system connecting indigenous ecological knowledge with disaster preparedness competencies.

4.4 Expert Validation of the Developed Model

To ensure pedagogical quality and instructional feasibility, the prototype underwent expert validation involving specialists in North Sumatran folklore, disaster risk reduction, educational technology, and primary education. The validation process assessed content accuracy, cultural authenticity, pedagogical suitability, interface design, language clarity, multimedia quality, and technical functionality before classroom implementation. Feedback

from validators was incorporated through iterative revisions, ensuring continuous refinement of the instructional product before field testing.

Table 4. Expert Validation Results

Validation Aspect	Evaluation
Content relevance	Very Good
Disaster mitigation accuracy	Very Good
Cultural authenticity	Very Good
Pedagogical suitability	Very Good
Multimedia design	Good–Very Good
Interface usability	Very Good
Language appropriateness	Very Good
Overall feasibility	Highly Feasible
Validation Aspect	Evaluation

The expert validation results confirmed that the developed Indigenous Digital Disaster Literacy Model met the essential criteria for instructional quality, pedagogical appropriateness, cultural authenticity, and technological usability for primary school disaster education. Experts highlighted that integrating indigenous folklore significantly enhanced the contextual relevance of disaster learning while preserving scientific accuracy in disaster mitigation content. Minor revisions focused on improving interface navigation, animation timing, and language simplicity to better accommodate elementary learners. Unlike previous digital disaster education studies that primarily emphasize technological functionality, the present evaluation recognized cultural authenticity as an equally important quality indicator. This finding extends conventional instructional design practices by positioning indigenous cultural representation as a fundamental dimension of culturally responsive digital learning (Branch, 2009; Mayer, 2021; Mercer et al., 2010; UNESCO, 2023).

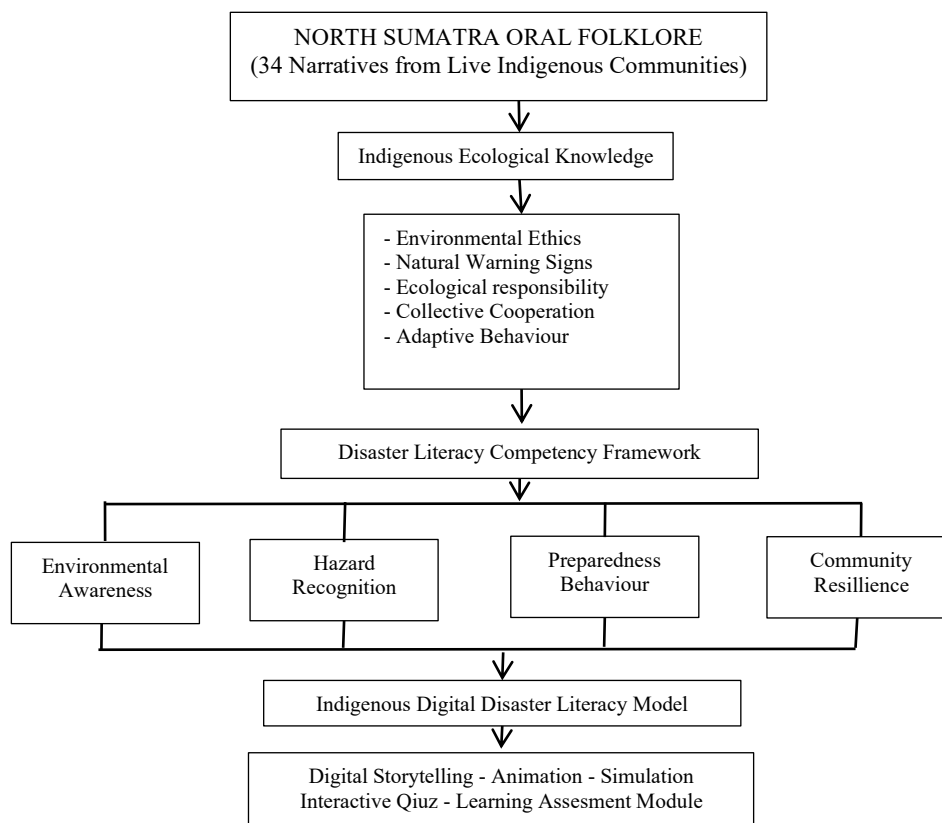


Figure 1. Conceptual Mapping of Disaster Educational Values Derived from North Sumatran Oral Folklore

Figure 1 further synthesizes these findings by conceptualizing disaster literacy as a multidimensional construct integrating environmental awareness, hazard recognition, preparedness behavior, and community resilience. Unlike conventional approaches that emphasize procedural disaster knowledge, this framework combines scientific understanding with indigenous ecological knowledge, thereby positioning disaster literacy as a holistic educational competency. The framework subsequently served as the conceptual foundation for designing the digital learning modules developed through the ADDIE instructional model (Branch, 2009). These findings extend previous studies by demonstrating that North Sumatran folklore functions not only as cultural heritage but also as a source of ecological intelligence that can be operationalized into measurable disaster literacy competencies. Accordingly, the study advances the propositions of Mercer et al. (2010) and Kelman et al. (2012) by moving beyond knowledge integration toward knowledge transformation, in which indigenous ecological knowledge is systematically reconstructed into culturally responsive digital learning resources for formal primary education.

4.5 Field Implementation and Effectiveness of the Digital Disaster Literacy Model

Following expert validation, the revised prototype was implemented in two Muhammadiyah primary schools in Medan City using a one group pretest posttest design. Students completed a disaster literacy assessment before and after participating in learning activities using the developed digital module. Classroom observations and teacher evaluations were also conducted to examine instructional practicality, student engagement, and classroom interaction throughout the implementation process.

Table 5. Pretest–Posttest Results

Variable	Mean	SD
Pretest	63.2	7.9
Posttest	85.7	6.3
Mean Difference	22.5	—
Percentage Increase	35.6%	—
Paired t-test	15.08	—
Significance	$p < .001$	—
Cohen's d	1.82	Large Effect
Variable	Mean	SD

Table 5 presents the pretest posttest comparison of students' disaster literacy scores following the implementation of the culture based digital learning intervention. The results demonstrate a substantial improvement in learning outcomes, with the mean score increasing from 63.2 (SD = 7.9) in the pretest to 85.7 (SD = 6.3) in the posttest. This represents a mean gain of 22.5 points, equivalent to a 35.6% increase in disaster literacy achievement. Statistical analysis using a paired-samples t-test confirmed that the improvement was highly significant ($t = 15.08$, $p < .001$), indicating that the observed differences were unlikely to have occurred by chance. Furthermore, the intervention produced a large practical effect (Cohen's $d = 1.82$), demonstrating a substantial educational impact beyond statistical significance. Collectively, these findings indicate that integrating culturally grounded digital learning materials derived from indigenous folklore effectively enhances students' disaster literacy, supporting both conceptual understanding and preparedness related competencies.

4.5 Discussion

The findings demonstrate that North Sumatran oral folklore constitutes a systematic source of Indigenous Ecological Knowledge (IEK) capable of supporting disaster literacy through culturally responsive digital education. The analysis of 34 folklore narratives revealed four recurring educational values environmental stewardship, recognition of natural warning signs, collective responsibility, and adaptive behaviour which collectively formed the conceptual basis of the proposed instructional model. These results reinforce previous studies arguing that indigenous knowledge preserves generations of ecological observation and adaptive environmental practices relevant to disaster risk reduction (Mercer et al., 2010; Kelman et al., 2012; Hiwasaki et al., 2014). However, unlike earlier research that primarily documented or preserved indigenous knowledge, the present study demonstrates how such knowledge can be systematically transformed into measurable disaster literacy competencies within a formal educational setting.

The effectiveness of the developed model also extends current perspectives on disaster literacy. Previous frameworks have generally emphasized scientific knowledge, evacuation procedures, and emergency response (Ronan et al., 2021; Kitagawa, 2022). In contrast, the present findings indicate that disaster literacy becomes more meaningful when scientific concepts are integrated with learners' cultural experiences. By embedding indigenous ecological values within interactive digital storytelling, students developed not only cognitive understanding of disaster risks but also environmental responsibility, preparedness behaviour, and community oriented resilience. This finding supports UNESCO's (2023) emphasis on culturally responsive education while demonstrating that indigenous knowledge should be regarded as a central pedagogical resource rather than supplementary cultural content.

The study further contributes to the growing literature on digital learning. Existing research consistently reports that multimedia technologies enhance engagement and conceptual understanding (Bond et al., 2024; Crompton & Burke, 2023). Nevertheless, many digital learning models remain technologically oriented and insufficiently incorporate local cultural contexts. The present findings show that combining digital storytelling, multimedia animation, hazard simulation, and indigenous folklore creates a more contextualized learning environment in which technology functions as a medium for cultural knowledge transformation rather than simply delivering information. Consequently, instructional effectiveness derives not only from technological innovation but also from the meaningful integration of cultural identity and scientific knowledge.

From a theoretical perspective, the proposed Indigenous Digital Disaster Literacy Model advances Indigenous Knowledge Theory by extending its application from knowledge preservation toward knowledge transformation. Earlier studies primarily emphasized documenting indigenous ecological knowledge as cultural heritage (Mercer et al., 2010; McMillen et al., 2022). In contrast, this study demonstrates that oral folklore can be systematically reconstructed into structured instructional resources that produce measurable educational outcomes. This transformation represents an important conceptual contribution because it positions indigenous knowledge as an active pedagogical framework capable of strengthening disaster literacy while simultaneously preserving cultural heritage.

The findings also provide practical implications for disaster education policy and instructional design. For educators, the model offers a culturally grounded strategy for integrating local wisdom into digital learning without compromising scientific accuracy. For

curriculum developers, it demonstrates how indigenous narratives can be translated into competency-based instructional materials aligned with disaster literacy objectives. For policymakers, the study highlights the importance of incorporating local cultural resources into disaster education programs to strengthen preparedness while supporting cultural sustainability. Such an approach is particularly relevant for disaster-prone regions characterized by rich indigenous traditions and diverse ecological knowledge systems.

Overall, the results indicate that culturally responsive digital learning provides a more comprehensive approach to disaster education than conventional procedural instruction. By integrating indigenous ecological knowledge, interactive digital pedagogy, and evidence-based instructional design, the proposed model simultaneously strengthens disaster preparedness, environmental awareness, cultural identity, and sustainable learning. These findings establish the Indigenous Digital Disaster Literacy Model as a transferable framework that may inform disaster education initiatives in other culturally diverse and disaster-prone regions while contributing to the broader integration of indigenous knowledge, digital pedagogy, and disaster risk reduction within contemporary educational research (UNESCO, 2023; UNDRR, 2023).

5. Conclusion

This study developed and validated an Indigenous Digital Disaster Literacy Model by transforming educational values embedded in 34 North Sumatran oral folklore narratives into culturally responsive digital learning resources for primary school students. The findings demonstrate that oral folklore constitutes not only intangible cultural heritage but also a dynamic repository of Indigenous Ecological Knowledge (IEK) encompassing environmental stewardship, hazard recognition, ecological responsibility, collective preparedness, and adaptive behaviour. Through the ADDIE instructional design framework, these values were systematically reconstructed into digital storytelling, multimedia animation, hazard simulations, and interactive assessments, demonstrating that indigenous knowledge can be effectively integrated into contemporary disaster education while preserving its cultural authenticity.

Classroom implementation in Muhammadiyah primary schools confirmed the model's effectiveness, as reflected in the significant improvement in disaster literacy scores (pretest = 63.2; posttest = 85.7) with a large effect size (Cohen's $d = 1.82$). These results indicate that integrating indigenous ecological knowledge with digital pedagogy provides a more contextualized and meaningful approach to disaster preparedness than conventional science-oriented instruction, consistent with Constructivist Learning Theory.

Theoretically, this study advances Indigenous Knowledge Theory by extending the concept of knowledge transformation, positioning oral folklore as an evidence based educational knowledge system rather than solely a medium of cultural preservation. Methodologically, it demonstrates the applicability of the ADDIE framework for integrating cultural analysis, instructional design, expert validation, and empirical evaluation. Although the study was limited to Muhammadiyah primary schools in Medan City, the proposed model offers a transferable framework for culturally responsive disaster education. Future research should validate the model across broader cultural contexts and incorporate emerging technologies, including artificial intelligence and immersive learning environments, to further strengthen disaster literacy and educational resilience.

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