Development of ISLE-Based Science E-Modules in Improving Disaster Mitigation Literacy of High School Students in Tectonic Prone Areas

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Abstract
Against the shortcomings of traditional science learning, which overemphasizes text memorization, separates scientific concepts from local disaster contexts, and neglects practical disaster reduction skills, this study developed the Si-AGAM (Aceh's Inquiry Science for Earthquakes and Disaster Mitigation) interactive electronic science module tailored to local conditions in Aceh. The module is built on the Inquiry-based Science Learning Environment (ISLE) model and aims to improve high school students' disaster reduction literacy. This research carried out the module's development using research-and-development methods alongside the ADDIE framework. The study completed expert validation, practicality assessments by teachers and students, and a 15-item disaster reduction literacy test in sequence. Data were analyzed using descriptive analysis and the normalized gain (N-gain) method. The results show that the module's average expert validity score was 4.83, its practicality rating from teachers and students reached 90.37%, and its overall N-gain was 0.83, which falls into the high-level gain category. These findings confirm that the module has both high validity and practicality and can significantly improve students' disaster reduction literacy.

1. Introduction

Located in the area affected by two active tectonic systems, Aceh, Indonesia is inherently highly vulnerable to tectonic disasters. This geological context, confirmed by a 2019 study by Muksin et al., involves two high-risk geological structures: the Sunda megathrust, which can trigger major earthquakes and tsunamis, and the Great Sumatran Fault, which runs through the region's densely populated areas. Studies by Maryani in 2021 and Turan Bayraktar et al. in 2024 both point out that strengthening the disaster preparedness and mitigation capacity of high school students, as a core target group, is a key approach to reducing disaster casualties and impacts. Only with sufficient disaster mitigation literacy can high school students understand the basic scientific mechanisms of disasters and make sound decisions in emergency situations. However, a 2022 study by Amri et al. shows that students in disaster-prone areas like Aceh still generally have low levels of disaster literacy. The root cause is that local science education still relies primarily on traditional rote memorization of concepts, and its scientific content is disconnected from local disaster scenarios. As a result, students' understanding of disaster mitigation only stays at the theoretical level, and they cannot develop practical mitigation skills adapted to local conditions.

In recent years, many countries worldwide have launched multiple measures to address the widespread problem of low disaster literacy on school campuses. Against this backdrop, the development of digital learning media and electronic modules (e-modules) which feature interactivity and flexibility and have the potential to improve people's understanding of disaster risks has continued to grow (Bachri et al., 2024). This trend aligns with research findings from a broader range of fields: multiple studies by Cabrera-Duffaut et al. (2024), Lampropoulos and Kinshuk (2024), Sakr and Abdullah (2024), Wang et al. (2023), and Yang et al. (2024) all confirm that virtual interactive learning technologies can effectively improve learning outcomes, engagement, and skill development in various educational and disaster-related scenarios. At the same time, systematic evaluations of such educational technologies usually rely on rigorous tools to measure user perception and practicality (Chen & Liu, 2020). Furthermore, the Investigative Science Learning Environment (ISLE) model, introduced in the field of science education, shifts traditional lecture-based learning to active scientific inquiry. It guides students to think and act as young scientists through a process of observing phenomena, identifying patterns, and testing hypotheses. This model has been proven to cultivate students' scientific reasoning abilities and boost their learning initiative (Etkina et al., 2021). Past research has also verified that interactive learning media based on ISLE can correct students' misconceptions in physics (Etkina et al., 2019). Even so, existing

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disaster-focused teaching materials still have key shortcomings: they fail to integrate structured scientific inquiry, context-specific local geotechnical phenomena, and practical disaster reduction activities.

Current academic research on electronic modules (e-modules) and the ISLE learning model, when studied separately, is already relatively sufficient. However, there remains a clear and prominent core research gap regarding the combined application of the two. First, no existing study has integrated the ISLE framework's structured scientific inquiry logic with locally relevant geoscience content such as the vertical and horizontal seismic characteristics of the great thrust fault along the Sumatran Fault Zone to develop digital teaching materials that align with the need to cultivate students' disaster reduction literacy. Second, the potential of local traditional knowledge like the Smong system is often overlooked, even though studies by Gadeng et al. (2018) and Hirono and Nurdin (2024) both note that integrating indigenous knowledge with specific geographical contexts is critical to fostering actionable disaster reduction awareness. Third, current formal science education lacks inquiry-based digital platforms that can enable students living in active fault zones to complete practical, self-directed disaster preparedness tasks, such as assembling emergency survival kits and simulating emergency scenarios.

The core innovative achievement of this study is the Si-AGAM interactive science e-module, whose full name is the Aceh Earthquake and Disaster Risk Reduction Inquiry Science Module. This module adopts the ISLE learning model, integrating scientific inquiry with place-based disaster education. The module incorporates interactive visual content of local seismic phenomena, comparative analysis of earthquake characteristics and impacts, modern scientific concepts, and the traditional Smong culture that carries indigenous knowledge. Aligned with the ISLE framework, the module is structured with five self-directed learning steps: observation, pattern identification, testing, indigenous knowledge analysis, and disaster preparedness application. This framework positions students as active learners who explore disaster risks and refine their disaster preparedness skills, rather than passive recipients of information. It not only provides students with a place-based learning experience but also enhances their ability to respond to geophysical disasters.

To address the research gaps, this study will carry out two core tasks. First, it will develop a scientific electronic module that integrates the Si-AGAM application and is built on the ISLE framework. Second, it will assess the module's validity, practicality, and learning gains in improving disaster risk reduction literacy among high school students in tectonically active regions, with the goal of filling the gap in educational resources in this related field.

2. Method

2.1. Research Design

This study adopts a research and development approach. Based on the ISLE model, it develops an interactive application named Si-AGAM (*Sains Aceh Gempa dan Mitigasi*, or Aceh Earthquake and Disaster Mitigation Inquiry Science) to host e-learning modules for disaster reduction science. The development process follows the ADDIE model, which includes five phases: analysis, design, development, implementation, and evaluation. The study cites research by Lukanina and Merkulova (2023) and Bachri et al. (2024) to support that this model is suitable for developing context-based teaching media and science learning media for disaster education. In subsequent work, the study will conduct expert validation and limited field trials targeting science teachers and students to test the effectiveness and practicality of the modules. Finally, it will examine changes in users' disaster reduction literacy through the implementation and evaluation phases.

2.2. Research Subjects and Settings

This study focused on the development and testing of a digital disaster risk reduction tool, which was implemented at a high school located in a tectonically active region. To protect the location's privacy, we did not disclose the school's specific name or exact geographical location. A total of six professionals and 31 students participated in this study. The six professionals included two media experts, two subject and disaster research specialists, and two science teachers. All participating 11th-grade students had prior science learning experiences related to the content of the electronic modules. Task responsibilities were clearly divided: media experts evaluated the technical performance, visual design, and usability of the Si-AGAM application; subject and disaster specialists assessed the accuracy of scientific concepts, the content related to tectonic disasters, and disaster risk reduction guidance; science teachers and students participated in a limited field trial to evaluate the practicality of the electronic modules and their potential to improve students' disaster risk reduction literacy.

2.3. Research Instruments

This study conducts an evaluation of the effectiveness and practicality of the Si-AGAM electronic module. Four types of data collection tools are adopted, and all tools uniformly use a 1-5 Likert scale for measurement to achieve the module's assessment objectives.

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2.3.1. Media Validation Sheet

The assessment tool used in this paper has the core purpose of evaluating the technical and visual quality of the Si-AGAM application. It covers four major dimensions and their detailed indicators: visual design, which includes interface attractiveness and other related elements; interactivity, which includes navigation functions and other related elements; software engineering, which includes accessibility and other related elements; and unique functions, which includes the "Touch the Line" feature and other related elements. This tool fully covers all areas of this assessment.

2.3.2. Material and Disaster Validation Sheet

The assessment tool proposed in this study is mainly designed to evaluate the scientific rigor, accuracy, and content quality of electronic modules. Its complete assessment content is divided into three parallel dimensions. The first dimension, the quality of scientific content, checks the integration of relevant geological concepts, seismic information, horizontal comparison content, and local indigenous knowledge. The second dimension, the integration of the ISLE model, verifies the rationality of learning materials, visualizations, question design, and test scenarios. The third dimension, disaster reduction content, examines the reasonableness of safety procedures, emergency kit design, and the final assessment process.

2.3.3. Teacher Practicality Questionnaire

This study developed a practicality assessment tool for the Si-AGAM application from the teachers' perspective, which includes five core assessment dimensions: convenience of operation and navigation, learning time efficiency, compatibility with the five-step ISLE independent learning process, actual benefits for teachers, and the potential of local content to support learning motivation. The five steps of this process are, in sequence: *Amati, Temukan Pola, Uji Nyali, Kearifan Lokal*, and *Cek Siaga*.

2.4. Student Practicality Questionnaire

This instrument was used to obtain students' responses after using the Si-AGAM e-module. The assessed aspects included ease of navigation, visual appeal and learning motivation, ease of understanding abstract science concepts through interactive visualization, and practical usefulness in encouraging students to prepare Disaster Preparedness Bag equipment.

2.5. Data Collection Procedures

Data collection was conducted through three structured stages: expert appraisal, product revision, and field evaluation.

2.5.1. Expert Appraisal

To validate the initial prototype of the Si-AGAM application, this study submitted the prototype, evaluation tools, and guidance documents to two experts in the media field and two experts in the disaster field. Media experts evaluated the prototype's technology, visuals, and interaction, while domain experts reviewed its scientific accuracy, ISLE integration level, and disaster reduction content. Expert feedback included quantitative scores from a validation form and qualitative suggestions. It was ultimately confirmed that the prototype only requires minor revisions before it can be put into use.

2.5.2. Product Revision

The Si-AGAM prototype was revised based on the quantitative assessments and qualitative feedback provided by the validators. Revisions focused on improving the technical and visual aspects of the application as well as the accuracy and clarity of the science and disaster mitigation content. After the required revisions were completed, the product was prepared for limited field evaluation.

2.5.3. Field Evaluation

This study conducted a small-scale field trial of the revised Si-AGAM electronic module. The participants were 2 science teachers and 31 11th-grade students from a high school. Teachers and students first used the application during their learning activities. After that, we arranged two types of assessments: first, teachers and students completed a practicality questionnaire to evaluate the module's usability and practicality; second, students took a disaster reduction literacy test containing 15 questions twice, before and after learning, to measure learning gains.

2.6. Data Analysis Techniques

Quantitative data obtained from the Likert-scale validation and practicality instruments were analyzed using descriptive statistical analysis by calculating the percentage of the average score (V) or feasibility score (Chen & Liu, 2020). The percentage was calculated by comparing the total score obtained with the maximum possible score, using the following formula:

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$$V = \frac{\sum X}{\sum X_{Max}} \times 100\% \quad (1)$$

Where V represents the percentage score, ΣX represents the total score obtained, and ΣXmax represents the maximum possible score. The resulting percentage scores from the experts and users were interpreted according to the validity and practicality criteria adapted from (Kusmaryono et al., 2022).

In addition to the quantitative scores, comments, criticisms, and suggestions provided by the validators were analyzed qualitatively and used as a basis for revising the Si-AGAM e-module. The final revision of the product therefore considered both the quantitative validation results and the qualitative feedback provided by the validators.

Students' disaster mitigation literacy was analyzed using the normalized gain (N-gain) to determine the improvement between pre-test and post-test scores. The N-gain was calculated using the following formula (Coletta & Steinert, 2020):

$$N - gain = \frac{(\text{Posttest score} - \text{Pretest score})}{(\text{Maximum score} - \text{Pretest score})} \quad (2)$$

The N-gain value was interpreted as high when N-gain ≥ 0.70, medium when $0.30 \leq$ N-gain < 0.70, and low when N-gain < 0.30 (Coletta & Steinert, 2020).

3. Results and Discussion

3.1. Results

The results of the study are presented according to the five stages of the ADDIE development model: Analysis, Design, Development, Implementation, and Evaluation. The findings from each stage are described sequentially to show the development process and the resulting quality and learning outcomes of the Si-AGAM e-module.

3.1.1. Analysis Stage

In the demand analysis phase of disaster risk reduction education for regions prone to tectonic disasters, this study identified two core types of demands. First, students need learning materials that connect scientific concepts, local contexts, and practical disaster mitigation actions. Second, there is a need for interactive digital resources that integrate scientific inquiry, local indigenous knowledge, and disaster preparedness content. These findings will serve as the core design basis for the Si-AGAM electronic module.

3.1.2. Design Stage

The development team of the Si-AGAM electronic module, during the design phase, centered their work on the ISLE learning model. They adapted this model into five self-directed learning steps with locally rooted names, which are, in sequence: *Amati, Temukan Pola, Uji Nyali, Kearifan Lokal* and *Cek Siaga*. At the same time, the team planned the module's learning content, teaching sequence, and other related elements, and incorporated six supporting design features including interactive visualization.

3.1.3. Development Stage: Product Validity Results

In this study, expert evaluation was conducted during the prototype development phase of Si-AGAM. Two media experts and two disaster-related field experts were invited to participate. A 5-point Likert scale was used, and experts carried out their assessments by assigned dimensions in accordance with a pre-established division of work. The compiled results are presented in Table 1.

Table 1. Results of Validation of the Si-AGAM E-Module by Experts

Yes	Expert Group / Validator	Average Score (V)	Eligibility Percentage (%)	Validity Criteria
1	Learning Media Member	4.75	95.00	Highly Valid
2	Science & Disaster Material Expert	4.90	98.00	Highly Valid
Combined Average		4.83	96.50	Highly Valid

Based on Table 1, the media experts gave an average score of 4.75, corresponding to 95.00%, while the subject matter and disaster experts gave an average score of 4.90, corresponding to 98.00%. Both results were categorized as highly valid. The validators also provided minor revision suggestions, particularly concerning the delivery of instructional videos. Based on the quantitative validation results and qualitative feedback, the Si-AGAM e-module was considered suitable for use with minor revisions.

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3.1.4. Implementation Stage: Product Practicality Results

After the required revisions were completed, the Si-AGAM e-module was implemented in a limited field trial involving two science teachers and 31 11th Grade students from one senior high school. Teacher and student practicality questionnaires were administered after the implementation. The results are presented in Table 2.

Table 2. Results of the Practical Assessment of the Si-AGAM Application by Teachers and Students

User Respondents	Key Aspects of Assessment	Average Score	Percentage (%)	Practicality Criteria
Science Teacher (Facilitator)	Ease of Operation and Navigation	4.80	96.00	Very Practical
	Time Efficiency and Flow of ISLE Syntax	4.33	86.67	Very Practical
	Field Condition Suitability	4.33	86.67	Very Practical
	Pedagogical Benefits for Educators	4.33	86.67	Very Practical
	Student Motivation and Engagement	4.67	93.33	Very Practical
Student (Student)	Ease of Self-Use	4.45	89.00	Very Practical
	Visual Appeal and Learning Motivation	4.72	94.40	Very Practical
	Ease of Understanding Science Content	4.38	87.60	Very Practical
	The Benefits of Real Mitigation Attitudes	4.65	93.00	Very Practical
Average Accumulation	Usability of the Si-AGAM Application	4.52	90.37	Very Practical

As shown in Table 2, the overall practicality score was 4.52, corresponding to 90.37%, and was categorized as very practical. From the teachers' perspective, ease of operation and navigation received the highest score of 4.80 (96.00%). Among students, visual appeal and learning motivation received the highest score of 4.72 (94.40%). These findings indicate that the Si-AGAM application was considered easy to operate and supportive of students' learning engagement.

3.1.5. Evaluation Stage: Disaster Mitigation Literacy Results

The Evaluation stage examined changes in students' disaster mitigation literacy using a 15 item multiple choice test administered before and after the implementation of the Si-AGAM e-module. The test covered conceptual understanding, natural pattern analysis, Smong local wisdom, practical mitigation applications, and technology and preparedness attitudes. The pre-test and post-test results and N-gain values are presented in Table 3.

Table 3. Comparison of Pre-test and Post-test Scores of Student Mitigation Literacy

Question Achievement Indicators	Average Pre-test Score	Average Post-test Score	Ability Enhancement (N-gain)	Effectiveness Criteria
Conceptual Understanding (Nos. 1–3)	65.59	93.55	0.81	High
Nature Pattern Analysis (Nos. 4–5)	17.74	96.77	0.96	High
Smong Local Wisdom (Nos. 6–8)	65.59	98.92	0.97	High
Practical Mitigation Applications (Nos. 9–11)	35.48	92.47	0.88	High
Technology and Preparedness Attitudes (Nos. 12–15)	25.81	69.35	0.59	Medium
Average Total Score	42.04	90.21	0.83	High

The N-gain analysis showed an overall value of 0.83, which was categorized as high. The highest gains were observed in Natural Pattern Analysis (N-gain = 0.96) and Smong Local Wisdom (N-gain = 0.97). The Technology and Preparedness Attitudes indicator showed a moderate gain (N-gain = 0.59). Overall, the results indicate an improvement in students' disaster mitigation literacy after using the Si-AGAM e-module.

3.2. Discussion

This study finds that the Si-AGAM electronic module has high effectiveness and practicality, and is significantly correlated with standardized increases in students' disaster reduction literacy. The module's core instructional design integrates the scientific inquiry process of the ISLE model, local contextual phenomena, indigenous knowledge, and hands-on disaster preparedness activities. The ISLE teaching approach positions students as active inquirers who must complete the full inquiry process of observing phenomena, identifying patterns, and testing explanations, rather than passively receiving knowledge. Existing confirm that this model can support the development of students' scientific reasoning abilities and their engagement in active learning studies (Etkina et al., 2021; Dhanil & Mufit, 2024). Meanwhile, the interactive digital application format adopted by the module can build a learning environment that connects scientific concepts to the familiar phenomena around students. The value of this digital design is also supported by relevant research (Dhanil & Mufit, 2024).

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This study conducted expert validity testing on the Si-AGAM electronic module. Media experts who participated in the assessment gave a validity score of 95.00%, while experts in science, technology, and disaster-related materials assigned a score of 98.00%. On this basis, all five core sets of the module technology, visual design, science, ISLE, and disaster reduction are deemed compliant. Media experts recognized the compatibility of its menu layout, interactive navigation, and split-screen function. Materials experts confirmed that the module's concept of seismic gap is accurate, and that it integrates local Smong knowledge with modern science. Combined with the findings of Etkina et al. (2021) and Dhanil and Mufit (2024), ISLE-based interactive learning media can indeed support science learning and reduce students' barriers to conceptual understanding, which confirms the rationality of the validity results obtained in this study. Although the module's validity level is classified as "highly effective", the assessing experts still put forward minor revision requirements: adjustments must be made to the instructional videos linked to YouTube. This product revision was completed in this study before the formal implementation of fieldwork.

This study conducted a practicality assessment of the Si-AGAM application, and measured an overall practicality score of 90.37%. When analyzed by group dimension, the teacher-side score for ease of operation and navigation reached 96.00%, which indicates that the application's structure is well-suited for classroom use. The student-side scores for visual appeal and learning motivation reached 94.40%, and the application's interactive presentation and contextually grounded content received positive feedback. Dhanil & Mufit (2024) proposed that digital learning media in disaster education can provide flexible and interactive learning experiences. The results of this study are consistent with that conclusion, which verifies that this application can support learning activities without requiring complex operations.

This study observed that improvements in disaster risk reduction literacy were concentrated in two specific indicators: analysis of natural patterns and Simeon indigenous knowledge. Their respective N-gain values were 0.96 and 0.97, with an overall N-gain of 0.83. These high gains stemmed from the core design of the Si-AGAM teaching program, which integrates scientific research and the interpretation of local disaster knowledge. The ISLE activities that implemented this program mapped the traditional Simeon sequence of Linnenong, Sulu, Simeon, and Manio to the scientific explanations and practical response measures for earthquakes, sea level changes, tsunami occurrence, and evacuation to safe areas, respectively. A 2024 study by MacAfee et al. also corroborates the importance of integrating indigenous knowledge into disaster risk reduction education.

Interactive visualization of tectonic phenomena can effectively promote students' improved understanding of tectonic science. The two types of visual teaching tools we developed the "Touch the Line" interactive map and the split-screen display can guide students to distinguish the core features of the Sumatra subduction zone and the Sumatran Fault. The former is linked to seabed earthquake processes and tsunami risks, while the latter is an active onshore fault that can trigger destructive shallow-focus earthquakes. According to research by Etkina et al. in 2021, distinguishing the characteristics of these two types of tectonic disasters helps students connect scientific concepts to potential local risks. This type of interactive visualization is not only a display medium, but also a contextual tool that supports students in understanding the spatial and tectonic links between related geological features.

The Uji Nyali disaster education outreach activity in Mombasa, Kenya, extended disaster prevention learning, which was previously limited to a conceptual level, into practical disaster reduction operations. Through two core design elements—scenario-based questioning and time-limited decision-making—it guided students to develop emergency response plans. For example, students learned to distinguish dangerous actions during earthquakes from the standard "drop, cover, and hold on" procedures, and identify post-earthquake secondary hazards such as downed power lines and accumulated water. This activity helped students build a connection between disaster prevention knowledge and real-world decision-making, a value that has been cited in the 2024 study by Dhanil and Mufit.

In the Si-AGAM project of this study, the normalized gain (N-gain) of the scores for the technology and preparation attitude indicators was only 0.59, which falls at a moderately low level. Two core main reasons account for this limited growth. First, technology-related issues involve complex and abstract geophysical concepts such as real-time GPS plate deformation tracking, which requires higher-level theoretical comprehension. Second, the measurement of preparation attitude covers the dimensions of emotional and behavioral commitment, for example, assembling emergency kits and developing family emergency plans. Disaster risk reduction studies by Amri et al. (2022) and Turan Bayraktar et al. (2024) both point out that translating cognition into sustained behavioral changes requires long-term reinforcement. Therefore, this study argues that while Si-AGAM can solidify the conceptual foundation, continuous experiential practice and community support are still needed to develop a fully established preparation attitude.

This paper proposes the Si-AGAM digital learning module, which integrates scientific investigation, Indigenous knowledge, and practical disaster preparedness content into a single learning sequence. Unlike traditional disaster mitigation teaching that only stays at the theoretical level, this module provides students

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with four types of learning opportunities, including investigating phenomena and interpreting local knowledge. Studies by MacAfee et al. (2024) and Dhanil and Mufit (2024) both confirm that this type of situated learning can effectively connect scientific concepts with surrounding risks.

3.3. Implications

This study carries both theoretical and practical value in the fields of science education and disaster education. At the theoretical level, we expand the ISLE approach, which was originally developed for physics learning, and extend its application to place-based disaster education. By relying on five core actions including observing real-world phenomena, we realize the localized integration of scientific inquiry and contextually rooted geological hazard scenarios.

The Si-AGAM electronic module developed in this study integrates four types of content for teachers: structural science, disaster risk reduction, local knowledge, and disaster preparedness activities. It embeds local carriers such as the Smong ethnic group's traditions and a disaster preparedness kit checklist, which connects in-class scientific learning with household disaster preparedness work. For students, the module supports three types of non-overlapping competency training: investigating local geological structural phenomena, interpreting disaster information, and planning context-appropriate disaster risk reduction measures. Practicality scores from field tests of the module were excellent, and it can support classroom instruction. However, the current findings only apply to this field experiment, and large-scale implementation and long-term evaluation are still needed in the future.

3.4. Limitations

Before interpreting the findings of this study on disaster risk reduction literacy related to the Si-AGAM electronic module, it is necessary to first clarify three limitations of this research, so as to define the scope of application of the study's conclusions. First, the sample size of this study is limited. It only includes 31 high school students from the same school, and the number of teachers and students participating in the field experiment is also small. The relevant findings cannot be generalized to a wider range of student groups, different school settings, other regions, or various disaster scenarios. Second, the effect analysis of this study adopts a single-group pretest-posttest design without a control group. Although the increase in students' standardized gain scores proves that disaster risk reduction literacy improved after the implementation of Si-AGAM, we cannot draw strong causal conclusions. We cannot confirm whether the improvement in literacy is specifically derived from this electronic module, nor can we distinguish its effect from that of traditional learning models. Third, this study only focuses on short-term learning outcomes and does not conduct long-term follow-up measurements on students' disaster preparedness behaviors. Future related studies need to expand the sample size, enrich the diversity of samples, adopt experimental designs with comparison or control groups, and carry out long-term follow-up at the same time. This will allow researchers to examine how long disaster risk reduction literacy is retained, and whether learning gains can be transformed into sustained disaster preparedness behaviors.

4. Conclusion

This study developed the Si-AGAM scientific e-learning module based on the ISLE framework, with the core goal of improving disaster risk reduction literacy among high school students in tectonically active regions. After the module was fully developed, it underwent multiple rounds of assessment and was then implemented for pilot use. First, two types of experts were invited to conduct a validity assessment: media experts gave a validity score of 95.00%, while experts in scientific and disaster-related materials gave a validity score of 98.00%. Subsequently, practicality assessments were carried out among teachers and students, and the overall total practicality score reached 90.37%. During the module's pilot use, we collected data on changes in students' disaster risk reduction literacy through standardized tests. The measured results showed that students' disaster risk reduction literacy improved significantly: the total normalized gain score after the pilot was 0.83, the gain in the natural pattern analysis dimension reached 0.96, and the highest gain, 0.97, was recorded in the Smong local indigenous knowledge dimension. Based on these findings, we propose that this module can serve as a contextualized interactive learning resource that connects scientific inquiry, local disaster knowledge, and practical disaster preparedness activities. At the same time, this study has certain limitations: the experiment adopted a single-group pretest-posttest design with no control group set up, and the sample size of the field trial was limited. Future related research needs to expand the sample size, add a control group, and extend the follow-up period to verify the module's generalizability and long-term educational impacts.

Author Contributions

Dian Rafika: Conceptualization, development of the Si-AGAM application, research design, data collection, data analysis, and writing of the original manuscript. Muslimatul Walidah, Rajibussalim, Nilataria, Yayu Risna Andani: Development and preparation of research instruments, coordination of expert validation, assistance with data collection, and supervision of the field implementation.

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Declaration of Conflicting Interests

The authors state that there is no conflict of interest, whether financial, personal, or professional, with any party or organization that could affect the objectivity, integrity, or results of research on the development of this e-module.

Data Availability

The data supporting the findings of this study, including raw data from expert validity assessments, teacher and student practicality questionnaires, and students' pre-test and post-test scores, are available from the corresponding author upon reasonable and scientifically justified request.

Declaration on AI Use

The authors declare that no artificial intelligence (AI) or AI-assisted tools were used in the preparation of this manuscript.

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