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Applying the Model of Educational Reconstruction to Needs Analysis for a STEM Based Disaster Mitigation Education

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Abstract
This study uses the Model of Educational Reconstruction (MER) as a theoretical framework to identify learning needs for STEM based flood mitigation education in junior high school. It focused on the preliminary needs analysis phase of a research and development at SMP Muhammadiyah Kluwut, Indonesia. The data were obtained from an interview with one science teacher and 12 students' responses, and a review of content relating to the curriculum and teaching materials. This broader project involved thirty seventh-grade students in a classroom pilot. The teacher reported that the students had difficulty connecting environmental science concepts to the causes of flooding and distinguishing between prevention and mitigation efforts and emergency response. Limited teaching time and resources were cited as barriers. These findings highlighted the importance of contextual learning that links human activities, environmental interactions and flood mitigation through integrated STEM activities. These insights became the basis for the development of a context-specific, STEM-based flood mitigation simulation. The study provides a contextual basis for subsequent instructional development; however, the simulation implementation and effectiveness were not evaluated in this phase.

Keywords: Model of Educational Reconstruction; Needs Analysis STEM; Disaster Mitigation Education.

INTRODUCTION

Education plays a vital role in shaping quality students who are able to adapt to the times. In The escalation in both the frequency and severity of natural disasters on a global scale underscores the critical need for disaster education (Kelman & Glantz, 2015). In response, UNESCO has developed supplementary pedagogical materials tailored for junior high and high school students, emphasizing preparedness for natural disasters through the lenses of education, science, and culture. The objective of this initiative is to enhance students' comprehension regarding various types of natural disasters and the methodologies for mitigating associated risks. To empower students to establish deeper connections between disaster phenomena and scientific principles, they must engage in a collaborative learning approach (Alfi et al., 2019). This pedagogical strategy is integral to a progressive educational paradigm that aims to foster a comprehensive understanding.

Conventional instructional methods, which predominantly focus on rote memorization of procedures, have been found insufficient in equipping students with the adaptive reasoning and problem-solving capabilities necessary for navigating real-world crisis scenarios (Sari et al., 2025). Science education, particularly in areas concerning the interactions between organisms and their environments, lays a vital foundation for comprehending the causative factors and repercussions of natural disasters. The field of Natural Sciences (IPA) is dedicated to the systematic observation of various natural phenomena occurring in our environment. Given its intrinsic connection to natural events, IPA represents a discipline ideally suited for integration with content on natural disaster mitigation, particularly through a STEM-oriented pedagogical framework (Zulfiya et al., 2023; Hayati et al., 2021).

The integration of Science, Technology, Engineering, and Mathematics (STEM) through simulation-based learning offers a promising pedagogical approach. Simulations allow students to experience complex and dynamic systems in a risk-free environment, making abstract concepts tangible and encouraging discovery-based learning (Ledger et al., 2025). However, the development of such innovative learning must be based on a rigorous analysis of student needs and scientific content to ensure educational effectiveness. STEM education is ideal for the topic of disaster mitigation, which inherently involves multiple disciplines, because it emphasizes the integration and application of knowledge to solve real-world problems (Kelley & Knowles, 2016).

MER is not a teaching method, but rather a holistic framework for researching and improving teaching and learning processes. The Model of Educational Reconstruction (MER) provides a solid framework for bridging scientific content to learners' perspectives when informing instructional design (Duit et al., 2012). This framework argues that educational reconstruction requires ongoing dialogue between three elements: analysis of scientific content, research on student perspectives and learning prerequisites, and the design of learning environments (De Zuani Cassina & Levrini, 2024). Scientific content to learners' perspectives when informing instructional design. The analysis brings together relevant scientific content, teacher reports, and student responses to identify learning needs and formulate requirements for subsequent simulation design. Teaching-learning interaction models such as MER can be employed to analyse learning needs in complex and interdisciplinary fields such as STEM-based disaster mitigation (Striligka et al., 2023).

Designing solutions based on conjecture rather than factual data regarding the needs of students is a frequent error in the development of educational technology. By identifying gaps between the desired and actual situations, needs analysis ensures that interventions are pertinent and focused (Stefaniak, 2020). Accordingly, this study uses MER to identify learning needs and translate the findings into proposed design specifications for a STEM-based flood mitigation simulation. This research question: 1) What scientific concepts and STEM connections relevant to flood mitigation are identified through the analysis of junior high school curriculum content and teaching materials? 2) What learning needs and corresponding simulation design requirements emerge from integrating the content analysis, teacher interviews, and student responses?

The contribution of this study is the explicit mapping of the findings from the needs analysis into proposed STEM instructional design requirements for flood mitigation education. Guided by MER, this study combined scientific content analysis, teacher reports, and student responses to link relevant concepts, learning difficulties, and classroom challenges to design decisions. For example, students' limited understanding of human contributions to flood risk formed the basis for a proposed task comparing how land cover and drainage conditions affect surface flow. Difficulty distinguishing between preventive mitigation and emergency response led to a task requiring students to classify actions and justify their choices using scientific explanations. This mapping of evidence to design extends assessment beyond simply identifying learning gaps by determining what subsequent STEM activities should address and why. The resulting requirements provide a foundation for the development of simulations, without claiming that such simulations have been developed or evaluated.

METHODS

This study reports a needs analysis conducted within a broader research and development project, using the Model of Educational Reconstruction (MER) as its guiding framework. MER connects the analysis of science content, research on teaching and learning, and the development and evaluation of instruction : (1) clarification and analysis of science content, (2) exploration of students' perspectives, and (3) development of evidence-informed specifications for the learning environment (Duit et al., 2012; Johann et al., 2020; Metaxas et al., 2021).

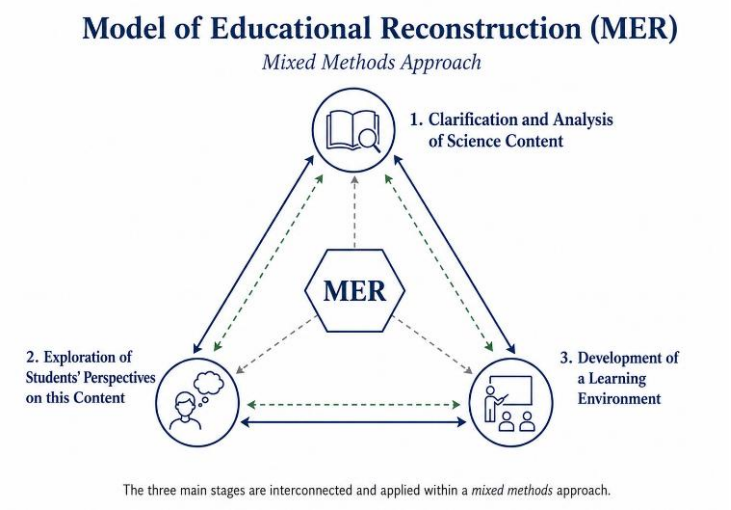


Figure 1. MER process (Duit et al., 2012; Johann et al., 2020; Metaxas et al., 2021)

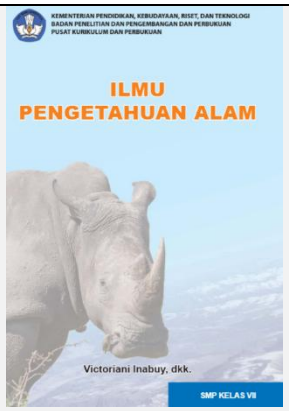
These interrelated components provide a framework for linking instructional content to students' perspectives and learning considerations. MER was effectively used in this study as a framework for a thorough needs analysis (Jáč, 2024). In this study, content analysis, interviews with one science teacher, and feedback from 12 students served as the basis for identifying learning needs for STEM-based flood mitigation education. The scope of this study is limited to needs analysis and the formulation of proposed instructional design requirements; the development and evaluation of the simulation are not reported in this article.

The study involved one science teacher and 12 Grade IX students at a private junior high school in Brebes, Indonesia. The teacher was purposively selected based on their responsibility for teaching the relevant science content, and the interview was conducted in May 2025. Additional student data were collected during manuscript revision using an open-ended questionnaire. The 12 students were randomly selected and had not participated in the pilot simulation. Their responses were used to identify their current understanding and learning needs concerning flood mitigation. The teacher interview and student questionnaire represented different data collection periods and were considered complementary sources rather than measurements of change over time.

The documents comprised two editions of a Grade VII science textbook, published in 2021 and 2023 (Inabuy et al., 2021, 2023), and a Grade VII science module on Earth's layers and natural disaster threats. The analysis focused on sections relevant to environmental interactions, flood causes, and disaster mitigation. Scientific concepts, relationships among concepts, learning activities, and opportunities for STEM integration were examined. This analysis examines specific sections of two 7th-grade science textbooks and one supplementary disaster education module. It focuses on scientific concepts, cause-and-effect relationships, disaster-related actions, representations, learning activities, connections to STEM, contextual relevance, and enrichment needs. Page numbers refer to the printed version. Content analysis examined two Grade VII science textbooks and one supplementary disaster education module, as listed in Table 1.

Table 1. Content analysis of the learning resources for STEM-based flood mitigation education

Code	Learning resource	Chapter/ Section analysed	Code/ Pages
B1	Inabuy et al. (2021). Ilmu Pengetahuan Alam untuk SMP Kelas VII. Pusat Kurikulum dan Perbukuan, Kemendikbudristek.	Chapter 6, Ecology and Indonesian Biodiversity: environmental threats, human influences on ecosystems, conservation, and the end-of-chapter project	B1/179-186

			
B2	Inabuy et al. (2023). Ilmu Pengetahuan Alam untuk SMP/MTs Kelas VII (Edisi Revisi). Kemendikbudristek.	Chapter VI, Ecology and Environmental Conservation: ecosystem interactions, human influences, conservation, and the end-of-chapter project	B2/ 170-182
			
M1	Herlina, L., & Iskandar, R. B. (2020). Modul pembelajaran SMP Terbuka IPA kelas VII: Modul 10: Lapisan Bumi dan Ancaman Bencana Alam. Direktorat Sekolah Menengah Pertama, Kementerian Pendidikan dan Kebudayaan.	Learning Activity 1, Earth's Layers: hydrosphere and water cycle; Learning Activity 3, Natural Disaster Threats: flood-related actions and assessment of local disaster potential	M1/16-20; 63-66
			

The teacher interview guide contains 12 questions covering students' understanding as perceived by teachers, the role of disaster mitigation in science lessons, teaching approaches, student enthusiasm, teaching challenges, school support, and teachers' views on simulation-based learning and STEM. The student questionnaire uses open-ended questions to explore students' own explanations of flood-related phenomena and mitigation efforts. Teachers' explanations of student understanding were distinguished from students' written responses.

The content analysis form, teacher interview guide, and student open-ended questionnaire were reviewed for relevance, conceptual accuracy, language clarity, neutrality, and operational clarity using a four-point scale. Two reviewers assessed the content analysis instrument, which

covered eight analytical aspects: scientific concepts, causal relationships, disaster-related actions, content representations, cognitive and practical demands, STEM connections, contextual relevance and feasibility, and enrichment needs. Feedback identified refinements to the STEM connection criteria, indicators of flood risk reduction actions, interview wording, and contextual clarity of student questions.

Table 2. Summary of instrument content review

Instrument	Items assessed	Mean rating (1–4)
Content analysis form	8	3,23
Teacher interview guide	9	3.64
Student open-ended questionnaire	9	3.51

The analysis qualitatively examined findings from documents, interview responses, and student questionnaire answers. We identified and grouped relevant sections and responses by content, including scientific explanations, learning challenges, teaching practices, and resource limitations. The analysis first examined findings within each source and then compared them across sources. This synthesis identifies relationships among scientific content, student explanations, and the classroom conditions teachers reported. The analysis then mapped the identified needs to the proposed STEM instructional design requirements, associating each requirement with supporting evidence. The proposed activities represent implications for future design, not interventions implemented or evaluated in this study. Focus group discussions and pretest–posttest data from a separate classroom pilot were excluded from the needs analysis reported in this article

Table 3. summarizes the needs analysis's data sources, analytical focus, and intended outputs.

Data source	Analytical focus	Output
Two editions of a Grade VII science textbook and one disaster education module	Relevant scientific concepts, relationships among concepts, learning activities, and opportunities for STEM integration	Mapping of content and potential STEM connections
Interviews with science teachers	Teaching practices, perceived student difficulties, instructional resources, and classroom constraints	Teacher-reported learning needs and instructional constraints
Open-ended questionnaires completed by 12 students from three Grade IX classes	Students' explanations of flood causes and mitigation	Patterns in students' understanding and identified learning needs
Synthesis across the three sources	Relationships among scientific content, student understanding, and classroom conditions	Proposed instructional design requirements linked to supporting evidence

RESULT AND DISCUSSION

Result

The content analysis identified opportunities to strengthen the connection between environmental science concepts and flood mitigation tasks. The reviewed materials included environmental content and data interpretation activities, but offered fewer opportunities for students to design and evaluate mitigation solutions. Explicit tasks connecting STEM disciplines within a single flood mitigation problem were not identified in these sections.

The reviewed resources provide a complementary foundation for learning about flood mitigation, including ecosystem interactions, conservation, the water cycle, and disaster-related actions. These resources also cover data collection, measurement, graphing, and environmental projects. However, these elements are not explicitly organized into a single investigation of flood mitigation in the reviewed sections. Table 4 summarizes the evidence, its interpretation, and its implications for instructional development.

Table 4. Content Analysis of Learning Material and Its Implications for Teaching Flood Mitigation

Analytical aspect	Evidence from the reviewed materials	Implications for instruction
Scientific concepts and causal relationships	B2 covers ecosystem interactions and human influences (pp. 170–176). B1 links environmental degradation with disasters (p. 183). M1 presents the water cycle and links tree removal, infiltration, and flooding (pp. 16–20).	Connect rainfall, vegetation, infiltration, runoff, and drainage in explanations of flood risk.
Disaster-related actions	M1 describes actions before, during, and after flooding (pp. 63–64).	Require students to distinguish risk reduction, preparedness, and emergency response by their purposes.
Representations and learning activities	Resources include diagrams, environmental observations, measurements, graphs, and projects: B1 (pp. 179, 185–186), B2 (pp. 170, 174–176, 181–182), and M1 (pp. 17, 65–66).	Use representations and observations to support explanations and evaluate proposed solutions.
STEM connections	B2 combines measurement, instrument use, averaging, and graph construction (p. 170). B1 and B2 include environmental solution projects (pp. 185–186 and 181–182, respectively).	Integrate these practices within a shared flood problem, linking scientific evidence with design decisions.
Local context and feasibility	B1 and B2 situate projects at home or school. M1 addresses local disaster potential (pp. 65–66).	Select contexts, materials, and activity duration using teacher and student evidence.

The interview provided the science teacher's account of existing instruction, perceived student difficulties, and classroom constraints. These findings are reported separately from the document analysis and students' written responses. Table 5 below summarizes the content structure analysis findings.

Table 5. Teacher Interview Findings and Impact for Instructional Development

Aspect	Teacher-reported findings	Instructional implications
Student understanding and content coverage	Students were perceived as more familiar with preventive actions than flood mechanisms. Mitigation received limited coverage within environmental topics.	Connect scientific explanations with practical mitigation actions.
Teaching and engagement	Contextual explanations, interactive lectures, and discussion were used. Familiar cases and visual examples attracted student interest.	Use local contexts and guided observation.
Classroom constraints	Limited time, facilities, and differences in student understanding constrained instruction.	Provide manageable activities, accessible materials, and clear guidance.
STEM and simulation	The teacher reported limited STEM experience and no implementation of simulation-based training, but expressed interest in practical activities.	Develop proposed activities for subsequent feasibility testing.

The teachers interviewed reported that students were more familiar with practical actions related to flooding than with explanations of the basic processes involved. Disaster mitigation was described as a topic covered in environmental education, rather than through a comprehensive series of lessons. The teachers used contextual explanations, interactive lectures, and discussions, but identified limitations in time, facilities, and experience with simulation-based learning as obstacles. Their interest in simulations and STEM activities reflects the instructional needs they perceive; it does not prove the effectiveness of these approaches.

Based on interview data, it was found that most students still consider flooding to be a normal natural phenomenon that is rarely discussed in terms of its causes and scientific ways to reduce its risks. The topic of disaster mitigation has not been specifically included in a special chapter in the junior high school science curriculum (Widiyatmoko & Shimizu, 2018) in Indonesia because junior high school science material is still fragmented and has not been

integrated into the curriculum. Teachers stated that they had little time and resources to talk about STEM integration in disaster mitigation, which suggests that simulation-based learning is necessary to inspire students to think critically and come up with solutions.

Disasters were often seen by students as entirely natural occurrences unrelated to human activity and environmental management (Keller & DeVecchio, 2019). The students' responses were categorized into five groups: the role of humans in causing floods, explanations of infiltration and runoff, disaster-related actions, reported learning difficulties, and learning experiences and preferences. Each respondent was assigned an anonymous identification code S01–S12 to connect each interpretation to the responses that supported it.

Table 6. Categories of Students' Open-Ended Responses

Code	Category	Response summary
C1	Human contributions	Waste disposal, blocked drainage, and land-use change.
C2	Flood mechanisms	Varied explanations of infiltration and runoff.
C3	Disaster-related actions	Uneven distinction between preventive and emergency actions.
C4	Learning difficulties	Flood prediction, risk maps, and water movement.
C5	Learning experiences and preferences	Varied experiences; interest in models, practical activities, and simulations.

The responses analyzed indicate that students are aware of the role humans play in causing floods. One response cited "dumping waste into rivers, illegal logging, and land-use changes" as examples of human activities that influence flood risk. This evidence suggests that human influence is already part of the students' explanations, although the level of detail in these explanations varies.

This difference was very clear when the students compared vegetated land with a concrete surface. One answer explained that "surface runoff is very heavy and fast because concrete is impermeable, so water cannot infiltrate". In contrast, another response stated, "Yes, because there are plants, so the water will be clear". The first response linked surface conditions to water movement, while the second focused on water clarity without explaining the processes of infiltration or surface runoff. This difference highlights the need to strengthen explanations regarding the mechanisms connecting land cover to flood risk

Responses regarding actions taken before and during the flood also varied in terms of completeness. One response mentioned cleaning drainage pipes before the flood and evacuation during the flood. Another response simply stated, "Before a flood occurs, clean the drainage channels", leaving the section on emergency response unanswered. This omission indicates that the response was incomplete, not sufficient evidence of a misunderstanding.

The students also described specific learning difficulties. One of them wrote that "the difficult part is understanding the signs that a flood is about to happen". Another student mentioned difficulties in making reliable flood predictions and calculating urban water absorption capacity. These responses highlight the need to link scientific explanations to the interpretation of observable conditions and simple measurements. Learning preferences include both concrete and digital representations. One respondent requested "an interactive flood simulation model/diorama or a computer-based digital simulation application," while another respondent suggested "digital simulations, applications, or games." These preferences support the inclusion of visual and interactive resources in future designs, but do not prove their effectiveness.

Discussion

The findings of this study reveal three interconnected needs for developing STEM-based flood mitigation education: strengthening students' causal explanations of flood mechanisms, connecting existing science curriculum content with integrated problem-solving activities, and accommodating the instructional constraints experienced by teachers. The analysis of two Grade

VII science textbooks and one supplementary disaster education module identified relevant content concerning ecosystem interactions, the water cycle, environmental degradation, and disaster-related actions. However, these resources offered limited opportunities to integrate scientific explanations, measurements, and engineering decisions within a single flood mitigation problem. Interviews with one science teacher and open-ended responses from 12 students further revealed differences in conceptual understanding and learning preferences. These findings address the study's research questions by identifying both the scientific content requiring educational reconstruction and the learning conditions that should inform subsequent simulation design. Importantly, they constitute evidence of instructional needs rather than demonstrated improvements in learning outcomes.

One particularly significant finding concerns the difference between students' recognition of human activities contributing to flooding and their ability to explain the underlying physical processes. Students identified waste disposal, blocked drainage, deforestation, and land-use changes as potential contributors to flood risk. Nevertheless, their explanations of infiltration, surface runoff, and the effects of land cover varied considerably. Some students established plausible causal relationships between impermeable surfaces and runoff, whereas others provided descriptive answers that did not adequately explain water movement. These findings suggest that students' difficulties should not be characterized as a complete absence of environmental awareness. Rather, they indicate a need to connect familiar environmental experiences with more systematic scientific reasoning. This interpretation aligns with Pallant et al. (2025), who examined how students develop explanations of flooding through scientific factors, human influences, potential impacts, and risk probabilities. Similarly, Lin and Opdyke (2024) demonstrated the importance of distinguishing general flood-risk awareness from accurate understanding of flood probabilities. Although their participants were university students, their findings reinforce the importance of examining the quality of risk-related reasoning rather than treating familiarity with disaster terminology as sufficient evidence of understanding.

The variation in students' explanations also has implications for the Model of Educational Reconstruction (MER). Educational reconstruction requires scientific knowledge to be transformed into teachable content through careful consideration of students' prior conceptions, learning difficulties, and instructional circumstances (Duit et al., 2012; Johann et al., 2020). The present findings illustrate the relevance of this framework by identifying specific differences between scientific explanations and students' existing interpretations. Rather than introducing increasingly complex information without considering learners' understanding, instructional development should begin with observable situations that can be investigated through relevant scientific concepts. Aroyandini et al. (2024) similarly demonstrated the importance of needs analysis before developing an integrated STEM-disaster education model for prospective science teachers in Indonesia. Nevertheless, the educational population and research design differed from the present study. Their investigation addressed prospective teachers and proceeded toward initial model development, whereas the present research concentrates on identifying content-specific learning requirements for junior high school flood mitigation education.

The document analysis further indicates that the central challenge is not necessarily the absence of disaster-related content but its limited instructional integration. The reviewed materials contain opportunities for environmental observation, measurement, graph interpretation, and project-based activities. However, these components are not consistently connected through a common flood mitigation problem requiring students to interpret evidence and evaluate possible solutions. This finding corresponds with the integrated STEM framework of Kelley and Knowles (2016) and the more detailed conceptualization proposed by Roehrig et al. (2021), which emphasize authentic problems, meaningful disciplinary connections, and engineering-oriented decision-making. An instructional sequence addressing flooding could therefore begin with comparisons of vegetated and impermeable surfaces, proceed toward measurements of water movement, and culminate in the evaluation of potential mitigation

strategies. Mathematics would support measurement and interpretation, technology would facilitate representations or simulation, and engineering would guide the comparison of proposed solutions. These connections must be made explicit to avoid treating the presence of several disciplines as sufficient evidence of integrated STEM learning.

International studies involving digital geohazard learning provide a useful basis for interpreting the proposed instructional direction. Pallant et al. (2025) showed how flood simulations can support students' risk-related explanations, while Lord et al. (2025) found that students' simulation experiences and teachers' instructional practices were associated with conceptual learning in wildfire education. Conrath et al. (2025) further demonstrated that students' uncertainty when interpreting digital representations can become productive when teachers facilitate discussion, comparison, and evidence-based reasoning. These findings suggest that simulations should not function merely as visual demonstrations. Their educational relevance depends on the investigative questions, representations, explanatory tasks, and teacher support accompanying their use. Consequently, a future flood mitigation simulation should enable students to manipulate relevant environmental conditions, compare resulting patterns, and justify conclusions using scientific evidence. However, these recommendations are prospective design requirements; the present study did not implement or evaluate such a simulation.

The teacher interview identified additional constraints involving instructional time, learning facilities, and limited experience with simulation-based STEM education. These findings suggest that instructional development must be responsive to classroom conditions rather than driven solely by technological possibilities. Amri et al. (2022) previously identified institutional and implementation challenges in integrating disaster risk reduction education into Indonesian schools, while Shernoff et al. (2017) emphasized the importance of teacher professional development and instructional support for integrated STEM education. More recently, Aroyandini et al. (2025) examined disaster knowledge elaboration within a learning model designed for prospective teachers, highlighting the role of structured knowledge development in disaster education. Together, these studies suggest that teacher preparation, suitable instructional materials, and institutional support should be considered alongside scientific content. The present findings support the development of manageable classroom activities with accessible materials and clear implementation guidance, although their practical feasibility remains to be tested.

The findings also correspond with Indonesian investigations emphasizing contextual disaster education. Wahyono et al. (2022) demonstrated the relevance of locally contextualized disaster learning modules in schools affected by disasters in Palu. Bachri et al. (2024) developed an ethnoscience-based digital disaster learning module to support preparedness among elementary students in the Mount Semeru region. Similarly, Saregar et al. (2025) reported improvements in disaster literacy following the implementation of integrated disaster education materials in secondary-level physics instruction. These studies provide evidence that disaster contexts can be incorporated meaningfully into disciplinary learning. Nevertheless, they differ from the present investigation because they involved the development or implementation of instructional interventions. Therefore, their reported learning improvements cannot be generalized to the proposed STEM-based flood mitigation simulation. Instead, they support the relevance of proceeding from the identified needs toward systematic development and subsequent evaluation.

Further comparisons reveal why conceptual understanding, risk perception, and disaster preparedness should be evaluated as distinguishable outcomes. Intaramuean et al. (2025) reported improvements in flood knowledge and preparedness among primary school students in southern Thailand, although changes in risk perception were less consistent. Zhong et al. (2021) likewise found that school-based disaster education and risk-related interactions between children and parents contributed to flood-risk perception in China. These findings suggest that students may acquire factual knowledge without necessarily developing

proportionate risk judgments or practical preparedness. Harada et al. (2023) additionally demonstrated that disaster education in Indonesia can influence family knowledge and behavior through intergenerational communication. Although the hazards examined in their study differed from flooding, the broader implication is that disaster education should connect classroom understanding with meaningful decisions beyond school. In the present study, such possibilities remain future considerations because neither household preparedness nor students' subsequent behavior was assessed.

The students' responses also indicate the importance of distinguishing prevention, risk reduction, preparedness, and emergency response. Some respondents recognized appropriate actions before flooding but provided incomplete explanations of actions required during emergencies. These responses do not necessarily indicate misconceptions; they reveal differences in the completeness of students' reasoning. Simulation activities could address these differences by requiring learners to classify actions according to their purposes, assess relevant environmental conditions, and justify proposed mitigation choices. Johar et al. (2025) demonstrated the educational relevance of incorporating disaster contexts into mathematical problem-solving among Indonesian junior high school students. Similarly, Emiroglu et al. (2025) developed a game-based flood mitigation environment incorporating interactive decision-making activities. These investigations illustrate possible approaches to contextual problem-solving, but their instructional characteristics should not be assumed appropriate for the present school without further feasibility assessment.

The theoretical, pedagogical, and policy implications of these findings are interconnected. Theoretically, the study supports the application of MER as a framework for relating scientific content, learners' explanations, and instructional design requirements. Pedagogically, it suggests that teachers should move beyond presenting disaster terminology toward guided investigation involving comparisons, measurements, visual representations, and evidence-based justification. Practical activities should remain accessible to students with different learning needs and should not depend exclusively on sophisticated digital infrastructure. Rofiah and Kawai (2025) demonstrate the importance of inclusive approaches to disaster education, while Lownsbery (2025) argues for greater attention to learning processes rather than relying exclusively on program outcomes. At the policy level, the findings support integrating disaster risk reduction into science curriculum planning, strengthening teacher professional development, and providing schools with contextually appropriate learning resources. These implications concern educational preparedness and instructional quality; claims regarding changes in emotional well-being, social media behavior, or mental health are not warranted because those outcomes were not investigated.

The novelty of this study lies in its explicit translation of multiple sources of needs-analysis evidence into proposed instructional design requirements for STEM-based flood mitigation education. Rather than merely identifying students' learning difficulties or recommending simulation technology in general, the study connects curriculum content, teacher-reported instructional conditions, and students' written explanations to specific investigative activities. For example, inconsistent explanations of infiltration and runoff inform the requirement to compare land surfaces and observe water movement, while incomplete explanations of disaster-related actions support tasks involving the classification and justification of mitigation decisions. This approach contributes a contextually grounded design rationale within the MER framework. Its contribution is methodological and conceptual rather than experimental: it provides an evidence-informed foundation for subsequent development without claiming that a new simulation has already demonstrated educational effectiveness.

Several limitations must be acknowledged. The investigation involved only one science teacher and 12 students from a single private junior high school in Brebes, Indonesia, limiting the diversity of perspectives represented. The curriculum analysis was confined to selected sections of two science textbooks and one supplementary module, while the teacher interview and student questionnaire were collected during different periods. Although triangulation across

these sources supported contextual interpretation, it did not establish the prevalence of misconceptions or provide evidence of changes in student learning. Furthermore, the proposed simulation requirements have not undergone prototype testing, usability assessment, or experimental evaluation. Future studies should involve additional schools, teachers, and students; examine the consistency of needs across learning contexts; and develop prototypes incorporating both physical and digital representations. Subsequent evaluation should investigate scientific understanding, disaster-risk reasoning, preparedness, accessibility, and implementation feasibility using appropriate comparison groups and delayed assessments. Such research would extend the present needs analysis toward a more comprehensive and empirically evaluated model of STEM-based disaster mitigation education.

CONCLUSION

This needs analysis identifies ecosystem interactions, infiltration, runoff, drainage, and human impacts as the scientific foundation for STEM-based flood mitigation simulations. The reviewed resources offer opportunities for measurement, data interpretation, and environmental projects, while feedback from teachers and students highlights the need for clearer causal explanations, a distinction between preventive and emergency measures, and accessible inquiry-based activities. These findings form the basis for the proposed simulation requirements: varying surface and drainage conditions, measurement of water movement, comparison of mitigation options, and justification of design choices with evidence. The resulting specifications provide a contextual foundation for developing simulations that connect science, technology, engineering, and mathematics within the context of the same flood problem. Future research should further develop this prototype and evaluate its feasibility and effectiveness in the classroom.

REFERENCE

Alfi, M., Darsiharjo, & Maryani, E. (2019). Development of natural disaster mitigation teaching materials to improve understanding of disasters. *Journal of Physics: Conference Series, 1387*(1), Article 012079. https://doi.org/10.1088/1742-6596/1387/1/012079

Amri, A., Lassa, J. A., Tebe, Y., Hanifa, N. R., Kumar, J., & Sagala, S. (2022). Pathways to disaster risk reduction education integration in schools: Insights from SPAB evaluation in Indonesia. *International Journal of Disaster Risk Reduction, 73*, Article 102860. https://doi.org/10.1016/j.ijdrr.2022.102860

Aroyandini, E. N., Supriyadi, Rusilowati, A., Hartono, & Juhadi. (2024). Disaster education model for prospective science teachers: Needs analysis and initial development. *Journal of Disaster Research, 19*(3), 560–569. https://doi.org/10.20965/jdr.2024.p0560

Aroyandini, E. N., Supriyadi, Rusilowati, A., & Hartono. (2025). The influence of disaster knowledge elaboration on disaster education implementation. *Journal of Disaster Research, 20*(2), 215–221. https://doi.org/10.20965/jdr.2025.p0215

Bachri, S., Hakiki, A. R. R., Wibowo, N. A., Sumarmi, Amini, R., Yosritzal, & Nursaribilah, E. (2024). Developing an education support system for disaster management through an ethnoscience-based digital disaster learning module. *International Journal of Disaster Risk Reduction, 100*, Article 104214. https://doi.org/10.1016/j.ijdrr.2023.104214

Conrath, B., Farris, A. V., & McDonald, S. (2025). Leveraging uncertainty as a means of facilitating sensemaking within a digital wildfire curriculum. *Journal of Science Education and Technology, 34*, 550–564. https://doi.org/10.1007/s10956-024-10168-y

De Zuani Cassina, F., & Levrini, O. (2024). Educational reconstruction of physics of complexity within a creative writing classroom activity. *Journal of Physics: Conference Series, 2750*(1), Article 012048. https://doi.org/10.1088/1742-6596/2750/1/012048

Duit, R., Gropengießer, H., Kattmann, U., Komorek, M., & Parchmann, I. (2012). The model of educational reconstruction: A framework for improving teaching and learning science. In D. Jorde & J. Dillon (Eds.), *Science education research and practice in Europe: Retrospective and prospective* (pp. 13–37). SensePublishers. https://doi.org/10.1007/978-94-6091-900-8_2

Emiroglu, E., Grant, C. A., Sermet, Y., & Demir, I. (2025). Floodcraft: Game-based interactive learning environment using Minecraft for flood mitigation for K–12 education. *International Journal of Disaster Risk Reduction, 130*, Article 105799. https://doi.org/10.1016/j.ijdrr.2025.105799

Harada, T., Shoji, M., & Takafuji, Y. (2023). Intergenerational spillover effects of school-based disaster education: Evidence from Indonesia. *International Journal of Disaster Risk Reduction, 85*, Article 103505. https://doi.org/10.1016/j.ijdrr.2022.103505

Hayati, M. N., Arfiani, Y., & Fatkhurrohman, M. A. (2021). The comparative analysis of technological content knowledge (TCK) through the digital module and Google Classroom in integrated science learning. *PSEJ (Pancasakti Science Education Journal), 6*(2), 109–117. https://doi.org/10.24905/psej.v6i2.176

Inabuy, V., Sutia, C., Maryana, O. F. T., Hardanie, B. D., & Lestari, S. H. (2021). *Ilmu pengetahuan alam untuk SMP kelas VII*. Pusat Kurikulum dan Perbukuan.

Inabuy, V., Sutia, C., Maryana, O. F. T., Hardanie, B. D., & Lestari, S. H. (2023). *Ilmu pengetahuan alam untuk SMP/MTs kelas VII* (Edisi revisi). Pusat Perbukuan.

Intaramuean, M., Nonomura, A., & Boonrod, T. (2025). Empowering flood preparedness: Enhancing flood knowledge, risk perception, and preparedness among primary school learners in flood-affected southern Thailand. *Progress in Disaster Science, 26*, Article 100410. https://doi.org/10.1016/j.pdisas.2025.100410

Jáč, M. (2024). What can educational case studies reveal about how teachers implement the model of educational reconstruction in biology instruction? In *New Perspectives in Science Education: 13th International Conference* (pp. 14–17). https://conference.pixel-online.net/library_scheda.php?id_abs=6344

Johann, L., Groß, J., Messig, D., & Rusk, F. (2020). Content-based and cognitive-linguistic analysis of cell membrane biology: Educational reconstruction of scientific conceptions. *Education Sciences, 10*(6), Article 151. https://doi.org/10.3390/educsci10060151

Johar, R., Harnita, F., Sasaki, D., & Oktari, R. S. (2025). Incorporating disaster context into mathematical problem-solving abilities: The role of cognitive and affective needs. *International Journal of Disaster Risk Reduction, 116*, Article 105083. https://doi.org/10.1016/j.ijdrr.2024.105083

Keller, E. A., & DeVecchio, D. E. (2019). *Natural hazards: Earth's processes as hazards, disasters, and catastrophes* (5th ed.). Routledge. https://doi.org/10.4324/9781315164298

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education, 3*, Article 11. https://doi.org/10.1186/s40594-016-0046-z

Kelman, I., & Glantz, M. H. (2015). Analyzing the Sendai Framework for Disaster Risk Reduction. *International Journal of Disaster Risk Science, 6*(2), 105–106. https://doi.org/10.1007/s13753-015-0056-3

Ledger, S., Mailizar, M., Gregory, S., Tanti, M., Gibson, D., & Kruse, S. (2025). Learning to teach with simulation: Historical insights. *Journal of Computers in Education, 12*(1), 339–366. https://doi.org/10.1007/s40692-024-00313-2

Lin, S., & Opdyke, A. (2024). University student flood risk perceptions and flood probability knowledge in Greater Sydney. *Natural Hazards, 120*, 13851–13873. https://doi.org/10.1007/s11069-024-06757-0

Lord, T., Horwitz, P., Lee, H.-S., Pallant, A., & Lore, C. (2025). Using simulations to support students' conceptual development related to wildfire hazards and risks from an experiential learning perspective. *Journal of Science Education and Technology, 34*, 474–488. https://doi.org/10.1007/s10956-024-10126-8

Lownsbery, D. S. (2025). A synthesis review of four literature reviews of disaster risk reduction education for children. *International Journal of Disaster Risk Reduction, 125*, Article 105555. https://doi.org/10.1016/j.ijdrr.2025.105555

Metaxas, I., Michailidi, E., Stavrou, D., & Pavlidis, I. V. (2021). Educational reconstruction of size-depended-properties in nanotechnology for teaching in tertiary education. *Chemistry Teacher International, 3*(4), 413–422. https://doi.org/10.1515/cti-2021-0011

Pallant, A., Lee, H.-S., Lord, T., & Lore, C. (2025). Framing geohazard learning as risk assessment using a computer simulation: A case of flooding. *Journal of Science Education and Technology, 34*(3), 532–549. https://doi.org/10.1007/s10956-024-10151-7

Roehrig, G. H., Dare, E. A., Ellis, J. A., & Ring-Whalen, E. (2021). Beyond the basics: A detailed conceptual framework of integrated STEM. *Disciplinary and Interdisciplinary Science Education Research, 3*, Article 11. https://doi.org/10.1186/s43031-021-00041-y

Rofiah, N. H., & Kawai, N. (2025). Integrating disability-inclusive disaster education in primary schools: A case from Yogyakarta, Indonesia. *Progress in Disaster Science, 28*, Article 100482.

https://doi.org/10.1016/j.pdisas.2025.100482
Saregar, A., Putra, F. G., Diani, R., Anugrah, A., Misbah, M., & Umam, R. (2025). Innovative integrated disaster education in physics learning: An effort to enhance students' disaster literacy skills. *Jurnal Pendidikan IPA Indonesia, 14*(2), 324–336. https://doi.org/10.15294/jpii.v14i2.23959
Sari, W. A., Artika, W., Oktari, R. S., Safrida, Rahmatan, H., & Sasaki, D. (2025). Assessing education for sustainable development (ESD) competencies and environmental empathy in disaster and environment knowledge to support SDGs 2030. *Jurnal Pendidikan IPA Indonesia, 14*(1), 42–58. https://doi.org/10.15294/jpii.v14i1.15401
Shernoff, D. J., Sinha, S., Bressler, D. M., & Ginsburg, L. (2017). Assessing teacher education and professional development needs for the implementation of integrated approaches to STEM education. *International Journal of STEM Education, 4*, Article 13. https://doi.org/10.1186/s40594-017-0068-1
Stefaniak, J. E. (2020). *Needs assessment for learning and performance: Theory, process, and practice*. Routledge. https://doi.org/10.4324/9780429287510
Striligka, A., Bliesmer, K., Sajons, C., & Komorek, M. (2023). Adaptation of constructivist learning and teaching models for non-formal science education research. In P. G. Patrick (Ed.), *How people learn in informal science environments* (pp. 497–526). Springer. https://doi.org/10.1007/978-3-031-13291-9_24
Wahyono, U., Kade, A., & Untara, K. A. A. (2022). The implementation of local context modules as an effort for disaster risk reduction (An empirical study in disaster-affected schools). *Jurnal Pendidikan IPA Indonesia, 11*(3), 363–370. https://doi.org/10.15294/jpii.v11i3.37399
Widiyatmoko, A., & Shimizu, K. (2018). An overview of conceptual understanding in science education curriculum in Indonesia. *Journal of Physics: Conference Series, 983*(1), Article 012044. https://doi.org/10.1088/1742-6596/983/1/012044
Zhong, S., Cheng, Q., Zhang, S., Huang, C., & Wang, Z. (2021). An impact assessment of disaster education on children's flood risk perceptions in China: Policy implications for adaptation to climate extremes. *Science of the Total Environment, 757*, Article 143761. https://doi.org/10.1016/j.scitotenv.2020.143761
Zulfiya, I., Sumarmi, S., Wagistina, S., & Rosyida, F. (2023). Pengembangan bahan ajar digital berbasis STEM (Science, Technology, Engineering, and Mathematics) pada sub materi mitigasi bencana alam di Indonesia. *Jurnal Integrasi dan Harmoni Inovatif Ilmu-Ilmu Sosial, 3*(8), 828–848. https://doi.org/10.17977/um063v3i8p828-848