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Stimulating Students’ Critical Mathematical Thinking through STEAM-Based Mitigation Learning Activities: Design and Validation

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ABSTRACT

Integrating Science, Technology, Engineering, Art, and Mathematics (STEAM) with real-world issues, such as disaster mitigation in mathematics education, has the potential to foster students’ critical thinking through interdisciplinary and problem-based learning. However, existing instructional designs often lack contextual relevance and do not fully incorporate STEAM principles or the Engineering Design Process (EDP). This study employed a research and development approach using the 4D model (Define, Design, Develop, Disseminate) to create STEAM-based mathematics learning activities centred on disaster mitigation topics. Ten ninth-grade mathematics teachers from junior high schools in Semarang and Blora were involved in the development and validation process. Data were collected through expert validation sheets and teacher questionnaires, and analyzed using the Rasch model with the Winstep application. The developed learning activities demonstrated high reliability with a Rasch reliability coefficient of 0.90, indicating strong internal consistency and practical relevance. Expert validation confirmed the content and construct validity of the materials, supporting their feasibility for classroom implementation. The validation results suggest that the design is potentially suitable for classroom implementation, based on expert judgment and instrument validation outcomes. The study provides a validated and practical design for STEAM-based mathematics instruction that contextualizes disaster mitigation to enhance students’ critical thinking. Moreover, this innovative integration of STEAM and EDP offers a validated, practical STEAM-based mathematics learning design that supports teachers and enhances students’ critical thinking through real-world contexts. Its novelty is that it integrates STEAM and the EDP into disaster-themed mathematics learning to contextualize problem-solving and enhance students’ critical thinking.

Keywords: Critical Mathematical Thinking; Design STEAM Activities; STEAM; STEAM-Mitigation; Rasch Model.

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Introduction

In the 21st century, modern education must equip students with four core competencies known as the 4Cs: critical thinking, creative thinking, communication, and collaboration (Lin et al., 2021; Nahdi, 2019; Nurlenasari et al., 2019; Pramasdyahsari, 2023; Pramasdyahsari et al., 2022; Rahmawati & Juandi, 2022; and Wulandari, 2019). Among these, critical thinking and innovation are emphasized as central components of 21st-century learning (Trilling & Fadel, 2009), highlighting the importance of developing higher-order thinking skills. Mathematics plays a significant role in fostering these competencies. Mathematics supports students in achieving targeted learning outcomes by promoting critical, systematic, logical, and creative thinking (Damayanti & Afriansyah, 2018). This perspective is consistent with Ruseffendi's (1988) argument that mathematics fosters systematic, logical, and innovative thinking through its focus on ideas, procedures, and reasoning, making it a key medium for developing 21st-century skills. Fatwa et al. (2019) highlight the importance of critical thinking, problem solving, reasoning, creativity, and connections in mathematics learning. Given the emphasis on 21st-century skills and students' performance in Indonesia, strengthening mathematical critical thinking is an urgent priority.

Indonesian ninth-graders continue to underperform in math, scoring around 366 in TIMSS 2023 and PISA 2022, well below the OECD average of 472. Studies from 2024–2025 reveal major gaps in critical thinking, especially in inference, flexibility, and reasoning. This highlights the urgent need for innovative Science, Technology, Engineering, Art, and Mathematics (STEAM) and Engineering Design Process (EDP) based approaches to build essential problem-solving skills. These results reflect the generally low level of mathematical ability among Indonesian students. Supporting this concern, several studies conducted by (Agus & Purnama, 2022; Fitri et al., 2023; Pramuditya et al., 2019; and Septiana et al., 2019) have reported that junior high school students in Indonesia exhibit generally low levels of mathematical critical thinking ability.

Improving students' mathematical critical thinking is urgent, as teacher-centred methods still dominate classrooms, limiting meaningful learning (Septiana et al., 2019). This leads to passive knowledge transfer, with students as recipients rather than active learners. A shift to student-centred, inquiry-based instruction is needed to promote engagement, collaboration, and problem-solving—key to developing higher-order thinking skills (Putri et al., 2024; Nuryadi et al., 2024).

Integrating real-world contexts, such as disaster mitigation, can enhance the relevance of mathematics instruction. Indonesia's location on the Pacific Ring of Fire makes it highly susceptible to natural disasters like earthquakes, tsunamis, floods, and volcanic eruptions—risks intensified by socio-demographic and climate factors (Hartono et al., 2021). In response, Law No. 24 of 2007 mandates mitigation as a key part of disaster management. Educating students on mitigation is thus timely and crucial, especially in high-risk areas Hayudityas (2020) emphasizes that students should learn about disasters through real-life experiences to build safety and preparedness. Integrating disaster themes into STEAM-based math instruction contextualizes abstract concepts while fostering critical thinking and responsible citizenship. This interdisciplinary approach equips students with both cognitive and practical problem-solving skills.

However, disaster mitigation education remains limited in Indonesian schools. According to Hayudityas (2020), Indonesia faces two major challenges: ineffective disaster management and low public awareness of mitigation efforts. Additionally, schools have yet to play a significant role in delivering comprehensive disaster mitigation education. Subjects such as Social Studies, particularly Geography, tend to provide only brief or superficial coverage of mitigation topics. Moreover, the content is often presented in a conventional and unengaging manner, causing students to quickly forget the material.

On the other hand, mathematics plays a crucial role in supporting integrated learning across various subjects. Students should understand the connections between mathematical concepts and other disciplines as part of their mathematics learning (Faturohman & Afriansyah, 2020). By linking mathematical ideas, students deepen their understanding through recognizing relationships among mathematical topics, other sciences, and real-life experiences (Hendriana et al., 2014; Saminanto & Kartono, 2015). This demonstrates the practical value of mathematics in solving everyday problems, including disaster mitigation. Given the demands of 21st-century education, current environmental challenges, and the state of mathematics learning, there is a clear need to develop learning activities and approaches that effectively support these objectives.

Integrating STEAM with real-world challenges, such as disaster mitigation in mathematics education, can significantly enhance students' critical thinking through interdisciplinary and problem-based learning. It also supports the connection between mathematical concepts and disaster mitigation efforts, helping students see the practical value of mathematics in everyday problem-solving. Additionally, STEAM fosters the development of vital 21st-century skills, including communication, critical thinking, leadership, teamwork, creativity, resilience, and higher-order thinking (Baharin et al., 2018; Cooke, 2022; Zakeri et al., 2023; Astutik et al., 2024; Hadinugrahaningsih et al., 2017; Mu'minah & Suryaningsih, 2020; Zubaidah, 2019; Pramasdyahsari et al., 2025; Pramasdyasari et al., 2024; Yuliari et al., 2020).

Research by Astutik et al. (2024) and Hadinugrahaningsih et al. (2017) supports STEAM integration to foster 21st-century skills, including critical thinking. Yet, few studies focus specifically on mathematics education within STEAM or evaluate how these designs are validated and adapted for classroom use, particularly on local issues like disaster mitigation. Therefore, there is a need to design mathematics activities that involve planning a learning process to produce specific outcomes aimed at solving real-world problems, such as disaster mitigation. This approach centres the learning experience on students, requiring them to participate and create products that address disaster-related challenges actively. Achieving these demands requires strong mathematical skills, particularly critical thinking.

Many current mathematics learning designs lack contextual relevance and fail to integrate STEAM principles or the Engineering Design Process (EDP), limiting opportunities to foster students' critical thinking. Traditional instruction often emphasizes abstract problems disconnected from real-world contexts, reducing engagement and higher-order thinking (Boaler, 2016; NCTM, 2014). The absence of interdisciplinary, design-based approaches like STEAM and EDP further restricts meaningful problem-solving experiences (Beers, 2011; Kelley & Knowles, 2016). Culturally relevant pedagogy is essential for critical thinking, especially in diverse settings (Gay, 2010; Ladson-Billings, 1995). To address this, the study uses the 4D model (define, design, develop, and disseminate) by Thiagarajan et al. (1974) to guide the development of a STEAM-Mitigation-based mathematical activity aimed at enhancing students' critical mathematical thinking.

Methods

This study employs a Research and Development (R&D) approach (Sugiyono, 2013) aimed at designing, developing, validating, and testing the practicality of a STEAM-based mathematics learning activity with a focus on disaster mitigation. The development process follows the 4D model by Thiagarajan et al. (1974), which includes four stages: define, design, develop, and disseminate. However, this study is limited to the first three stages (define, design, develop), while the disseminate phase is planned for future research, as shown in Figure 1.

In the Define stage, a needs analysis through literature review, curriculum analysis, and field observations revealed gaps in connecting math concepts with real-world contexts like disaster mitigation. Student traits, competencies, and Grade 9 learning goals were also mapped. In the Design stage, learning objectives were set, and STEAM and mitigation content were integrated with EDP into draft activities. The initial prototype included task sheets, media, and assessments aligned with critical thinking indicators, ready for expert review.

During development, experts validated the learning design's content and construct, followed by a limited trial with ten Grade 9 math teachers from Semarang and Blora, selected based on experience, willingness, and proximity to disaster-prone areas. The main product was a STEAM-based math activity integrating disaster mitigation. Instruments included: (1) a validation sheet assessing relevance, clarity, feasibility, and STEAM–EDP alignment; (2) a practicality questionnaire evaluating usability and clarity; and (3) a validation sheet for the questionnaire's construct validity.

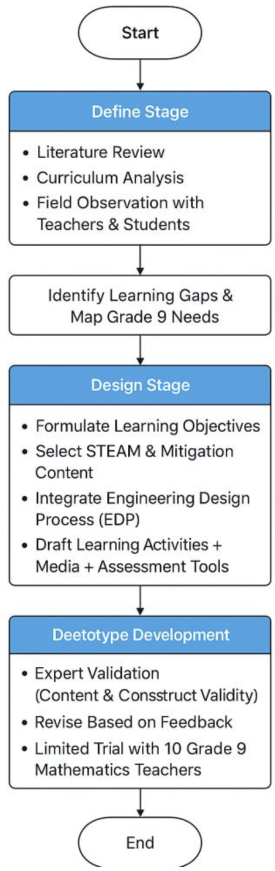


Figure 1. *Research Procedures using 4D Model*

All instruments were self-developed, guided by established frameworks in instructional design and STEAM education (e.g., Wiggins & McTighe, 2005; Bybee, 2010), and were validated by content experts.

Two main analysis techniques were used: (1) Aiken's V was applied to analyze expert validation data. Aiken's V values ≥ 0.80 were interpreted as indicating a high level of content validity (Azwar, 2017); (2) to evaluate the practicality of the learning design based on teacher responses, Rasch model analysis was conducted using Winsteps software. This analysis yielded item and person reliability scores, item fit statistics, and logit-based scales to assess the internal consistency and appropriateness of the instrument. A reliability coefficient of ≥ 0.80 was considered acceptable (Bond & Fox, 2015).

This rigorous multi-step methodology ensures the initial feasibility, validity, and practicality of the developed STEAM-Mitigation learning design, while also laying the groundwork for future dissemination and implementation studies.

Results and Discussion

The development of a STEAM-Mitigation-based mathematics activity design aimed at stimulating the mathematical critical thinking skills of ninth-grade junior high school students was carried out in stages following the 4D development model. This model consists of four key phases: (1) Define, (2) Design, (3) Develop, and (4) Disseminate.

1. Define

The Define phase identified key issues in current math instruction, highlighting the need for a STEAM-Mitigation-based activity design. Law No. 24 of 2007 defines disasters as events causing harm to life, property, and the environment. A lack of disaster knowledge increases risk (Raja et al., 2017). Observations in nine junior high schools across Semarang and Blora revealed low academic performance and limited disaster education. Hayudityas (2020) notes poor disaster management and low public awareness, with schools rarely integrating mitigation into learning, underscoring the urgency of curriculum reform.

Issues in math instruction also emerged, notably students' low critical thinking skills, largely due to traditional, teacher-centred methods Septiana et al. (2019). These limit engagement and hinder higher-order thinking. Fatwa et al. (2019) stress the need to prioritize skills like reasoning, problem-solving, and creativity. Given current environmental risks and educational gaps, there's a clear need for learning activities that strengthen critical mathematical thinking while integrating disaster mitigation education. , notes that most mathematics teachers in primary and secondary schools continue to rely on teacher-centred learning approaches. Such approaches limit student engagement and reduce opportunities for developing higher-order thinking skills. Consequently, traditional instructional methods are likely contributing to the underdevelopment of students' critical mathematical thinking abilities.

Faturohman & Afriansyah (2020) stress the importance of connecting math concepts with other subjects, which can be achieved through the STEAM approach. This study develops a STEAM-Mitigation-based math activity to support disaster education and foster critical thinking in ninth-grade students. STEAM learning promotes active engagement and enhances critical thinking (Pramasdyahsari et al., 2022). Instructional goals were set based on students' needs, focusing on real-world math applications related to disaster mitigation.

2. Design

The Design stage involves creating activity designs based on needs analysis and instructional goals from the Define phase. Each math project presents a disaster scenario requiring mitigation tools that use ninth-grade math concepts. Problem frameworks are developed using the EDP, which fosters analytical and systematic problem-solving (Kelley & Knowles, 2016) and aligns with STEAM's interdisciplinary approach. EDP stages—defining, researching, planning, creating, testing, redesigning, and communicating—guide students in developing real-world mitigation projects while enhancing critical mathematical thinking (Guzey et al., 2016).

The design also outlines how teachers can implement the approach through structured sequences, instructions, and sample activities aligned with STEAM and disaster themes, ensuring practicality and pedagogical clarity. Media selection follows the Define stage, involving hands-on projects with limited materials to promote critical thinking. Five projects are developed in both teacher and student versions. The teacher version includes detailed guidance, analysis, and evaluation tools, while the student version presents simplified content and visual aids within the same STEAM-EDP framework.

This study uses Facione's (2015) critical thinking indicators: interpretation, analysis, evaluation, inference, explanation, and self-regulation. Interpretation involves understanding problems through project construction. Analysis requires examining math use and appropriate mitigation strategies. Evaluation reflects decision-making based on gathered information. Inference involves identifying components for effective solutions, while explanation requires logical justification. Self-regulation is shown in planning and making purposeful decisions. Facione's framework is well-suited for assessing critical thinking in this context.

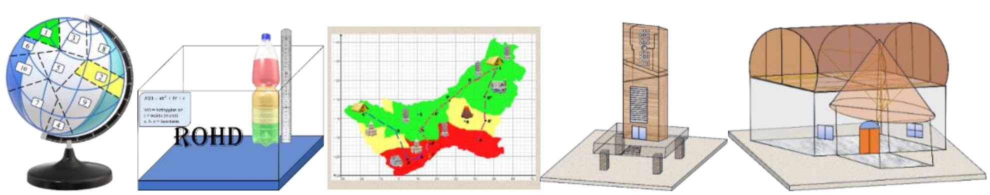
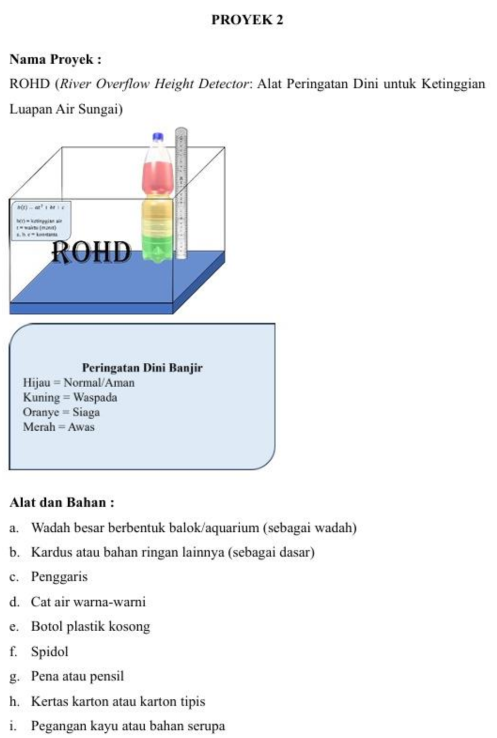


Figure 2. *Illustration of the product produced from the mathematics activity.*

Figure 2 shows the initial version before testing with teachers. It will first undergo expert validation and necessary revisions before being implemented in the fourth stage, disseminated. Meanwhile, Figure 3 shows the final design activities of the River Overflow Height Detector. Thus, during the Design phase, alongside developing the mathematics activity design, a research instrument, a practicality questionnaire for teachers, is also created. This questionnaire aims to evaluate whether the activity design is practical and supports teachers in delivering instruction. The evaluation criteria in the questionnaire are aligned with the research objectives and the elements included in the activity design. The instrument will be further validated during the development phase.


PROYEK 2

Nama Proyek :
ROHD (*River Overflow Height Detector*: Alat Peringatan Dini untuk Ketinggian Luapan Air Sungai)

Alat dan Bahan :
a. Wadah besar berbentuk balok/aquarium (sebagai wadah)
b. Kardus atau bahan ringan lainnya (sebagai dasar)
c. Penggaris
d. Cat air warna-warni
e. Botol plastik kosong
f. Spidol
g. Pena atau pensil
h. Kertas karton atau karton tipis
i. Pegangan kayu atau bahan serupa

PROJECT 2
Project Name:
ROHD (River Overflow Height Detector): Early Warning Tool for River Water Overflow Height

[Picture showing the ROHD model with colour-coded levels]

Flood Early Warning System
Green = Normal/Safe
Yellow = Alert
Orange = Standby
Red = Danger
Tools and Materials:
a. Large rectangular container/aquarium (as the water container)
b. Cardboard or other lightweight material (as the base)
c. Ruler
d. Colorful water-based paint
e. Empty plastic bottles
f. Marker
g. Pen or pencil
h. Cardstock or thin cardboard
i. Wooden handle or similar material

Figure 3. *The River Overflow Height Detector*

3. Develop

In the Develop phase, the STEAM-Mitigation-based math activity design was produced to enhance ninth-grade students' critical thinking. The researcher prepared validation instruments to ensure the design and practicality questionnaire accurately measured their targets (Sumintono & Widhiarso, 2013).

Two instruments were developed:

1. A design validation sheet covering STEAM learning, math content, mitigation, and critical thinking.
2. A practicality validation sheet assessing clarity, evaluation criteria, and language.

Five experts reviewed the instruments, including lecturers, a SEAQIM expert, and math teachers. Validation results are shown in Table 1.

Table 1 shows that the activity design was generally well validated, with strong ratings for STEAM integration and mitigation education. However, aspects of math learning and critical thinking received slightly lower scores, indicating a need for improvement to better support mathematical understanding and higher-order thinking.

Table 1. *Results of the validation test of the mathematical activity design for STEAM mitigation based*

Validator	STEAM Aspects	Mathematics Learning Aspects	Mitigation Education Aspects	Critical Mathematical Thinking Aspects	Average
1	100%	100%	100%	100%	100%
2	80%	80%	80%	80%	80%
3	93.33%	93.33%	93.33%	83.33%	90.83%
4	93.33%	83.33%	93.33%	83.33%	88.33%
5	83.33%	73.33%	86.67%	80.00%	80.83%
Average	**90%**	**86%**	**90.67%**	**85.33%**	**87.62%**

According to Sugiyono's (2015) validity standards, this indicates the activity design is highly suitable for testing. To further support these results, the researcher analyzed the validation data using Aiken’s V coefficient. The criteria for instrument validity using Aiken’s V in this study are outlined in Table 2.

Table 2. *Validity Criteria* (Sugiyono, 2015)

Score	**Description**
0.8 – 1	Very High
0.6 – 0.79	High
0.4 – 0.59	Moderate
0.2 – 0.39	Low
0.0 – 0.19	Very Low

The activity design achieved an Aiken’s V validity coefficient of 0.8452, indicating a very high level of validity. This confirms that the STEAM-Mitigation mathematics activity design effectively captures the key aspects needed to stimulate critical mathematical thinking in ninth-grade students, making it well-suited for implementation. Following the validation process, revisions were made to the design by the expert feedback received. The validation result on activity design is described in Figure 4.

Item	Validator					S_1	S_2	S_3	S_4	S_5	Σs	n(c-1)	V	Explanation
	I	II	III	IV	V									
Item-1	5	4	5	5	4	4	3	4	4	3	18	20	0.9	Very High
Item-2	5	4	5	5	5	4	3	4	4	4	19	20	0.95	Very High
Item-3	5	4	5	4	4	4	3	4	3	3	17	20	0.85	Very High
Item-4	5	4	5	5	4	4	3	4	4	3	18	20	0.9	Very High
Item-5	5	4	4	5	4	4	3	3	4	3	17	20	0.85	Very High
Item-6	5	4	4	4	4	4	3	3	3	3	16	20	0.8	Very High
Item-7	5	4	5	4	3	4	3	4	3	2	16	20	0.8	Very High
Item-8	5	4	5	4	3	4	3	4	3	2	16	20	0.8	Very High
Item-9	5	4	4	5	4	4	3	3	4	3	17	20	0.85	Very High
Item-10	5	4	4	4	5	4	3	3	3	4	17	20	0.85	Very High
Item-11	5	4	5	4	4	4	3	4	3	3	17	20	0.85	Very High
Item-12	5	4	5	4	3	4	3	4	3	2	16	20	0.8	Very High
Item-13	5	4	5	5	5	4	3	4	4	4	19	20	0.95	Very High
Item-14	5	4	5	5	4	4	3	4	4	3	18	20	0.9	Very High
Item-15	5	4	4	4	4	4	3	3	3	3	16	20	0.8	Very High
Item-16	5	4	5	5	4	4	3	4	4	3	18	20	0.9	Very High
Item-17	5	4	4	4	4	4	3	3	3	3	16	20	0.8	Very High
Item-18	5	4	3	4	4	4	3	2	3	3	15	20	0.75	High
Item-19	5	4	5	4	4	4	3	4	3	3	17	20	0.85	Very High
Item-20	5	4	5	4	4	4	3	4	3	3	17	20	0.85	Very High
Item-21	5	4	3	4	4	4	3	2	3	3	15	20	0.75	HIgh

Item	Validator					S_1	S_2	S_3	S_4	S_5	Σs	n(c-1)	V	Explanation
	I	II	III	IV	V									
Item 1-21	105	84	95	92	84	84	63	74	71	63	355	420	0.845238	Very High

Figure 4. *Activity Design Expert Validation Results Using Aiken's V*

Figure 4 shows the results of expert validation for 21 items in the activity design using Aiken's V index. Most items (19 out of 21) have very high validity ($V \geq 0.80$), while 2 items have high validity ($V = 0.75$). The overall Aiken's V score is 0.845, indicating that the instrument has very high content validity based on expert judgment.

Meanwhile, the questionnaire for testing the practicality of mathematical activity design was then reviewed by validators. There are four validators for the practicality test questionnaire (two mathematics education lecturers and two mathematics teachers). The results in Table 3 were obtained through an expert validation process. Four experts assessed the questionnaire based on three aspects: instruction, evaluation, and language. Each expert rated the questionnaire using a percentage scale. The scores were then averaged per aspect and overall. This process confirmed that the questionnaire is valid and suitable for evaluating the practicality of the mathematical activity design.

Table 3. *Results of the validation test of the questionnaire for testing the practicality of mathematical activity design*

Validator	Instruction Aspects	Evaluation Aspects	Language Aspects	Average
1	90%	97.50%	100%	95.83%
2	80%	80%	80%	80%
3	100%	95%	100 %	98.33%
4	100%	90%	80%	90%
Average	**92.50%**	**90.63%**	**90%**	**91.04%**

Table 3 shows that the questionnaire for assessing the practicality of the mathematical activity design was generally rated highly by the validators. The strongest aspect was the clarity of instructions (92.50%), followed by evaluation quality (90.63%) and language use (90%). While most validators found the questionnaire clear, relevant, and well-structured, some suggested minor improvements, especially in language. Overall, the questionnaire is considered valid and appropriate for use in measuring the practicality of the activity design.

Figure 5 indicates that the assessment sheet is highly suitable for practical implementation. Additionally, using Aiken's V, the validity coefficient was calculated at 0.885, reflecting a very high level of validity. This suggests that the practicality questionnaire for the STEAM-Mitigation-based mathematics activity design aimed at enhancing 9th-grade students' critical mathematical thinking is valid and comprehensively captures all relevant aspects of practical application for teachers. Consequently, the questionnaire is deemed appropriate for distribution following expert-recommended revisions.

Item	Validator				S_1	S_2	S_3	S_4	Σs	n(c-1)	V	Explanation
	I	II	III	IV								
Item-1	5	4	5	5	4	3	4	4	15	16	0.9375	Very High
Item-2	4	4	5	5	3	3	4	4	14	16	0.875	Very High
Item-3	5	4	5	5	4	3	4	4	15	16	0.9375	Very High
Item-4	5	4	5	5	4	3	4	4	15	16	0.9375	Very High
Item-5	4	4	4	5	3	3	3	4	13	16	0.8125	Very High
Item-6	5	4	4	4	4	3	3	3	13	16	0.8125	Very High
Item-7	5	4	5	4	4	3	4	3	14	16	0.875	Very High
Item-8	5	4	5	4	4	3	4	3	14	16	0.875	Very High
Item-9	5	4	5	4	4	3	4	3	14	16	0.875	Very High
Item-10	5	4	5	5	4	3	4	4	15	16	0.9375	Very High
Item-11	5	4	5	4	4	3	4	3	14	16	0.875	Very High
Item-12	5	4	5	4	4	3	4	3	14	16	0.875	Very High

Item	Validator				S_1	S_2	S_3	S_4	Σs	n(c-1)	V	Explanation
	I	II	III	IV								
Item 1-12	58	48	58	54	46	36	46	42	170	192	0.88542	Very High

Figure 5. *Validation Results of the Practicality Test Questionnaire for the Activity Design Using Aiken's V*

The next phase involved development testing. After validation and revision of the activity design and practicality questionnaire, the materials were trialed in a limited test. Teachers' responses on the practicality sheet yielded an average Likert-scale score of 86.93%, indicating a high level of practicality, though further analysis is recommended.

In the Disseminate stage, the aim is to share the developed activity design. Although this phase typically includes broader distribution, constraints limited the focus to validity testing only. Data from the Develop stage were analyzed for validity and reliability using the Rasch Model to assess whether the design is ready for wider implementation or requires further refinement.

The Winstep analysis showed a practicality score of 34.8% (Figure 6), indicating the design is reasonably effective for classroom use. The results suggest the STEAM-Mitigation-based activity design is practical for supporting disaster education while promoting critical mathematical thinking in Grade IX.

```
      Table of STANDARDIZED RESIDUAL variance in Eigenvalue units = ITEM information units
                                          Eigenvalue   Observed   Expected
 Total raw variance in observations     =      27.5946 100.0%         100.0%
   Raw variance explained by measures   =       9.5946  34.8%          34.5%
     Raw variance explained by persons  =       6.6191  24.0%          23.8%
     Raw Variance explained by items    =       2.9755  10.8%          10.7%
   Raw unexplained variance (total)     =      18.0000  65.2% 100.0%   65.5%
     Unexplned variance in 1st contrast =       6.5537  23.8%  36.4%
     Unexplned variance in 2nd contrast =       3.3561  12.2%  18.6%
     Unexplned variance in 3rd contrast =       2.8448  10.3%  15.8%
     Unexplned variance in 4th contrast =       1.9961   7.2%  11.1%
     Unexplned variance in 5th contrast =       1.6727   6.1%   9.3%
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Figure 6. *Practicality Validation Results of the Activity Design Using Winstep Software*

Following this, a reliability test was conducted on the responses from the practicality questionnaire. The calculation of the reliability of the practicality of the activity design is displayed in Figure 7. Instrument reliability refers to the consistency of a measurement tool over time. As noted by Slamet & Wahyuningsih (2022), reliability testing determines whether a measuring instrument consistently produces dependable results across repeated uses. In this study, Cronbach's Alpha was used to evaluate the reliability of the questionnaire items. This coefficient measures the internal consistency between respondents and items (Sumintono & Widhiarso, 2013). The interpretation of Cronbach's Alpha reliability in this research is based on criteria established by (Sugiyono, 2013).

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     SUMMARY OF 12 MEASURED (EXTREME AND NON-EXTREME) PERSON
-------------------------------------------------------------------------------
|          TOTAL                         MODEL         INFIT        OUTFIT    |
|          SCORE      COUNT     MEASURE   S.E.      MNSQ   ZSTD   MNSQ   ZSTD |
|-----------------------------------------------------------------------------|
| MEAN      78.9       18.0       2.80     .62                                |
|  SEM       1.9         .0        .56     .11                                |
| P.SD       6.2         .0       1.87     .37                                |
| S.SD       6.5         .0       1.96     .39                                |
| MAX.      90.0       18.0       7.30    1.84                                |
| MIN.      71.0       18.0        .72     .46                                |
|-----------------------------------------------------------------------------|
| REAL RMSE    .76 TRUE SD    1.71  SEPARATION  2.24  PERSON RELIABILITY  .83 |
|MODEL RMSE    .72 TRUE SD    1.73  SEPARATION  2.40  PERSON RELIABILITY  .85 |
| S.E. OF PERSON MEAN = .56                                                   |
-------------------------------------------------------------------------------
PERSON RAW SCORE-TO-MEASURE CORRELATION = .97
CRONBACH ALPHA (KR-20) PERSON RAW SCORE "TEST" RELIABILITY = .90  SEM = 1.99
STANDARDIZED (50 ITEM) RELIABILITY = .94
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Figure 7. *Reliability Calculation of the Practicality of the Activity Design Using Winstep Software*

Using the Winstep application, the practicality test of the activity design yielded a reliability score of 0.90, placing it in the "highly reliable" category. This indicates that the STEAM-Mitigation-based mathematics activity design is not only dependable but also consistently practical for teachers to use in fostering critical mathematical thinking skills among Grade IX students.

The findings show that the STEAM-Mitigation-based math activity design has strong content validity, confirmed by expert validation using Aiken's V. This indicates alignment with educational goals and suitability for real-world, integrated learning. The validated practicality instrument ensures reliable feedback for future use. The design is effective for fostering critical mathematical thinking and interdisciplinary learning with a disaster mitigation focus. This study also provides a replicable model for developing and validating STEAM-based instructional tools and underscores the value of expert involvement in ensuring clarity, relevance, and effectiveness.

Conclusion

This study designed and validated a STEAM-based mathematics activity integrating disaster mitigation to promote critical thinking in Grade IX students. Grounded in the STEAM framework and EDP, the activity supports contextual, student-centered learning. Expert validation and Rasch analysis (reliability = 0.90) confirmed the design's validity, though the practicality score (34.8%) suggests moderate usability. The study offers a structured, empirically supported model aligned with disaster education policies and 21st-century skill development. While dissemination was not conducted due to resource limits, future research will involve student trials to assess learning outcomes. The study's novelty lies in integrating STEAM and EDP within a disaster context, making mathematics learning more meaningful and locally relevant—an innovative model for curriculum development.

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