User-Centered Interface Design and Usability Evaluation of SEISMORA: An Augmented Reality Application for Earthquake Mitigation

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ABSTRACT

Indonesia's high seismic exposure requires disaster education media that are understandable and usable by the general public. This study designed and evaluated SEISMORA, a mobile Augmented Reality (AR) application for earthquake mitigation education, using a User-Centered Design (UCD) approach. The design process comprised four iterative stages: specifying the context of use, identifying user requirements, developing design solutions, and evaluating the prototype. SEISMORA integrates PDF and video materials, AR-based evacuation simulations, and evacuation-route guidance within a simplified interface tailored to users in earthquake-prone communities. An initial summative usability evaluation involved 30 Android smartphone users aged 17–50 years in Yogyakarta. Perceived usability was measured using the 10-item System Usability Scale (SUS) and complemented by brief post-test feedback. The application obtained a mean SUS score of 78.5, indicating good and acceptable perceived usability. Descriptive responses suggested that the interface was easy to use and learn, while post-test feedback identified marker scanning under inadequate lighting or camera angles as the main interaction challenge. The findings provide initial evidence that context-specific integration of UCD and AR can produce an acceptable interface for community earthquake education. Broader multi-site testing, objective task-performance measures, and pretest–posttest preparedness assessment are required before claims of real-world effectiveness or population-level generalizability can be made.

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I. INTRODUCTION

Indonesia is among the countries with the highest seismic vulnerability worldwide. Its location at the convergence of the Indo-Australian, Eurasian, and Pacific plates places the archipelago in a region with frequent earthquakes [1]–[4]. The Pacific Ring of Fire crosses Indonesia and produces seismic activity almost every day, although most events are not felt by the public [4]. Nevertheless, destructive earthquakes remain a persistent threat, as demonstrated by Indonesia's long history of seismic disasters.

Physical vulnerability is compounded by limited community preparedness. Mulyandari (2025) reported that most hamlets in Jogotirto Village, Sleman, located along the active Opak Fault, were classified from "unprepared" to "extremely unprepared" [1]. Jlatren Hamlet recorded a Disaster Resilience Index of 0.25, indicating very high vulnerability [1]. Similar preparedness challenges have been reported in coastal communities exposed to earthquake and tsunami hazards, including Kampung Nelayan Seberang, Belawan [2], [5].

Low preparedness is partly associated with disaster education that relies on lectures, outreach, and posters, which may not provide sufficiently interactive learning experiences [1], [2]. Understanding procedures such as "Drop, Cover, and Hold On" is essential during an earthquake. A participatory program in Tegaltirto that combined explanation with hands-on practice increased post-test scores by 72%, suggesting that active learning can reinforce mitigation knowledge [2].

Digital technology creates opportunities for more interactive disaster education. Augmented Reality (AR) overlays 3D virtual objects on the physical environment in real time and can support immersive learning. Prayogi and Hendarto (2024) developed an AR earthquake teaching aid for elementary school students that presents actions before, during, and after an earthquake [3], while Fulvian (2026) implemented AR in book-based earthquake mitigation education [4]. Yahaya and Mat Zain (2024) reported a SUS score of 73.5 for an AR flood simulation [6], and Covarrubias et al. (2024) explored HoloLens-based emergency training in an industrial setting [7]. More recent disaster-preparedness research has combined mobile AR with task performance and workload assessment across age groups, while location-based AR studies have shown that tracking accuracy can influence perceived usability and have used multiple usability instruments. These studies demonstrate the potential of AR, but also show that interface design, technical reliability, and alignment with user characteristics are critical.

In emergency-related contexts, interface design must account for users who may face distraction, time pressure, and high cognitive demand. Elmasllari and Kirk (2023) emphasize that emergency-response systems should be designed around the needs of people working in chaotic and high-pressure situations [8]. Complex or unintuitive interaction can slow response and increase risk; consequently, a User-Centered Design (UCD) approach is relevant to the development of disaster-mitigation applications.

Existing work has generally focused on school teaching aids, flood simulations, professional emergency training, or standalone navigation and warning interfaces. Less attention has been given to integrating locally derived community requirements, multi-format mitigation materials, AR evacuation practice, and evacuation-route guidance within a single mobile interface for the general public. Accordingly, this study aims to design and conduct an initial usability evaluation of the SEISMORA AR application using UCD. The distinct contribution is not the use of UCD or AR in isolation, but their context-specific integration through: (1) requirements derived from communities in earthquake-prone areas; (2) a unified interface for PDF and video materials, AR simulation, and route guidance; and (3) a standardized SUS evaluation complemented by post-test feedback. SUS was selected because it provides a concise and widely used measure of perceived usability [9]–[11].

II. METHODOLOGY

This research employs a Research and Development (R&D) methodology within a User-Centered Design (UCD) framework, which consists of four iterative stages:

1. specifying the context of use,
2. specifying user requirements,
3. developing design solutions, and
4. evaluating the prototype.

The UCD approach was selected because it emphasizes user involvement throughout the development cycle and supports iterative alignment between the product, user characteristics, and use context [9], [12].

A. Phase 1: Usage Context Specification

This phase aims to understand user characteristics, the tasks to be performed, and the application's usage environment. The target users are the general public in earthquake-prone areas aged 17–50, representing the productive age group and possessing the cognitive capacity to use smartphone-based applications. The target areas include the villages of Jogotirto and Tegaltirto in Sleman Regency, which lie along the active Opak Fault, as well as coastal areas at risk of earthquakes and tsunamis [1], [2], [5].

A usage context analysis identified that users will access the app in potentially emergency situations as well as for self-directed learning at home. The usage environment includes varying lighting conditions and potential external distractions. The app's primary function is to educate users on earthquake mitigation procedures through interactive 3D visualizations and simulations of self-rescue steps.

B. Phase 2: User Requirements Specification

User needs were identified through a literature review, field observations informed by previous studies of earthquake-prone communities [1], [2], and questionnaires. The primary needs identified include:

1. A simple interface with minimal text to accommodate users with varying levels of literacy and technological understanding;
2. Easy-to-follow, step-by-step visual guides that do not require reading lengthy instructions;
3. Instant feedback to ensure users understand the actions they need to take;
4. Intuitive navigation with a clear information hierarchy;
5. Use of Indonesian language that is easily understood by the general public;
6. Ability to use the system without assistance from others or technicians [9].

C. Phase 3: Solution Design

Based on the requirements specifications, an AR application was developed using the Unity platform and the Vuforia Engine. Unity was chosen as the primary game engine because it supports cross-platform development and has a mature ecosystem for AR development [4], [7]. The

Vuforia Engine was used to detect and track AR markers that trigger the appearance of 3D objects.

The app's main content includes:

1. PDF materials related to earthquake mitigation guidelines and information,
2. Video materials on disaster preparedness education,
3. Evacuation simulations in an AR environment,
4. Evacuation route maps,
5. Tutorials on using the app
6. Scan the marker for evacuation route information.

The interface design follows the principles of learnability and ease of use by placing key navigation elements within easy reach of the thumb (thumb zone) and using easily recognizable icons.

D. Stage 4: Usability Evaluation Using SUS and Post-Test Feedback

Perceived usability was evaluated with the System Usability Scale (SUS), which contains 10 statements rated on a five-point Likert scale (1 = Strongly Disagree; 5 = Strongly Agree) [9]. Odd-numbered items are positively worded and even-numbered items are negatively worded to reduce acquiescence bias [13]. SUS is interpreted primarily as a single composite score rather than as separate item-level usability dimensions. Accordingly, the item labels in Table I are used only as descriptive design diagnostics and not as independent validated subscales.

TABLE I. SUS ITEMS AND DESIGN-ORIENTED DIAGNOSTIC INTERPRETATIONS

No	Statement	Type	Item Focus	Design Diagnostic
1	I plan to use this system again	Positive	Frequency of use	Willingness to use again
2	I find this system complicated to use	Negative	Complexity	Perceived ease of access
3	I find this system easy to use	Positive	Ease of use	Perception of operational ease
4	I need help from someone else/a technician	Negative	Need for support	User independence
5	I feel that the system features are working as they should	Positive	Function	System Functional Performance
6	I feel there are many inconsistencies	Negative	Consistency	Design consistency
7	Others will understand this system quickly	Positive	Learnability	Speed of adaptation
8	I find this system confusing	Negative	Confusion	Clarity of navigation
9	I feel there are no obstacles to using this system	Positive	Confidence	Level of confidence
10	I need to get used to it first	Negative	Prior learning needs	Initial cognitive load

The scale used is the Likert scale (5-point Likert scale), namely,

STS = 1 (Strongly Disagree)

TS = 2 (Disagree)

RG = 3 (Undecided)

ST = 4 (Agree)

SS = 5 (Strongly Agree)

SUS Score Calculation Formula:

a. For odd-numbered items (positive): contribution = (respondent's score - 1)
b. For even-numbered items (negative): contribution = (5 - respondent's score)
c. Total score = sum of all contributions × 2.5

The item contributions are summed and multiplied by 2.5, producing a total score from 0 to 100; higher values indicate better perceived usability [9], [14].

Respondents and Data Collection Procedures:

The evaluation involved 30 respondents from the earthquake-prone Yogyakarta region. The sample was selected for an initial summative usability evaluation. Guidance synthesized by Macefield places many summative usability studies within approximately 8–25 participants, while larger samples provide more stable quantitative estimates; therefore, 30 participants was considered adequate for an initial descriptive prototype assessment within one region. The sample was not intended to represent the wider Indonesian population. The inclusion criteria were:

1. aged 17–50 years,
2. owning a smartphone with the Android operating system, and
3. willing to participate voluntarily.

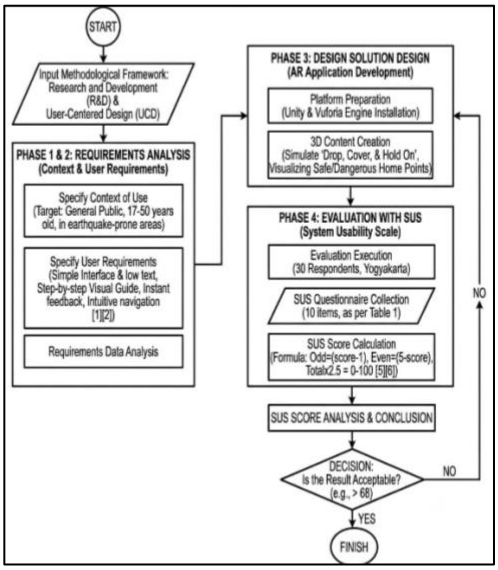

Fig. 1. Flowchart

After using the AR application and participating in the mitigation simulation, respondents completed the SUS independently. The total SUS score was calculated for each respondent before the mean and frequency distribution were summarized using the interpretation of Bangor, Kortum, and Miller [13]. Brief post-test questions were also used to clarify interaction difficulties, particularly during marker scanning; these comments were used only to explain the quantitative results. Objective measures such as task completion time, error rate, workload, and knowledge gain were not collected in this initial evaluation. Figure 1 summarizes the research procedure.

E. SEISMORA AR Application Interface Design

The SEISMORA main menu presents four core functions PDF Materials, Video Materials, Evacuation Simulation, and Evacuation Routes using recognizable icons, short labels, and a consistent grid. This arrangement directly addresses the requirements for minimal text, clear information hierarchy, and rapid access. File size and video duration help users anticipate content before opening it, while consistent back and home controls reduce navigation uncertainty.

The AR module allows users to scan markers to display evacuation routes, assembly points, and interactive simulations in the surrounding environment. Camera guidance on lighting and marker position is placed before scanning to prevent avoidable tracking failures. Safety prompts such as “Cover!” and “Hold On!” are presented at relevant stages of the simulation so that the interface reinforces the sequence of protective actions rather than functioning only as a visual display. Figures 2–8 present the implemented screens.

Fig. 2. SEISMORA Application Logo

Fig. 3. SEISMORA Home Screen

Fig. 4. SEISMORA Main Navigation

Fig. 5. Video Content Design

The visual elements operationalize the user requirements identified in Phase 2. Icons and short labels reduce reading demand; the PDF and video modules support different learning preferences; numbered simulation steps support sequential comprehension; and the route screen combines a map, destination marker, distance information, and a single navigation action to limit unnecessary choices. Positioning frequently used controls within the thumb zone supports one-handed smartphone interaction, while high-contrast safety cues improve recognition. Thus, the screenshots represent traceable design decisions intended to improve learnability, navigation clarity, and user independence, rather than decorative elements alone.

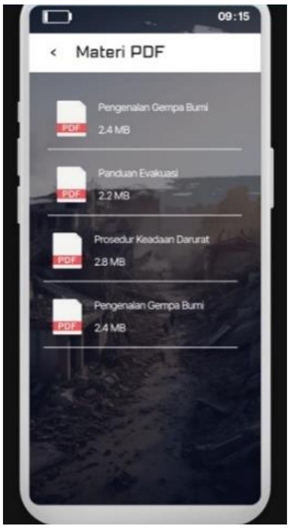

Fig. 6. PDF Learning Content

Fig. 7. Evacuation Simulation

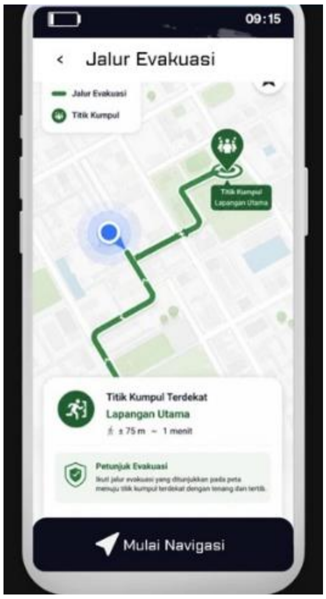

Fig. 8. Evacuation Route Navigation

III. RESULT AND DISCUSSION

Among the 30 respondents, the mean SUS score was 78.5. Based on the interpretation of Bangor et al., this indicates good and acceptable perceived usability [13]. The value is also above the commonly used SUS benchmark of 68. Table II presents item responses as descriptive diagnostics; the composite SUS score remains the primary outcome. The score distribution comprised 2 respondents (6.7%) in the 90–100 range, 5 (16.7%) in 80–89, 14 (46.7%) in 70–79, 7 (23.3%) in 60–69, and 2 (6.6%) below 60, totaling 30 respondents (Table III).

TABLE II. DESCRIPTIVE SUS ITEM RESULTS

No	Item	Mean	Diagnostic
1	Use again	4.1	High reuse intention
2	System complexity	2.0 (rev. 3.0)	Low complexity

No	Item	Mean	Diagnostic
3	Ease of use	4.2	High ease of use
4	Need for assistance	2.2 (rev. 2.8)	Moderate independence
5	Feature integration	4.0	High feature confidence
6	Inconsistency	1.9 (rev. 3.1)	Low inconsistency
7	Learnability	4.3	Strongest response
8	Confusion	1.8 (rev. 3.2)	Low confusion
9	Confidence	3.9	High confidence
10	Familiarization	2.4 (rev. 2.6)	Improvement priority

Figure 9 presents the item means after negatively worded items were reverse-oriented so that higher values consistently indicate a more favorable response.

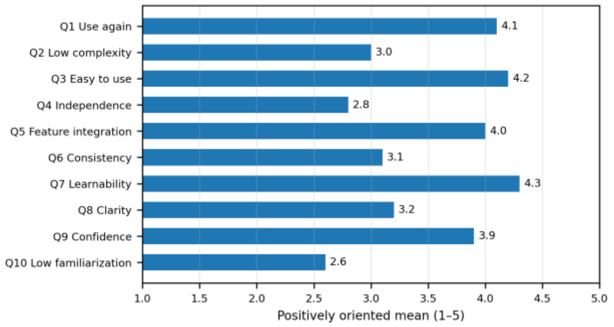

Fig. 9. Likert Scale Results

A. SUS Item Analysis and Design Implications

Descriptively, Item 7 ("Others will understand this system quickly," mean 4.3) and Item 3 ("The system is easy to use," mean 4.2) received the strongest responses. These results are consistent with the interface's short labels, recognizable icons, and stepwise interaction flow. They suggest favorable perceived learnability and ease of use, although the SUS items are not treated as independent subscales.

TABLE III. FREQUENCY DISTRIBUTION OF SUS SCORES

Score Range	Category	Frequency	Percentage
90–100	Excellent	2	6.7%
80–89	Good to Excellent	5	16.7%
70–79	Good	14	46.7%
60–69	OK to Good	7	23.3%
< 60	Marginal	5	6.6%

Responses to Item 3 also support the observed ease of navigating content and interacting with AR features. This pattern is consistent with Akbar et al.'s UCD-based earthquake warning interface [15] and Yahaya and Mat Zain's AR flood simulation [6], although differences in participants, tasks, and application scope prevent direct performance equivalence.

After reverse orientation, the lowest means were Item 10 (2.6), concerning the need for familiarization, and Item 4 (2.8), concerning assistance. Post-test feedback indicated that marker scanning was the main source of initial difficulty because successful detection depended on lighting, camera angle, and marker placement. These findings are consistent with calls to simplify physical interaction in emergency AR systems [16]. Future versions should provide a short guided onboarding sequence and may adopt markerless plane-detection technology to reduce dependence on physical markers [17], [18].

B. Comparison with Related Research

SEISMORA's SUS score of 78.5 is higher than the 73.5 reported for an AR flood simulation [6] but lower than the 86.7 reported for a UCD-based earthquake early warning interface [15]. These values should be interpreted cautiously because the systems serve different purposes: SEISMORA focuses on preparedness education and route guidance, the flood application simulates a different hazard, and the early warning interface prioritizes rapid delivery of real-time information. The comparison therefore supports acceptable usability rather than superiority.

Recent studies also demonstrate the value of broader validation. De León Aguilar et al. evaluated a mobile AR disaster-preparedness guide using usability, task load, hazard-recognition performance, and age-group comparisons. Mercier et al. combined SUS, UEQ, HARUS, behavioral logs, and eye tracking in a location-based AR test and showed that tracking accuracy can affect usability. Compared with these studies, the present work contributes a locally grounded UCD integration of learning materials, AR evacuation simulation, and route guidance, but its validation remains narrower because it relies primarily on SUS and a single regional sample. Nugroho's UCD-based seismic vulnerability interface further supports the relevance of user-centered methods in earthquake-related applications [19].

C. Limitations and Practical Implications

This study is an initial prototype evaluation and has several limitations. The 30 participants were drawn from one region and were limited to Android users aged 17–50 years; the analysis did not stratify results by age, education, digital literacy, prior disaster experience, or disability. Testing took place in a controlled setting rather than under field-drill or emergency conditions. The evaluation measured perceived usability but did not record task success, completion time, errors, cognitive workload, knowledge gain, preparedness behavior, or retention. Consequently, the findings should not be generalized to the Indonesian population or interpreted as evidence that the application improves real-world preparedness.

The practical value of SEISMORA lies primarily in pre-disaster education. Local governments, schools, universities, and community disaster-resilience groups can use the application during training sessions and evacuation drills to present consistent guidance, demonstrate protective actions, and introduce locally validated routes and assembly points [20]–[23]. Its modular structure also permits content to be adapted to local hazards, language needs, and evacuation plans.

For real-world deployment, route data must be verified by authorized disaster-management agencies, essential learning content should remain available offline, and the application should complement not replace official warnings and immediate protective action. A stronger validation phase should recruit a larger, stratified, multi-site sample; compare SEISMORA with conventional learning media; and combine SUS with task success, time-on-task, error rate, UEQ, NASA-TLX, and pretest–posttest knowledge and preparedness measures.

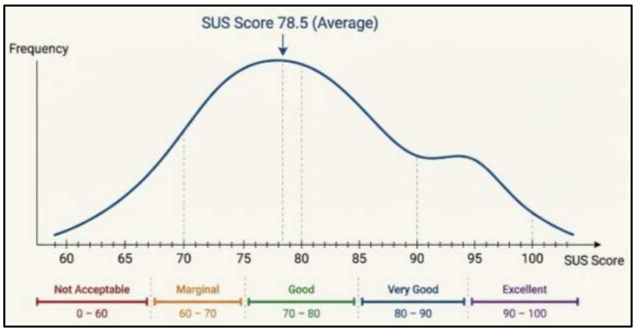

Fig. 10. SUS Score Results

Fig 10 positions the score of 78.5 within the good and acceptable range. Table 4 summarizes the interpretation framework used [13].

TABLE IV. SUS INTERPRETATION RESULTS

Score Range	Grade	Adjective Rating	Acceptability
0–25	F	Worst Possible	Not Acceptable
26–39	F	Poor	Unacceptable
40–52	D	OK	Marginal
53–73	C	Good	Marginal
74–85	**B/C**	**Good**	**Acceptable**
86–100	A	Excellent	Acceptable

IV. CONCLUSION

This study developed SEISMORA, a mobile Augmented Reality application for earthquake mitigation education, through four User-Centered Design stages: context-of-use specification, user-requirement specification, design-solution development, and evaluation. The application integrates PDF and video materials, AR evacuation simulation, and evacuation-route guidance in a simplified interface derived from user needs.

The mean SUS score of 78.5 provides initial evidence of good and acceptable perceived usability. Descriptive item responses were strongest for ease of use and rapid learnability, while lower positively oriented responses for familiarization and assistance identify onboarding and marker scanning as priorities. Because SUS is a composite measure, these item responses are interpreted only as design diagnostics.

The study's distinct contribution is the context-specific integration of multi-format learning materials, AR evacuation simulation, and route guidance within a UCD process for earthquake-prone communities. However, the single-region sample and absence of objective performance or preparedness outcomes limit the scope of the conclusions. Future research should use larger and more diverse multi-site samples, objective task and workload metrics, comparative designs, and longitudinal pretest–posttest assessments before the application is used to support broader emergency-preparedness programs.

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