Multimodal Technologies and Interaction

Article

Location-Based Game for Thought-Provoking Evacuation Training

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Abstract: Participation in evacuation training can aid survival in the event of an unpredictable disaster, such as an earthquake. However, conventional evacuation training is not well designed for provoking critical thinking in participants regarding the processes involved in a successful evacuation. To realize thought-provoking evacuation training, we developed a location-based game that presents digital materials that express disaster situations corresponding to locations or times preset in a scenario and providing scenario-based multi-ending as the game element. The developed game motivates participants to take decisions by providing high situational and audiovisual realism. In addition, the game encourages the participants to think objectively about the evacuation process by working together with a reflection-support system. We practiced thought-provoking evacuation training with fifth-grade students, focusing on tsunami evacuation and lifesaving-related moral dilemmas. In this practice, we observed that the participants took decisions as if they were dealing with actual disaster situations and objectively thought about the evacuation process by reflecting on their decisions. Meanwhile, we found that lifesaving-related moral dilemmas are difficult to address in evacuation training.

Keywords: location-based game; evacuation training; realism; lifesaving-related moral dilemma; experiential learning; reflection

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1. Introduction

Natural and artificial disasters are a matter of concern on a global level. Global statistics indicate an increasing number of disaster occurrences [1,2]. As disasters are unpredictable and can occur at any time, disaster preparedness is essential for survival. A typical indicator of disaster preparedness is the participation in evacuation training, which provides simulated experiences wherein participants reach a shelter safely and quickly. For example, Japan is an earthquake-prone country, and evacuation training for mega earthquakes (and a resulting tsunami) is regularly conducted in local communities (e.g., in residential areas, companies, and schools). However, several residents may not always participate in evacuation training, and all participants (including employees and students) may not always be highly motivated. One reason for the lack of participation or motivation is that conventional evacuation training is not well designed. For example, participants are informed prior to the training and are required to simply follow a predetermined route to a known shelter. This prior knowledge helps participants to simply recollect an evacuation route to a shelter but does not stimulate critical thinking of the process of successful evacuation. Considering these limitations, evacuation training should be designed to be thought provoking.

A promising approach to the improvement in evacuation training is to utilize Information and Communication Technology (ICT) that can heighten parameters, such as expressiveness, interactivity, recordability, and repeatability, i.e., ICT-based evacuation training. For example, disaster simulation and visualization technologies have been actively utilized not only for evacuation training but also for various kinds of disaster trainings [3]. Virtual reality (VR) has been used as an alternative to real-world evacuation training. Many VR-based evacuation training systems enable participants to evacuate according to their own consideration in worlds that are secure, immersive, and with variable conditions [4]. For example, an earthquake evacuation training VR faithfully modeled an actual hospital and was used to analyze participants' evacuation behaviors [5].

For the enhancement of real-world evacuation training, location-based mobile computing has been utilized. For example, a mobile application for earthquake evacuation training aims to cultivate participants' judgment to decide routes and shelters by displaying possible disaster situations at designated locations [6]. A mobile application for tsunami evacuation training enables a participant to consider proper evacuation routes by presenting an inundation depth around their current location based on the data of the tsunami caused by a mega earthquake [7]. Another mobile application enables a participant to not only migrate to a shelter while viewing a simulated tsunami approach and their current location displayed on a digital map but also evaluate their evacuation speed and route from the evacuation log overlaid on the map [8]. Mitsuhara and Shishibori also developed a tsunami evacuation training application that enables participants to seek refuge against a simulated approaching tsunami while occasionally having visual access to a map-based tsunami simulation on mobile devices [9]. These examples provoke a constructive thought process by visualizing disaster situations on smartphone or tablet devices.

Evacuation training involves the consideration of critical issues such as injury and death, which may lower the training motivation of participants. Therefore, to increase motivation, ICT-based evacuation training frequently introduces game elements. In particular, several VR-based evacuation trainings have been designed around serious games. For example, a serious VR game that focuses on an active shooting emergency has been developed to improve surviving knowledge, self-efficacy, and motivation [10]. An evacuation training game using augmented reality (AR) expresses simulated disaster situations (e.g., fire and smoke) superimposed onto real-time vision captured on a mobile device [11]. Furthermore, the training can be enhanced by the inclusion of direct human interaction. For example, keeping the focus on emergency response training rather than evacuation training, a mobile game was developed for field players to learn disaster information management (i.e., rescue operations) in building fires while carrying out missions presented on smartphones based on disaster scenarios [12]. In a geofencing game, the field players can learn about disaster response coordination by observing the virtual disaster situations (e.g., radioactive-pollution areas) on a digital map and interacting with a computer planning agent and a human coordinator [13]. Another mobile game for emergency response training controlled training using a mobile device and social media, and it involved interactions with volunteer actors playing various roles (e.g., victims and police officers) to make virtual disaster situations realistic [14]. These examples attempted to make simulated disaster experiences more realistic by human–human interaction in the real world.

Real-time evacuation support applications working on mobile or wearable devices guide users toward shelters or building exits in the event of a disaster. For indoor evacuation, for example, AR applications provide guidance with a directing arrow [15] and a virtual agent [16]. These applications are also available for smart glasses. For example, a Google Glasses-enabled application presents evacuation instructions and a floor map with the degree of congestion predicted from multiagent simulation [17]. Another application presents navigation cues and virtual fire and smoke on a floor map using Microsoft HoloLens [18]. Another application uses HoloLens to present the best evacuation route available based on dynamic evacuation simulation [19]. These AR applications can be used for evacuation training if disaster situations are realistically simulated and visualized. These applications can guide users to not only remember an evacuation route to a shelter but also to think about evacuation plans. Evacuees' behavior occasionally influences their success or failure in evacuation using these applications. If many evacuees rush into a narrow path, evacuation might fail owing to gridlock or deadlock. Another AR application expresses tense evacuation scenes by simulating evacuees' migration in 3D models generated from a real building and superimposing the evacuees onto real-time vision [20].

Mitsuhara et al. had previously developed a location-based game for real-world evacuation training [21] and a dedicated scenario authoring system [22]. This game adopted a geo-fencing framework that presents digital materials (e.g., video, AR, and single-choice question) on smartphones or tablets corresponding to the preset locations or times. The game element was scenario-based multi-ending showing a customized storyline according to the participant's responses to a single-choice question. This game was experimentally extended to present AR materials that superimposed three-dimensional computer graphics expressing disaster situations (e.g., fire and debris) onto the real-time vision from the smartphone's rear camera [23–25]. The previous versions of the developed game [21–25] are consistently scenario-based and do not include completely unified geo-fencing methods (i.e., the trigger of digital material presentation) between indoor and outdoor evacuation training. Moreover, AR-based digital material presentation occasionally exhibited difficulty in detecting fiducial markers or planes owing to environmental disturbances. To ensure the presentation of digital materials, the latest version of the developed game adopts a Bluetooth low energy beacon (BLEB) and a global positioning system (GPS) as geofencing methods for indoor and outdoor areas, respectively. The latest version can be differentiated from related works in terms of compatibility (i.e., seamless transition) between inside and outside evacuation training. The previous versions were used at one-shot educational events and evaluated with respect to realism and usability. However, the effects of location-based games on thought-provoking evacuation training have not been evaluated in detail.

This article conceptually organizes thought-provoking evacuation training and describes the developed location-based game while reporting the extended research outcome and practices using the developed game to present its effects.

2. Target Evacuation Training

Disaster management (or disaster risk reduction) frequently follows a four-phase cyclic model that begins with a disaster occurrence [26].

(1) Response Phase

Short-term activities, such as rescue and firefighting, for minimizing casualties and property damage are conducted. Evacuation is an important activity in this phase.

(2) Recovery Phase

Medium-term activities, such as providing housing and medical care, for damaged property and injured individuals, respectively, are conducted.

(3) Mitigation Phase

Long-term activities for mitigating possible damages in predicted disasters, such as development of resilient-infrastructure and disaster education, are conducted.

(4) Preparedness Phase

Practical activities aiming for the smooth Response Phase are conducted on individual, family, and community levels till the occurrence of the next disaster. Evacuation training is a practical activity in this phase.

It is essential to understand that regardless of having encountered a disaster, disaster management should be continuously incorporated for preparedness for future disasters.

2.1. Evacuation Training in Disaster Education

Evacuation training is regarded as a part of long-term disaster education in the Mitigation phase and a practical activity in the Preparedness phase. To maximize the benefits of evacuation training, Mitsuhara et al. proposed a comprehensive model of disaster education, including evacuation training [23]. The proposed model "GLI" consists of three layers: Global, Local, and Individual. Although encouraging people to follow the Global, Local, and Individual Layers in order, the GLI model allows shuffling among the layers. Figure 1 shows the GLI model together with the cyclic model of disaster management.

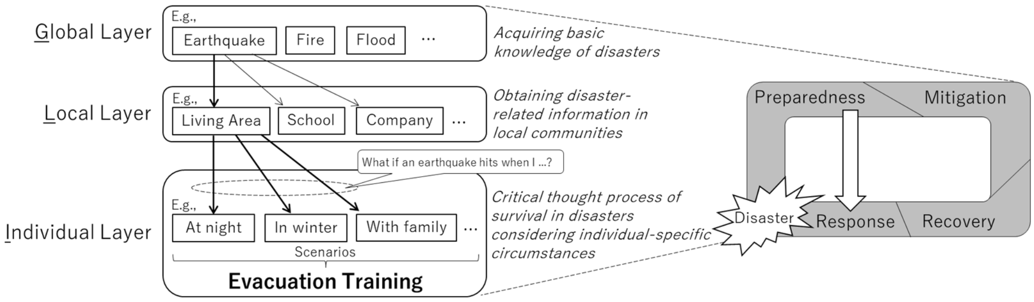


Figure 1. GLI model with cyclic disaster management.

2.1.1. Global Layer

This layer includes acquiring basic knowledge of disasters, such as terminologies related to disasters, their occurrence mechanisms, past damages, and primary response measures. Knowledge resources for this layer include various media such as books, digital materials, and classroom lectures, with a focus on disasters they are likely to encounter.

2.1.2. Local Layer

This layer involves obtaining disaster-related information in local communities, such as predicted disaster damages and available shelter locations. This information can be practically utilized by applying the knowledge acquired in the Global Layer. Evacuation training that focuses on memorizing a predetermined evacuation route is included in this layer.

2.1.3. Individual Layer

This layer includes a critical thinking process of survival in disasters considering individual-specific circumstances (e.g., location, time, residential area, health status, and family structure). Considering earthquake evacuation as an example, a parent may consider evacuation options while prioritizing helping their children. A school-goer may consider evacuation options with a possibility of an earthquake occurrence en route to school. A recommended activity in this layer is to frequently participate in evacuation training to improve critical thinking based on various scenarios. The participants in such a training can appropriately consider (including whether, when, and to where) the evacuation options by applying the information obtained in the Local Layer. However, conventional evacuation training frequently does not stimulate critical thinking and motivate repeated participation.

2.2. Evacuation Process

Evacuation differs with disaster types. For example, individuals may have time to consider the best evacuation process after a typhoon is predicted; if the current place is safe, evacuation may not be necessary. In contrast, prompt decisions are critical in an earthquake and the resulting tsunami to avoid loss of life and property. Evacuation in unpredictable disasters is more challenging than in predictable disasters as it requires prompt and proper decisions against sudden crises. An evacuation process in building fires is represented as three phases in the timeline: detection, alarm, and evacuation [27]. In this process, individuals may recognize fire occurrence by hearing a fire alarm, respond to the surrounding hazards (e.g., removing immediate dangers), and begin moving to a safe place.

We propose an evacuation process generalized for unpredictable disasters. This process has four phases in the timeline: recognition, protection, decision, and evacuation.

Figure 2 shows the proposed process together with example events in (a) an earthquake and the resulting tsunami and (b) building fire.

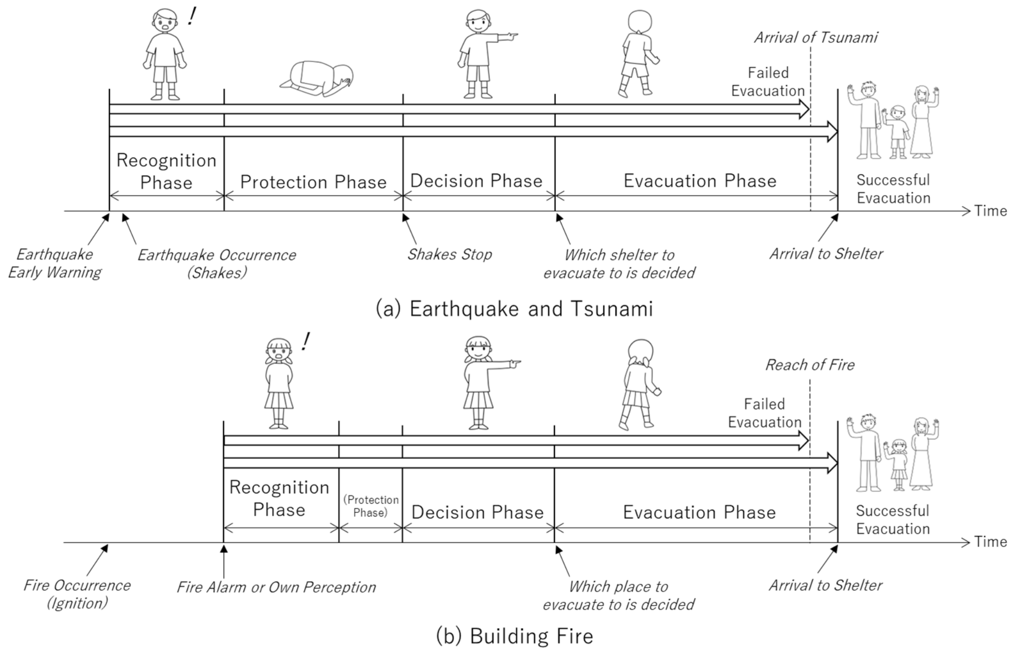


Figure 2. The proposed evacuation process together with examples of unpredicted disasters.

2.2.1. Recognition Phase

A person recognizes the disaster occurrence and surrounding situations by visual and auditory stimulations. For example, an earthquake can be immediately recognized by tremors. In some cases, an earthquake early warning system informs that strong tremors will occur several seconds later. Fire can be recognized by a fire alarm, but the alarm may not go off immediately depending on several factors; fire may also be occasionally recognized by the presence of smoke.

2.2.2. Protection Phase

If needed immediately after the recognition of a disaster, the individual takes actions to protect their life and that of the others (depending on the circumstances). When an earthquake occurs, for example, sequential actions of "drop, cover, and hold on" should be taken.

2.2.3. Decision Phase

After the immediate danger disappears, the individual (or a group) decides on the process of evacuation; they may follow a predetermined evacuation route if not subject to any difficulty. The individual cannot always evacuate in the same manner as participated in evacuation training. For example, when a tsunami approaches at a rate faster than the anticipated rate, the individual might decide to evacuate to a random available shelter rather than to a predetermined shelter.

2.2.4. Evacuation Phase

Based on the decision taken, the individual may evacuate toward a shelter (or a safe place) and is required to reach the shelter within a specific time limit (e.g., tsunami arrival time). During this phase, the person will repeatedly be required to take decisions against challenging situations. For example, finding alternative routes when a predetermined evacuation route is impassable and deciding whether to rescue an injured individual.

In conventional evacuation training, the Recognition Phase is simulated using a fake alarm, and participants are trained to quickly take proper actions needed in the Protection

Phase. However, the Decision Phase is frequently skipped because the decisions and behaviors of participants are diverse and difficult to control. In other words, the participants are directed to simply follow a predetermined evacuation route. Furthermore, the Evacuation Phase, i.e., the repetition of decision-making, is not simulated. Conventional evacuation training does not provide realistic decisions and is not fully effective as the participants are not trained to take decisions. Therefore, we target realistic evacuation training for unpredictable disasters by simulating realistic decision, i.e., enabling participants to make decisions in the Decision and Evacuation Phases.

2.3. Realistic Evacuation Training

In realistic evacuation training, it is expected that participants can take decisions against simulated realistic situations. We define two types of realism.

2.3.1. Situational Realism

This realism depends on a disaster scenario and corresponds to the participants' opinion on whether the simulated situations could occur. For example, an earthquake scenario may include a situation that evacuation routes are impassable due to landslides caused by strong shakes. If the scenario is created based on reliable data in a local community, participants who have obtained disaster-related information about the local community in the Local Layer will feel the situation to be realistic.

2.3.2. Audiovisual Realism

This realism is difficult to simulate in conventional evacuation training and corresponds to whether participants feel the simulated disaster situations are realistic from an audiovisual perspective. In earthquake evacuation training, for example, clattering sounds and scattered objects by shakes cannot be frequently reproduced. The use of audiovisual effects to make the situations realistic may induce emotional disturbance in participants (e.g., feeling anxiety and fear) and influence their decision making.

2.4. Evacuation-Training Model Based on Experiential Learning

Evacuation training, regarded as simulated disaster experiences, can be compatible with Kolb's experimental learning theory, which consists of four cyclic stages: concrete experience (CE), reflective observation (RO), abstract conceptualization (AC), and active experimentation (AE) [28]. Based on this theory, we proposed an evacuation-training model to optimize the training effects [23]. This model assumes that through the Global and Local Layers, participants have acquired basic knowledge of a target disaster and known predicted damage and shelter locations in a target local community. Figure 3 shows the proposed evacuation-training model.

2.4.1. CE Stage

This stage corresponds to scenario-based evacuation simulation where a participant (or a participant group) can simulate disaster experiences ranging from the Recognition to the Evacuation Phases. Following the Recognition and Protection Phases, a participant decides which shelter to evacuate to and starts moving to the shelter. En route to the shelter, the participant takes decisions against simulated challenging situations. Depending on the decisions, the participant may change their shelter or evacuation route and occasionally fail in evacuation. In many cases, a time limit is set to judge the success or failure of the participant's evacuation, i.e., the appropriateness of their decisions.

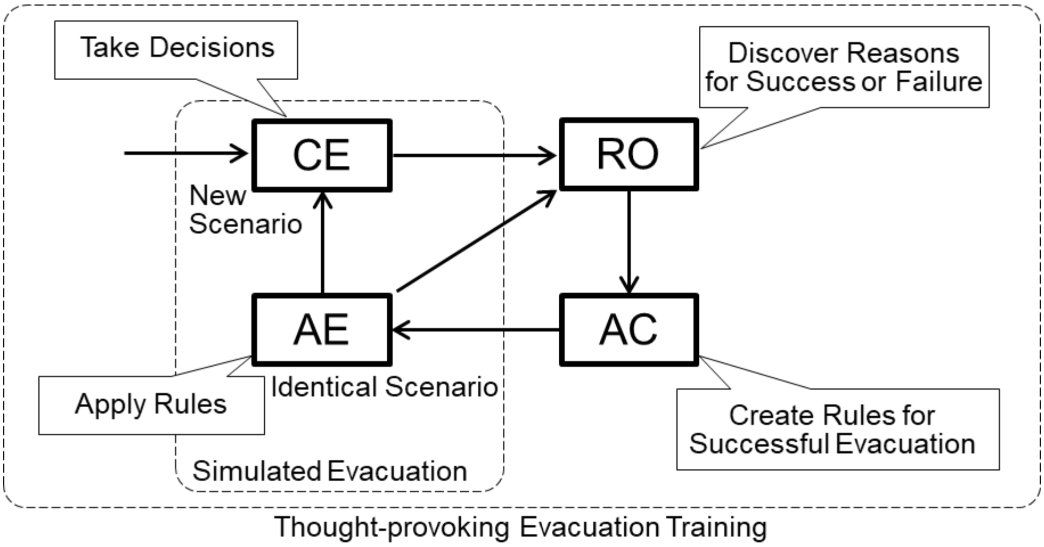


Figure 3. The proposed evacuation-training model. CE, concrete experience; RO, reflective observation; AC, abstract conceptualization; and AE, active experimentation.

2.4.2. RO Stage

The participant reflects on their decisions taken in the CE stage to discover possible reasons for success or failure. This stage can provoke objective thinking of the process of evacuation. This is because the participant may not have taken decisions objectively by being emotionally disturbed in the CE stage. If possible, a participant should refer to the decisions taken by the other participants to analyze the reasons objectively. A serious game VR for earthquake evacuation training adopts a reflection-in-action approach that enables a participant to reflect on their incorrect decision for a short time and reanalyze the decision of evacuating [29]. The RO stage focuses not on reflection-in-action but on reflection-on-action [30].

2.4.3. AC Stage

The participant conceptualizes a more successful evacuation based on the possible reasons discovered in the RO stage. In other words, the participant creates their rules for a successful evacuation. For example, if not reaching a shelter within a time limit by rescuing the injured, the participant may act on this rule, "I must prioritize my life when evacuating". Together with the RO stage, this stage can provoke thinking about the evacuation process.

2.4.4. AE Stage

The participant attempts to apply their rules made in the AC stage to simulate challenging situations identical to those in the CE stage. In other words, the participants can retry the CE stage to validate the rules. After the AE stage, the participant may step into the next CE stage (i.e., new evacuation simulation) or the RO stage to reflect on their decisions taken in the AE stage.

The CE and AE stages aim to provoke decision-making, and the RO and AC stages aim to provoke thinking objectively of the process of evacuation. The CE stage should induce failure in moderately challenging scenarios. This is because a participant is expected to think more in the RO and AC stages when failing in the CE stage. The proposed model regards following the four stages as a thought-provoking evacuation training and recommends repeated participation in evacuation training in various scenarios.

3. Game Development

We focused on enhancing real-world evacuation training and developed a location-based game for thought-provoking evacuation training based on the proposed evacuation-training model. The developed game presents digital materials corresponding to preset locations or times and has a game element that changes a scenario depending on a participant's decisions. This game element is (1) fit for thought-provoking evacuation training and (2) useful for motivating the participants to repeatedly participate in the evacuation training. We initially adopted a geo-fencing framework using a GPS that is available specifically for outdoor evacuation training and then extended the framework to be compatible with indoor evacuation training using a BLEB. The developed game works on GPS- and Bluetooth-enabled Android smartphones or tablets.

3.1. Scenario

A scenario in the developed game is branched to provide multi-ending. For higher situational realism, the branched scenario should be well conceived to express disaster-caused challenging situations with a high probability of occurrence in a local community. In addition, the challenging situations should be influenced or changed by a participant's decisions. For example, a building fire scenario may need the situation that if a participant does not close a fireproof door, the fire spreads.

3.1.1. Scenes and Cuts

The scenario consists of scenes, and each scene has at least one cut corresponding to a digital material (e.g., video and single-choice question). The scenario begins and ends at preset locations or times. If reaching locations preset as shelters within a preset time, a participant is judged to have a good ending (i.e., a successful evacuation) or a bad ending (i.e., a failed evacuation). Figure 4 shows an overview of the branched scenario.

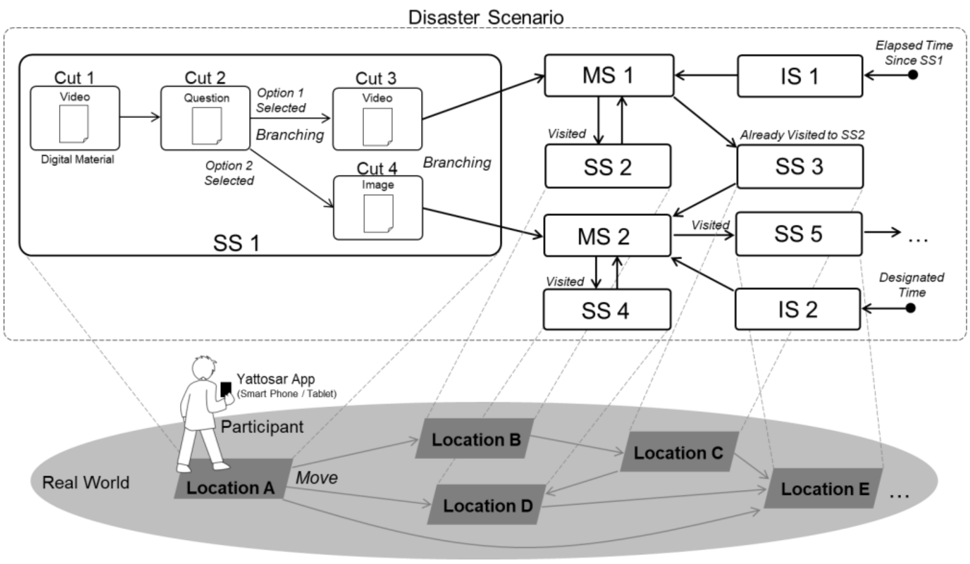


Figure 4. Scenario constitution. SS, stay scene; MS, move scene; and IS, interrupt scene.

The preset locations and times are referred to as the following scenes:

Stay Scene (SS). Each SS corresponds to a location and expresses a situation that may arise at the location. In a flood scenario, for example, a participant who arrives at a riverbank may encounter a situation wherein bridges were washed away by a flash flood. For an outdoor location, an SS is a rectangular area preset by latitude and longitude. For an indoor location, an SS is preset as a combination of IDs recorded in a corresponding BLEB device.

Interrupt Scene (IS). Each IS, independent of locations, corresponds to an elapsed time or a designated time and expresses a time-dependent situation. In an earthquake scenario, for example, a participant may encounter afterquakes suddenly, regardless of their current location.

Move Scene (MS). Each MS, conceptually assigned between SSs, is needed for a participant to reach the next SS.

3.1.2. Branching Conditions

To determine the next scene/cut in the branched scenario, the following conditions are set:

Options Selected. The next cut is determined according to the option a participant chooses in a single-choice question. This condition is frequently used to branch the scenario.

Already Visited. The next cut/scene is determined according to the cut/scene a participant has visited in/till the current scene.

Visited. This condition is valid only for an MS. A participant visits one of the linked SSs from the MS.

Elapsed Time. When a threshold time has elapsed since visiting a scene, a participant compulsorily visits (enters) an IS.

Designated Time. During a designated time, a participant compulsorily visits an IS.

The branched scenario, written in the Extensible Markup Language (XML), enables participants to take decisions against challenging situations. In other words, the branched scenario controls the storyline in the CE and AE stages.

3.2. Digital Materials

Digital materials, presented in cuts, are designed to realistically express disaster situations in terms of audiovisual realism. Digital materials available in SS and IS are images, sounds, texts, videos, and single-choice questions. The video is the most expected to heighten audiovisual realism. In an earthquake scenario, for example, videos may express situations such as collapsed buildings, panicking people, and ground liquefaction. In many cases, a video expressing a challenging situation is presented in the first cut, and a single-choice question is presented for a participant to decide against the situation. Digital materials available in MS are sounds (e.g., siren and scream) and maps displaying a participant's current location and visitable SSs. Figure 5 shows examples of digital materials presented on a smartphone screen.

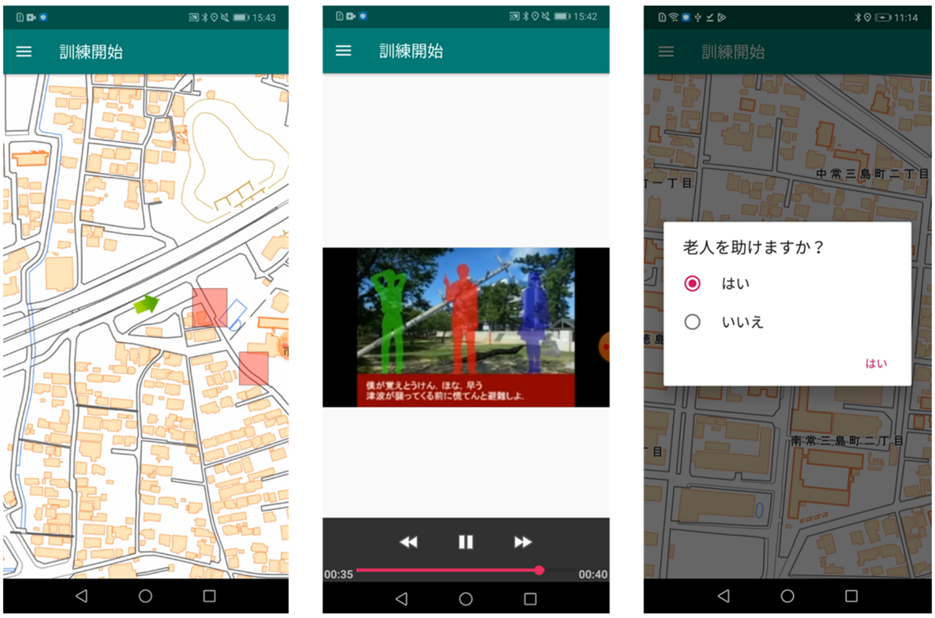


Figure 5. Digital materials. The **left** picture shows a map displaying a participant's current location (the green arrow) and visitable SSs (red rectangles). The **middle** picture shows a video expressing the situation, "I remember an evacuation route. Let's evacuate quickly before tsunami arrives". The **right** picture shows a single-choice question asking about the situation, "Do you rescue the elderly?".

3.3. Mobile Application

We developed a geo-fencing mobile application called "Yattosar" using a programming language, Kotlin. Note that a user needs to download disaster scenarios and digital materials from the scenario authoring system to the mobile application before starting evacuation training. The developed application comprises the following main modules. Figure 6 shows the module composition.

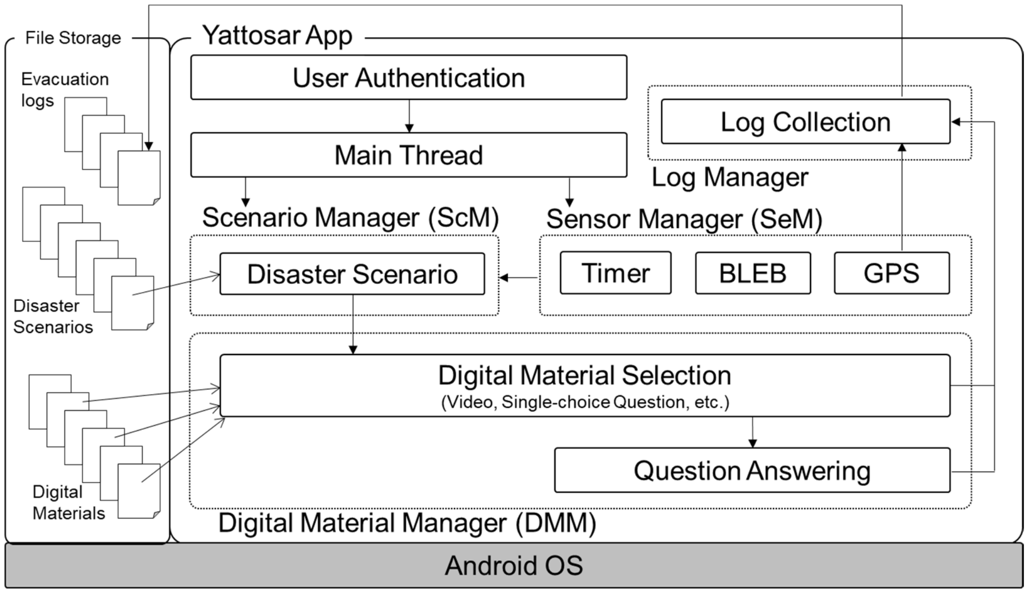


Figure 6. Module composition of the mobile application.

Scenario Manager (ScM). After successful user authentication via an ID and a password, this module loads a disaster scenario selected by the authenticated user and then controls the storyline according to the scenario while waiting for interruptions from the sensor manager. The interruptions activate the digital material manager.

Sensor Manager (SeM). This module receives a signal from GPS or a near BLEB device and checks whether the user is in an SS (i.e., preset location) by comparing the received signal (i.e., his/her current location) and the scenario. Simultaneously, this module receives time data from the Android's clock.

Digital Material Manager (DMM). This module presents the digital material designated by the ScM. If presenting an image, sound, or a video in SS or IS, this module plays the file on the corresponding viewer. If presenting a single-choice question described in the scenario, this module presents on a pop-up window and checks the user's selected option and records it in an evacuation log.

Log Manager. This module receives the log data from the SeM and the DMM and saves it in file storage. The log data is used to visualize the user's evacuation route and decisions (i.e., responses to the single-choice questions).

3.4. Reflection-Support System

In the RO stage, it is difficult for a participant to reflect on their decisions taken in the CE stage (and the AE stage) by relying solely on memory. Therefore, we developed a reflection support system that works on a standard web browser (e.g., Google Chrome). This system not only visualizes their evacuation route and decisions on Google Map by receiving the participant's log data from the mobile application but also presents digital materials that were viewed by the participant. If the evacuation route is covered by Google Street View, a participant can see the first-person street view from a spot on the route. Under the assumption that Google's services may be unavailable, we prepared another mode that visualizes the evacuation route on another digital map and presents videos recorded by the user's action camera. This system can provoke easy and objective thinking on evacuation. Figure 7 shows the user interface of the reflection support system.

Figure 7. Reflection support system's user interface. The **left** area shows the participant's path in the evacuation training displayed on Google Maps. A pop-up box on the map displays information and the participant log data of a visited SS, "Elapsed time: 6 m 11 s passed"; "Scene name: Crack in the road"; link to the corresponding digital material (video); "Question: Do you jump the big crack in the road?"; "Decision: Yes". The **top right** area shows the Google Street View synchronous to the scene. The **bottom right** area shows the linked video, "It's dangerous. We should not do that!".

4. Practice and Evaluation

Although thought-provoking evacuation training applies to a wide range of people, we focused on elementary school students. This is because they are disaster-vulnerable and need adult protection; they may encounter disasters when left alone or with friends (e.g., on their way to schools).

We practiced thought-provoking tsunami-evacuation training with fifth-grade students in a coastal area called "Hiwasa", Tokushima, Japan, which faces the Pacific Ocean. The practice was limited to two days because of the curriculum restrictions. As a result, we conducted one cycle of the proposed evacuation-training model.

In this practice, we aimed to demonstrate the effects of thought-provoking evacuation training by observing how participants develop critical thinking. Note that no comparative practices requiring a control group were conducted in this study, as we focused on providing the students with equitable training along the school curriculum.

4.1. Settings

4.1.1. Target Area

Massive damages by a mega earthquake known as the "Nankai subduction-zone earthquake" and a tsunami are anticipated in the Hiwasa area. The first and second tsunami waves, measuring approximately 20 cm and 10 m, will reach within 10 and 30 min, respectively. Residents in this area must quickly evacuate to tsunami shelters rather than stay inside their houses. This area has fourteen tsunami shelters (e.g., concrete towers and maintained hills) within approximately 1 km^2, but landslides and ground liquefaction may make shelters unavailable. It is uncertain if all the residents can safely evacuate to the shelters. The sceneries of the Hiwasa area are presented in Figure 8.

Figure 8. Sceneries of the Hiwasa area. The **top-left** picture shows the coast facing the Pacific Ocean. The **bottom-left** picture shows a dense wooden-house section. The **top-right** picture shows a high-capacity tsunami-evacuation tower. The **bottom-right** picture shows a maintained hill.

4.1.2. Participants

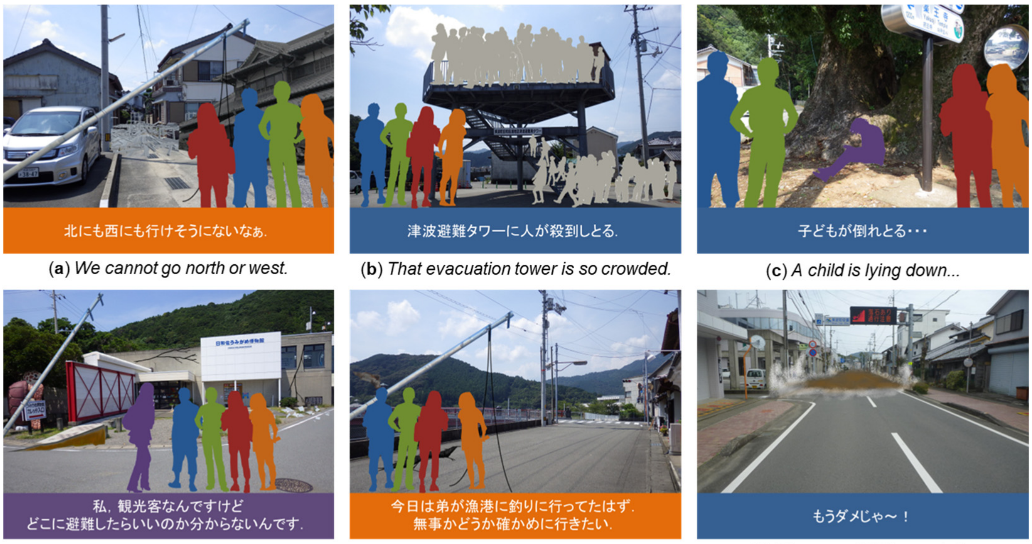
The participants were twenty-five fifth grade students who were between ten and eleven years old. The participants had completed activities in the Global and Local Layers and were regularly trained to evacuate to the nearest shelter (the hill behind the school buildings) from their classroom. Because of a limited number of prepared Android tablets, a class teacher divided participants into four groups (A, B, C, and D) based on their personality, physical strength, and other factors. On day 1, one participant of Group D was injured and needed to use a wheelchair. Each group consisting of six or seven students was given a tablet with the installed Yattosar app. Therefore, each group would take decisions through discussion, which might generate dissension and consume time.

4.1.3. Scenarios

Two scenarios were created for the CE (day 1) and AE (day 2) stages. For higher situational realism, both scenarios set a time limit of 20 min and simulated challenging situations based on instances from the Great East Japan Earthquake in 2011 [31]. Furthermore, both scenarios attempted to provoke thinking regarding whether to rescue or assist others during the tsunami evacuation. In other words, a lifesaving-related moral dilemma entailing tough decision-making was included as a challenging situation. Note that such a moral dilemma has no correct answer and emphasizes the importance of thinking on the basis of possible answers in a what-if manner.

In both scenarios, each group started evacuation from a different starting location (a first SS) simultaneously. In the first SS, a video depicting an earthquake early warning was shown (i.e., the Recognition Phase), and group members were given a trigger to take proper actions (i.e., the Protection Phase). When a member did not take proper action, such as avoiding objects that could fall, someone in the group had to attach 2 kg weight to their leg (simulating an injured leg) or wear half-blindfolded glasses (simulating an injured eye). After viewing the video, each group decided which shelter to evacuate to through a discussion or member's dogmatic decision during the Decision Phase. Until reaching a shelter or exceeding the time limit, each group took decisions against simulated challenging situations presented at the SS or IS during the Evacuation Phase. Different groups could visit the same SS. During MS, emergency sirens were played as sound effects.

The CE scenario focused on encountering a mega earthquake on the way to school. Typical challenging situations (SS and IS) set in the scenario are shown as follows, and screenshots of videos corresponding to the situations are presented in Figure 9.



(**a**) *We cannot go north or west.* (**b**) *That evacuation tower is so crowded.* (**c**) *A child is lying down...* (**d**) *I have no idea where to evacuate.* (**e**) *I want to confirm my brother's safety.* (**f**) *Oh my gosh! We must die.*

Figure 9. Typical challenging disaster situations (screenshots of videos) present in the CE stage.

Blocked Evacuation Route [SS]. In this scenario, evacuation routes are blocked by house collapse and fire (Figure 9a). Against this situation, a group must find alternative routes and decide on one. Corresponding SSs were set to the predicted evacuation route of Group C.

Crowded or Unavailable Shelter [SS]. In this scenario, a few shelters have already been crowded or unavailable when a group reaches there (Figure 9b). Against this situation, they must decide on another shelter and begin moving. Corresponding SSs were set to the predicted evacuation routes of Groups C and D.

Whether to Rescue [SS]. Whether to rescue others may influence the success or failure of a tsunami evacuation. For example, physically strong adults may carry an injured person on their backs to evacuate. However, in the worst-case scenario, both could be engulfed by the tsunami if it takes time to rescue. In this scenario, an unconscious child is laying down (Figure 9c). Against this situation, they have difficulty rescuing the child because of their physical strength, but they can endeavor to cooperatively rescue the child while believing that lifesaving is right. A corresponding SS was set to the predicted evacuation routes of Groups A and B. In this practice, a heavy doll (approximately 25 kg) that looked such as an unconscious child was placed at the SS; if they decided to rescue the child, they must carry the doll.

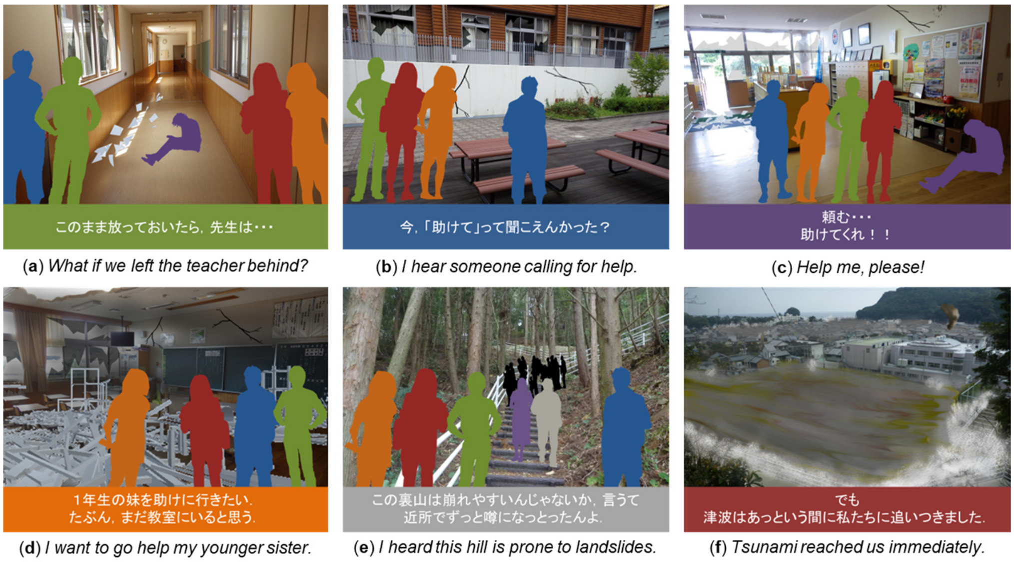
Whether to Assist [SS]. Assisting others may also influence the success or failure of a tsunami evacuation. In this scenario, a confused tourist who does not know shelter locations is standing on a street (Figure 9d). Against this situation, they may decide to propose evacuating together. A corresponding SS was set to the predicted evacuation route of Group B. In this practice, an actor playing the tourist stood at the SS. If they decided to assist the tourist, they must evacuate with the actor by giving directions or leading by hand.

Whether to Confirm [SS]. In the event of a disaster, everyone will be worried about the safety of important people. In this scenario, a younger brother is possibly still in a playground (Figure 9e). Against this situation, they must decide whether to head to a shelter or the playground. A corresponding SS was set to the predicted evacuation route of Group D.

Approaching Tsunami [IS]. The tsunami reached the seashore 18 min after the first SS (Figure 9f). Against this situation, they must move faster.

Arrival of the Tsunami [IS]. The tsunami reached the entire area 20 min after the first SS. Entering this IS indicates failure in evacuation.

The AE scenario focused on encountering a mega earthquake in the school. Participants were expected to evacuate to the nearest shelter because they had been trained to do so. There were steep stairways on all routes to the nearest shelter. The challenging situations in the AE stage were identical to those in the CE stage, so the rules created in the AC stage could be applied. SSs inside the school building were detected by BLEB. Typical challenging situations set in the scenario are shown as follows, and screenshots of videos corresponding to the situations are shown in Figure 10.



(**a**) *What if we left the teacher behind?* (**b**) *I hear someone calling for help.* (**c**) *Help me, please!* (**d**) *I want to go help my younger sister.* (**e**) *I heard this hill is prone to landslides.* (**f**) *Tsunami reached us immediately.*

Figure 10. Typical challenging disaster situations (screenshots of videos) present in the AE stage.

Whether to Rescue [SS]. In this scenario, an unconscious teacher is lying in a corridor (Figure 10a). Against this situation, they must decide whether to rescue the teacher. In this practice, if they decided to rescue, they had to carry a heavy doll (the same one used in the CE stage). In another situation, a student calls for help from another school building (Figure 10b). Against this situation, they may decide whether to go to the place where the student may be staying. In this practice, another heavy doll was placed on a stairway near an art room. They had to locate and carry the doll. Corresponding SSs were set to the predicted evacuation routes of Groups B and D.

Whether to Assist [SS]. In this scenario, an injured teacher who has difficulty walking is lying down at the entrance (Figure 10c). Against this situation, if they decide to assist the teacher to evacuate, they may lend shoulders or use a wheelchair. The corresponding SS was set onto the predicted evacuation routes of all groups. In this practice, a few real teachers acted as though they were injured.

Whether to Confirm [SS]. In this scenario, a younger sister (first-grade student) is possibly still in her classroom (Figure 10d). Against this situation, they must decide whether to head to a shelter or the classroom. The young sister, along with the class teacher and classmates, has already been evacuated, so heading to the classroom is a waste of evacuation time. The corresponding SS was set to the predicted evacuation route of Group A. In another scenario, an SS that a mother is possibly at her workplace is set outside the school. Against this situation, they must decide whether to head to a shelter or the workplace.

Unreliable Shelter. In this scenario, a resident who has reached the nearest shelter doubts that the ground around the shelter is loose and unlikely to collapse because of tremors, whereas another suggests that evacuating to another shelter may be the best option (Figure 10e). Against this situation, they must decide whether to evacuate to another shelter from the one they have just reached.

Blocked Evacuation Route [SS]. In this scenario, evacuation routes outside the school are blocked by house collapse and fire.

Crowded Shelter. In this scenario, a few shelters other than the nearest shelter have already been crowded.

Afterquake [IS]. An afterquake occurred between 12 and 15 min after the first SS. Against this situation, they must take proper action to protect themselves.

Approaching Tsunami [IS]. The tsunami reached the seashore 18 min after the first SS.

Arrival of the Tsunami [IS]. The tsunami arrived in the entire area 20 min after the first SS (Figure 10f).

4.2. Results

We practiced the tsunami-evacuation training in 2021 using the scenarios described above. One and a half hours were given to each of the two days. The CE and RO stages, AC stage, and AE and RO stages were assigned to day 1, homework, and day 2, respectively. In the CE and AE stages, a few teachers accompanied each group to ensure the participants' safety and the app's operation. Each group's training was video recorded using an action camera. The RO stage was provided as teacher-led classes in a classroom where the reflection-support system and recorded videos were used and presented in timely fashion.

Table 1 summarizes each group's evacuation training in the CE (day 1) and AE (day 2) stages, and each group's decisions and behavior are described as follows. Figure 11 shows snapshots during the CE and AE stages.

Table 1. Success or failure in evacuation and time spent for evacuation (elapsed time since the first SS). The time limit was 1200 s.

Group (No. of Members)	CE (Time)	AE (Time)
A (N = 6)	Success (1002 s)	Success (1069 s)
B (N = 7)	Success (932 s)	Failure
C (N = 6)	Failure	Failure
D (N = 6)	Success (870 s)	Success (866 s)

Figure 11. Snapshots for the CE and AE stages.

4.2.1. CE Stage

The CE stage was conducted on a sunny day on November 17 (approximately 20 °C). In the Protection Phase, no group took a proper action to avoid danger. Accordingly, a weight was attached to one member's leg in each group.

Group A. Following the first SS, in 18 s, they decided to evacuate to the nearest shelter and started to sprint; they tended to sprint in all MSs.

CE-A-1. Against the situation of "blocked evacuation route", in 12 s, they decided to take a route leading to another shelter.
CE-A-2. Against the situation of "whether to rescue", in 11 s, they decided to rescue an unconscious child; they worked together to carry a heavy doll.
CE-A-3. They reached the shelter within the time limit.

Group B. Following the first SS, in 14 s, they decided to evacuate to the nearest shelter and started to sprint; they tended to sprint in all MSs.

CE-B-1. Against the situation of "unavailable shelter", in 11 s, they decided to evacuate to another shelter.
CE-B-2. Against the situation of "whether to assist", they immediately decided to lead a confused tourist to the shelter.
CE-B-3. Against the situation of "whether to rescue", they immediately decided to rescue an unconscious child; they worked together to carry a heavy doll.
CE-B-4. They reached the shelter within the time limit.

Group C. Following the first SS, in 10 s, they decided to evacuate to the nearest shelter and started walking; they tended to walk in most MSs.

CE-C-1. Against the situation of "crowded shelter", in 8 s, they decided to evacuate to another shelter.
CE-C-2. Against the situation of "blocked evacuation route", in 5 s, they decided to avoid narrow routes through a dense wooden-house section and evacuate to a longer but wider route.
CE-C-3. Against the situation of "unavailable shelter", they immediately decided to evacuate to another shelter.
CE-C-4. They did not reach the shelter within the time limit.

Group D. Following the first SS, in 14 s, they started to sprint to the nearest shelter. They tended to sprint in all MSs, but sometimes looked back and called out the wheelchair user member (e.g., "are you okay?"). A teacher pushing the wheelchair chased the members.

CE-D-1. Against the situation of "whether to confirm", they immediately decided not to visit a playground (harbor) that a young brother often visits after school.
CE-D-2. Against the situation of "crowded shelter", in 7 s, they decided to evacuate to another shelter.
CE-D-3. They reached the shelter within the time limit.

4.2.2. RO Stage on Day 1

In the beginning, the class teacher requested each group to reflect on and describe their encountered situations, decisions, and behavior on a worksheet. After they completed the worksheet, the teacher requested a representative from each group to present the worksheet content orally. During the presentations, the teacher encouraged the students to explain the presented decisions and behavior in more detail by asking questions. After the representatives finished their presentations, each group discussed what to do in a real evacuation. Table 2 shows the principal interactions (questions and replies) in each group.

Table 2. Principal teacher–student interactions in the RO stage on Day 1.

Group	Situation	Interaction
A	CE-A-3	R [1]: We climbed the fence of the shelter because we could not find the shelter entrance. T [2] (while viewing the recorded video): You took time to climb the fence. What do you think will happen if you do this in a real evacuation? R: Waste of time. We may die. T: You will be much upset if you do not know the shelter entrance. I believe that you got a good experience in the training.
	Do's	T: What did you get via your reflection? Based on it, what do you think you should do in a real evacuation? [3] R: We should know about shelters, take decisions quickly, move fast, carry the injured softly, and not choose the wrong routes.
B	CE-B-2 CE-B-3	R: We found a tourist who got lost. We guided the tourists to the shelter but left her on the way. Then, we carried a child to the shelter but did not know where the entrance is. As a result, we had to rush to the top floor of the shelter. T: You encountered many events. Did you succeed in the evacuation? R: Yes, we did. T: If you took decisions faster or slowly, the consequences would have changed.
	Do's	R: We should have paid more attention to the tourists. We will cooperatively carry the injured. T: It is a difficult decision to carry the injured. You want to carry the injured, but you will dither in a real situation. Do you have any idea about how we should deal with a situation like this? R: Umm . . . I do not want to die.
C	CE-C-2 CE-C-3	T: You encountered fire. Then, you returned to the starting location and took another route. What do you think about the decision? R: The route to the shelter was also on fire. Maybe, we should have chosen another route directly from the location of the first fire. T (while viewing their evacuation route): You moved a lot. How fast did you move? R (while viewing the recorded video): We should have run faster.
	Do's	R: We prioritize our lives, but depending on the circumstances, we want to help persons in need. We should look around during the evacuation. T: I guess that you want to help persons within your reach, so you thought that you should look around.
D	CE-D-2	R: We went to the nearest shelter, but it was full. Then, we decided to evacuate to the hill behind the school. T (accompanied by this group): You debated whether to evacuate to the hill or a recently built shelter, did not you? What happened to anything else? R: A member had sprained his leg. We moved slowly for him but should have moved more slowly.
	Do's	R: We want to attend to the injured we found. We should quickly decide whether to evacuate and keep silent during evacuation. T: I guess that you recalled that silent and calm evacuation is required as instructed in the past training.

[1] Representative student. [2] Teacher. [3] This question was delivered to all the groups.

4.2.3. AC Stage

The AC stage was provided as homework rather than classwork, with each member creating their own rules for successful evacuation. The rules were written out on a questionnaire provided during the AE stage. Table 3 shows the rules collected.

Table 3. Rules for the successful evacuation made in the AC stage.

Group	ID [1]	Rule [2]
A	A3	I calm myself down, run, and do my best.
	A4	I cooperate with everyone together.
	A6	I protect myself quickly. Drop, cover, and hold on.
B	B2	I hide under the table quickly when an earthquake happens.
	B4	I stay away from the stuff that may fall down.
	B5	I hide under the table quickly.
	B6	I never get upset when an earthquake.
C	C1	I evacuate speedily.
	C2	If an earthquake happens when I am at school, I move to a wide area and protect my head. After the shake stop, I evacuate to the hill behind the school buildings.
	C3	When outside, I evacuate to a place where nothing falls.
D	D1	I call out the injured.
	D2	When playing outside, I start to evacuate calmly after the shakes stop.
	D3	I evacuate speedily and quietly.
	D4	I start to evacuate immediately after the shakes stop.
	D5	I avoid dangers such as falling objects and evacuate via the shortest route.

[1] ID was assigned to each participant. [2] Creating rules was not forced; thus, not all members created the rules.

4.2.4. AE Stage

The AE stage was conducted on a sunny day on December 1 (approximately 15 °C). Following the first SS, all the groups immediately started to evacuate to the nearest shelter (i.e., the hill behind the school buildings) as usual training. Inside the school building, they did not sprint but moved with moderate speed while adhering to the basic policy of "evacuating calmly" in the usual training.

Group A. A weight was attached to one member because one or more members did not take proper action to avoid danger in the Protection Phase. The afterquake (set as IS) hit twice until they reached the shelter.

AE-A-1. Against the situation of "whether to confirm", they immediately decided not to visit a classroom where a young sister is possibly staying.

AE-A-2. Against the situation of "whether to assist", in 56 s, they decided to help an injured teacher and put the teacher in a wheelchair found nearby. They got out of the school building while pushing the wheelchair, but could not push it smoothly because of the muddy schoolyard. After approximately 40 s of discussion, while moving slowly, they decided to leave the wheelchair there and lend their shoulders to the teacher to move.

AE-A-3. When reaching the stairway to the shelter, they noticed that they had difficulty carrying the teacher. In 25 s, they decided to leave the teacher there, expecting him to move. (Note, we did not set any SS for this situation).

AE-A-4. Against the situation of "unreliable shelter" presented when reaching the nearest shelter, in 44 s, they decided to stay there. That is, they reached the shelter within the time limit.

Group B. They took proper action during the Protection Phase and started the evacuation without attaching the weight. The afterquake hit twice until the time limit was reached, and the approaching tsunami was recognized once.

AE-B-1. Against the situation of "whether to rescue", they immediately decided to rescue an unconscious teacher; they worked together to carry a heavy doll.

AE-B-2. Against the situation of "whether to assist", in 22 s, they decided to assist an injured teacher and put the teacher in a wheelchair. They divided the roles into carrying the unconscious teacher (doll) and the injured teacher (real teacher). However, they suggested that carrying a wheelchair to the shelter would be difficult, so a member proposed using an elevator to evacuate to the top floor of the school building. In response, the teacher said, "The use of an elevator is dangerous when disasters and tsunamis attack the top floor". Consequently, they abandoned using the wheelchair and lent their shoulders to the teacher to evacuate to the shelter.

AE-B-3. Against the situation of "unreliable shelter", a member proposed leaving the teacher there. Simultaneously, another member noticed that another group was heading to a shelter outside the school. In 41 s, they decided to evacuate to another shelter together with the teacher and started descending the hill.

AE-B-4. When going down to the schoolyard, they found a wheelchair that Group A left and put the injured teacher in it. (Note, this situation occurred by chance).

AE-B-5. Against the situation of "crowded shelter", they dithered over whether to re-evacuate to the first-reached shelter (hill). In 25 s, they decided to evacuate to another shelter on the opposite side of the coast.

AE-B-6. Against the situation of "whether to confirm", in 21 s, they decided not to visit a mother's workplace believing that she has already evacuated.

AE-B-7. They did not reach the shelter within the time limit.

Group C. A weight was attached to a member. They followed the same evacuation route as Group B from the middle. Until the time limit, the afterquake hit twice, and the approaching tsunami was recognized once.

AE-C-1. Against the situation of "whether to assist", in 16 s, they decided to assist an injured teacher and lend their shoulders to the teacher to evacuate to the shelter.

AE-C-2. Against the situation of "unreliable shelter", in 40 s, they suggested a few shelters and decided to evacuate to another shelter together with the teacher.

AE-C-3. Against the situation of "crowded shelter", in 21 s, they suggested a few shelters again and decided to evacuate to another shelter.

AE-C-4. Against the situation of "whether to confirm", they immediately decided not to visit a mother's workplace.

AE-C-5. They did not reach the shelter within the time limit.

Group D. The member who had used a wheelchair because of the injury during the CE stage (day 1) recovered and moved without the wheelchair. A member wore half-blindfolded glasses because one or more members did not take proper action to avoid danger during the Protection Phase.

AE-D-1. Against the situation of "whether to rescue", they immediately decided to go to the possible place to rescue an immobile student. After 2 min, they found and carried the student (the heavy doll).

AE-D-2. Against the situation of "unavailable shelter", in 20 s, they decided to stay there. That is, they reached the shelter within the time limit.

4.2.5. RO Stage on Day 2

The teacher conducted the RO stage following the same procedure on day 1, arranging interactions to provoke more thoughts of lifesaving situations. Finally, the teacher requested each group to create and present do's as outcomes from days 1 and 2 (i.e., the CE, RO, AC, and AE stages). Table 4 shows the principal interactions in each group and their presented do's. Based on the interactions and presented do's, the teacher indicated that "quickly" and "in advance" are important keywords related to "decide and evacuate" and "know local communities", respectively, and then concluded that these keywords simply represent preparedness for disasters.

Table 4. Principal teacher–student interactions and lessons in the RO stage on Day 2.

Group	Situation	Interaction
A	AE-A-2 AE-A-3	R: We found an injured teacher at the entrance and assisted the teacher to evacuate. T: How did you assist the teacher? R: We could not push the wheelchair in the schoolyard. As a result, we gave up pushing it and instead gave him an umbrella to use as a walking stick. T: What happened then? R: We left him there and kept evacuating because we had no time.
	Do's	R: We should know shelters in advance, decide quickly, protect our heads, and evacuate speedily.
B	AE-B-2 AE-B-3 AE-B-5	R: While carrying the doll, we assisted another injured teacher. T: How did you assist? R: Two students lent their shoulders to the teacher. Then, we moved to the hill behind, but someone said that a landslide may hit the hill. Therefore, we decided to go to a town hall designated as a shelter, but it was crowded, and we had to change our destination. T: Where did you try to go? R: Another shelter other than the evacuation tower. However, the tsunami reached us on the way.
	Do's	R: We should know more about the area and cooperate more quickly without getting upset.
C	AE-C-4 Tsunami	T: What decision did you take when asked whether to confirm a mother's safety? R: We kept our evacuation because we had been taught that individuals protect life by him/herself. T: After that, you saw that a tsunami is coming. Then, you started to sprint very fast. R: We evacuated at almost walking speed at first, but we should have evacuated speedily from the beginning.
	Do's	R: We should cooperate, decide calmly, and evacuate speedily.
D	AE-D-1 AE-D-2	T: You went to rescue a student. Was the student heavy? R: So heavy. T: Did you carry it only by yourself? R: Yes! T: This group decided to stay on the hill and completed evacuation in approximately 15 min. What do you think was good about your evacuation? R: Umm . . .
	Do's	R: We should obtain knowledge about the area in advance, protect ourselves, decide quickly, and cooperate, for example, help the person who is helping others.

4.2.6. Questionnaire Results

A questionnaire was distributed to all participants, which asked about the AE stage using five-point Likert scale questions with the following options: "1. Strongly disagree: 2. Disagree: 3. Neutral: 4. Agree: 5. Strongly agree". Table 5 shows the medians and mean ranks of the questionnaire. Their subjective evaluation of growth in the evacuation from day 1 was asked through a question, "Do you think that you evacuated more successfully than on day 1?" The medians of Groups A, B, C, and D were 4, 3, 4, and 4, respectively. The median of Group B was one-point lower than those of the other groups. However, the Kruskal–Wallis test revealed no significant differences, χ^2 (3) = 6.252, p = 0.099. Their motivation to re-participate in the evacuation training was asked through a question, "Do you want to participate in this evacuation training again?" The medians for Groups A, B, C, and D were 4.5, 5, 4, and 5, respectively. The Kruskal–Wallis test revealed no significant differences, χ^2 (3) = 1.496, p = 0.68. Regardless of success or failure in the AE stage, participants were allowed to describe factors (e.g., decisions and behavior) that they believed were actually or possibly leading to a successful evacuation. Table 6 shows the described factors.

Table 5. Medians and mean ranks of the five-point Likert scale questions.

Question	Group (No. of Respondents [1])	Median (Mean Rank)
Do you think that you evacuated more successfully than on day 1?	A (N = 6)	4 (4.0)
	B (N = 7)	3 (13.42)
	C (N = 4)	4 (6.75)
	D (N = 6)	4 (4.33)
Do you want to participate in this evacuation training again?	A (N = 6)	4.5 (9.66)
	B (N = 7)	5 (7.28)
	C (N = 4)	4 (10.0)
	D (N = 6)	5 (5.0)

[1] Two members in Group C did not submit the questionnaire sheet.

Table 6. Factors leading to a successful evacuation.

Group	ID	Reply [1]	Description [2]
A	A1	4	I completed the evacuation slightly faster and cooperated.
	A2	3	N/A
	A3	4	I recalled day 1 and had many thoughts.
	A4	5	I cooperated better than the previous.
	A5	5	I behaved calmly and quickly.
	A6	4	I cooperated better and reached the shelter faster than on day 1.
B	B1	4	I protected my head when an earthquake happened.
	B2	3	N/A
	B3	4	I took decisions more quickly than on day 1.
	B4	2	I could not reach the shelter by the time limit.
	B5	3	N/A
	B6	3	N/A
	B7	2	I failed in the evacuation, but everything else was well done.
C	C1	4	I sprinted on day 2.
	C2	4	N/A
	C3	4	I behaved calmly.
	C4	2	The tsunami reached me.
D	D1	4	I encouraged a friend who was carrying a person during the evacuation.
	D2	4	I made decisions calmly.
	D3	4	I cooperated quickly.
	D4	3	N/A
	D5	4	I quickly decided and evacuated.
	D6	4	I evacuated while watching out for objects that may fall down.

[1] Each participant's replied value of subjective evaluation. Two members in Group C did not submit the questionnaire sheet. [2] Describing the factors was not forced. Note that Groups B and C failed in the evacuation in the AE stage.

4.3. Discussion

4.3.1. CE Stage

Groups A, B, and D were successful in the evacuation, and they tended to sprint in MS. Contrarily, Group C failed in the evacuation, and because they were forced to detour or retrace their route but tended to walk in MS. If Group C had sprinted, they might have reached a shelter within the time limit. Sprinting in MS may indicate that they thought and took decisions in emotional disturbances as if they were in real disaster situations, and that the created scenario provided high situational and audiovisual realism.

Each group made decisions through short-time discussions at most SSs. Thus, we assumed that decision-making was well-provoked in the CE stage. Decision-making time varied in the type of scenes. Following the first SS, all the groups needed more than 10 s to decide which shelter to evacuate to. For example, when Group A started to discuss which shelter to evacuate to, their opinions were divided into the nearest but cliff-top shelter and a somewhat distant but concrete shelter. These decision-making times are reasonable and acceptable because group members had to decide on one from several possible shelters in the area. Regarding the situation of "whether to rescue", Group A needed 11 s to decide to rescue (CE-A-2), whereas Group B immediately decided to rescue (CE-B-3). Both groups reached the same corresponding SS approximately 6 min after the first SS, and their remaining time to reach the shelter was sufficient. The differences in decision-making time resulted from their personalities or group policy. Generally, fifth-grade students are taught that the principle for a successful evacuation is that individuals should prioritize their own lives. However, they frequently believe that altruistic actions, such as lifesaving, are right even in the event of a disaster, and when not alone, they probably take such actions. In the CE stage, as group members evacuated together, they may have dared to rescue others regardless of danger (i.e., death by a tsunami). Although a certain time was spent on rescue, Groups A and B succeeded in evacuation. They may have recognized that the successful evacuation was a correct consequence of their decisions. Because of this principle, it is not easy to explain whether their decisions to rescue others are right. From another viewpoint, their decisions could be an important thought-provoking theme in the RO stage.

4.3.2. RO Stage on Day 1

As shown in Table 2, each group discovered important foci for the successful evacuation because of their reflection. For example, it is a frequently overlooked focus that not only shelter locations but also entrances (and how to enter) should be known. Representatives of Groups A and B presented not focusing much on what they rescued for others. This may be because they thought that lifesaving is undoubtedly right, and there is no need to detail that.

As wrap-ups in the RO stage, Group A presented comprehensive do's by integrating their reflection and other groups' reflection outcomes. Group B presented do's focused on their reflection outcomes. These groups do's mentioned rescuing (carrying) the injured, and they may have been further convinced from their successful evacuation that their decisions were right. The teacher asked Group B about their lifesaving action but put off this focus because the Group B representative struggled to answer the conflict of which life to prioritize. Groups C and D presented do's about lifesaving, and they may have been influenced by other groups' reflection outcomes. Furthermore, Group D may have been influenced by their actual experience, in which they evacuated with the actual wheelchair user. We assumed that objective thinking was provoked in the RO stage. Simultaneously, we recognize that it was difficult to promote and deepen the reflection on a lifesaving-related moral dilemma.

4.3.3. AC Stage

Although do's presented in the RO stage can be regarded as rules for successful evacuation, we assigned optional homework that requested each member to create such rules. As a result, fifteen participants created their rules. Other participants may have created their rules but forgotten them by the AE stage. We assumed that the RO and AC stages should be temporally integrated.

As shown in Table 3, some rules were abstract, e.g., C1's "I evacuate speedily". Only D1's rule "I call out to the injured" was related to lifesaving. Although rules such as C1's may imply that lifesaving should be avoided, many members might have felt that they did not need to make undoubted rules that lifesaving should be undertaken with initiative. If Groups A and B failed in the evacuation due to lifesaving, a rule that lifesaving should be avoided might have been created as a precautionary example. A few rules, such as D3's "I evacuate speedily and quietly", mentioned speedy evacuation. C1's rule may have been derived from their group's reflection, whereas D3's rule may have been inspired by Group C's reflection and their negative reflection on the reply of the Group D representative in the RO stage, " ... should have moved more slowly". This instance may indicate that objective thinking was also provoked in the AC stage. Similar rules, such as A6's "I protect myself quickly. Drop, cover, and hold on" and B4's "I stay away from the stuff that may fall down" mentioned proper actions when an earthquake occurs. They may have, impressively, remembered that a group member had evacuated while still attached to the weight. If proper actions were not taken in the Protection Phase, they might have been unable to start the evacuation and died when a real disaster occurs. Although thought-provoking evacuation training focuses on the Evacuation Phase, we should think about it positively in the sense that rules focusing on the Protection Phase were created.

4.3.4. AE Stage

When hearing an early earthquake warning in the first SS, Group B took proper actions, but Groups A, C, and D did not, although at least one member of each group had created a rule that they take should take proper actions. This indicates that Group B, of which three members created such a rule, applied their rules in the Recognition Phase. Actually, a few members began to search for a place to hide immediately after hearing the warning, and the others imitated it.

All groups tended to spend more time taking decisions than in the CE stage. Against the situation of "whether to assist", Groups A, B, and C decided to assist an injured teacher in 56 s (AE-A-2), 22 s (AE-B-2), and 16 s (AE-C-1), respectively. These decisions are understandable because no explicit rule was created that lifesaving should be avoided, but they seemed to be confused when they faced their familiar teachers who were desperately asking for help (e.g., "I cannot move. Help me!"). They may have realized that after day 1, lifesaving entails a physical burden and can be a factor in a failed evacuation. We assumed that in addition to this recognition, the confusion caused by an unpredicted sight delayed the time before taking a decision. However, against the situation of "whether to rescue", Groups B and D immediately decided to rescue and did not hesitate to carry a heavy doll (AE-B-1 and AE-D-1). Through day 1, they had known of carrying the doll and may have recognized the situation, but they may have underestimated the physical burden. From these instances, human interaction can be a useful factor to make simulated disaster experiences more realistic (i.e., more emotionally disturbing) in thought-provoking evacuation training.

Against the situation of "unreliable shelter", Groups A and D took decisions to stay there in 44 s (AE-A-4) and 20 s (AE-D-2), respectively. Groups B and C took decisions to leave there and move to another shelter in 41 s (AE-B-3) and 40 s (AE-C-2), respectively. All the groups needed a longer time to take decisions because their opinions were bisected. Members who claimed "stay" denied residents' statements (i.e., possible landslide) and predicted that the remaining time to reach another shelter is not enough. Members who claimed "leave" believed residents' statements and predicted that they could reach another shelter within the remaining time. These decision-making times are unavoidable because they had to think of various risks and weighed the two decisions. Occasionally, a rumor during a disaster amplifies distrust and influences decision-making. Spending time in decision-making may indicate that they thought and took decisions in emotional disturbances as if they were in real disaster situations and that the created scenario provided high situational and audiovisual realism. Against the situation of "crowded shelter", Groups B and C took decisions in 25 s (AE-B-5) and 21 s (AE-C-3), respectively. They seemed to decide on another shelter while being upset over consuming the remaining time. If they kept calm, decision-making time might have been shortened. Against the situation of "whether to confirm", Groups A and C immediately decided not to confirm family members' safety (AE-A-1 and AE-C-4). They may have taken a decision based on the principle of successful evacuation (shown in Section 4.3.1). Group B also decided not to confirm, but they needed 21 s to take the decision (AE-B-6). This may be because they increased their upset due to the successive difficult decisions. We assumed that group members' personalities can influence their decisions, particularly when they have emotional disturbances (e.g., temporal upset) caused by encountered disaster situations.

4.3.5. RO Stage on Day 2

In the AE stage, each group encountered at least one lifesaving situation, and these situations were more challenging than in the CE stage. Accordingly, their worksheets mentioned lifesaving more than in the RO stage on day 1, and the teacher actively asked about lifesaving. Groups A, B, and C had difficulty when they took an injured teacher to the shelter using a wheelchair and/or lending their shoulders (AE-A-2, AE-B-2, and AE-C-1). Group A decided to prioritize their lives and was forced to leave the injured teacher behind. This tough decision, a typical lifesaving-related moral dilemma, may have confronted them with a touchy subject. This is because they did not present do's about lifesaving. Groups B and C had difficulty when deciding to evacuate to another shelter together with injured teachers (AE-B-3 and AE-C-2). Following that, they were forced to evacuate slowly though feeling upset. After recognizing that the tsunami is approaching, they started to move faster while pushing the wheelchair or pulling the injured teacher's arm. This resulted in a failed evacuation without outcomes from cooperation. Based on this failure, they might have presented do's such as "cooperate more quickly without getting upset" and "decide calmly, and evacuate speedily". Group D evacuated to the nearest shelter while carrying the doll (AE-D-1) and decided to stay there (AE-D-2). As a result, they succeeded in evacuation. The Group D representative could not explain positive factors for their successful evacuation; however, it is natural because natural phenomena are frequently unpredictable. The teacher said that it might have been just luck that a landslide did not occur around the shelter, especially regarding their decision to remain there. From this instance, we recognized that participants could reflect more easily and clearly on a failed evacuation than a successful one.

The medians of each group's subjective evaluation indicate that Groups A, C, and D felt that the AE stage was completed more successfully than the CE stage, whereas Group B did not feel this owing to their failed evacuation in the AE stage. Focusing on Group B in Table 6, the descriptions indicate that B1, B3, and B7 discovered their positive factors. Group C failed in the evacuation in the CE and AE stages, but the median of their subjective evaluation was favorable, and C1 and C3 discovered positive factors from successive failures. Groups A and D were successful in the evacuation during the CE and AE stages, and their described factors seem common to the presented do's. The medians of each group's motivation to participate in the evacuation training were favorable.

From the above results, we assumed that the thought-provoking evacuation training can work based on the proposed evacuation-training model, and repetition of failed evacuation cannot necessarily lower the effects or participant motivation for the training.

4.4. Limitations

In this practice, the participants were limited to fifth grade students who had completed the Global and Local Phases. Even when a scenario targets the same disaster and local community, differences in the participants' ages could influence their decision making. For example, fourth grade students may tend not to rescue others during an evacuation because of their insufficient physical strength. Participants may be upset and not provoked to think about the successful evacuation if they lack basic knowledge about disaster and shelter locations.

To avoid traffic accidents, we set more SSs inside sections with relatively light traffic in the Hiwasa area. In other words, we intentionally limited the sections where the participants can move. If we set SSs in wider sections, the participants' decisions may have differed, such as which shelter to evacuate to. Moreover, if individual participants were given a smartphone and allowed to start evacuations from arbitrary locations, their decisions would have become more diverse.

The practice followed a single cycle (i.e., the CE, RO, AC, AE, and RO stages in the mentioned order). The true effects of thought-provoking evacuation training may not have been obvious because of the one-cycle practice. In pursuing the details, for example, we could not analyze the validity of the two-week interval between the CE and AE stages.

Our obtained data were insufficient to clarify the effects, e.g., activated consideration of evacuation options. We could not interview each participant to confirm their intentions about group decisions. Additionally, we did not apply detailed statistical analysis to the obtained data and did not precisely detect each member's statements and behavior from the recorded videos.

4.5. New Agenda

We believe that repeated participation in thought-provoking evacuation training following our proposed evacuation-training model leads to prompt, proper decision-making and survival in the event of a disaster. However, we are yet to establish how to evaluate the effects of thought-provoking evacuation training. For example, self-efficacy is frequently used as an evaluation indicator that is subjective but easily collectible from participants. Heightening participants' self-efficacy for evacuation is undoubtedly an important purpose of evacuation training. However, regarding lifesaving, we are not sure if self-efficacy should be enhanced for the public other than emergency responders, that is, if thought-provoking evacuation training should provide participants with "simulated" lifesaving experiences. Real lifesaving differs from and is more difficult than training in various aspects, such as required expertise and available tools. Participants with high self-efficacy for lifesaving may make every effort to rescue others even in highly difficult situations, even if it means sacrificing themselves. We believe that thought-provoking evacuation training should aim at provoking participants to create and confirm their rules about lifesaving before a real disaster occurs, and the participants should be able to take decisions, regardless of the decisions being selfish or altruistic, based on their rules with strong confidence. In other words, participants may be able to accept their decisions without any regret even if they fail to evacuate during real disasters. The only certainty at present is that when creating a disaster scenario, we must consider how to treat lifesaving-related moral dilemmas (i.e., the relationship (ratio) between self-efficacy for lifesaving and the principle for a successful evacuation that individuals should prioritize their own lives).

5. Conclusions

Herein, we proposed a few models for effective evacuation training and described a location-based game that enables thought-provoking evacuation training. The developed game works on GPS- and Bluetooth-enabled Android smartphones or tablets, adopting a geofencing framework to present digital materials (e.g., videos and single-choice questions) that express disaster situations corresponding to locations or times preset in a scenario. A participant (or a participant group) views digital material expressing a simulated disaster situation and decides against the situation, (i.e., responds to a single-choice question). The response branches the storyline; therefore, the game element is scenario-based multiending. The developed game provokes participants to not only take decisions by providing high situational and audiovisual realisms but also think objectively about the evacuation process by working with a reflection-support system.

We practiced thought-provoking evacuation training with fifth grade students, focusing on tsunami evacuations. The scenarios used in this practice attempted to provoke thinking regarding whether to rescue or assist others during a tsunami evacuation, (i.e., lifesaving-related moral dilemmas). During the two-day practice, we observed that the participants took decisions as if they were in actual disaster situations and then thought objectively about the evacuation process by reflecting on their decisions. Moreover, we recognized that dealing with lifesaving-related moral dilemmas in evacuation training for fifth-grade students is difficult. Based on the data obtained, we conclude that thought-provoking evacuation training could work well because decision-making and objective thinking were provoked. Note that this conclusion is limited to the conditions set in the practice. As mentioned earlier, the previous versions of our location-based game were effective in improving situational and audiovisual realisms, participant emotion, motivation in participation, etc. It may be difficult to compare the effects of the latest and previous versions owing to the differences in participant demographics and disaster scenarios. However, we believe that thought-provoking evacuation training is fruitful as an accumulation of our past research outcomes.

The developed game can be used in other local communities, but thought-provoking evacuation training cannot necessarily be conducted in any community. This is because higher situational and audiovisual realisms may cause participants to become emotionally disturbed and sprint around the community. In other words, the participants may be injured in traffic accidents or by other dangers. Before preparing thought-provoking evacuation training, one should consider how it can be conducted safely.

To clarify the obscurities, such as effects and sustainability of thought-provoking evacuation training, we would like to practice it with a wider range of participants in more local communities, focusing on different types of disasters. Moreover, in the future, we intend to conduct comparative practices (experiments) to analyze the essence of thought-provoking evacuation training more in detail.

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