A Mobile Application for Earthquake Education Targeting Foreigners Intending to Visit Japan

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Meiqin Liu[1(✉)], Hiroyuki Mitsuhara[2], Masami Shishibori[2]
[1] Graduate School of Advanced Technology and Science, Tokushima University, Tokushima, Japan
[2] Graduate School of Technology, Industrial and Social Sciences, Tokushima University, Tokushima, Japan
C501947008@tokushima-u.ac.jp

Abstract—Japan is in the Pacific Rim Seismic Belt, and earthquakes happen frequently. Foreigners who lack the necessary earthquake knowledge and escape skills may not survive strong earthquakes in Japan. Therefore, it is essential to provide earthquake education to these foreigners. Since rich-formed earthquake education has been available for foreigners living in Japan, this research works to improve the earthquake education situation for foreigners who intend to visit Japan. Receiving earthquake education in advance helps enhance foreigners' earthquake risk awareness, gain more opportunities to master earthquake survival knowledge, and build earthquake survival confidence. This paper proposed a learning model called 'FOE+G' to achieve the research goals. 'FOE' means the frequency of occurrence of earthquakes in Japan, and 'G' means gamification. A prototype system in the form of a cross-platform application has been developed to confirm that the learning model improves earthquake education for the target audience. The application delivers an earthquake notification to target objects each time an eligible earthquake occurs in Japan. The High-frequency earthquakes in Japan lead to relatively frequent updates, which enable users to build earthquake awareness, realise the importance of earthquake education, and participate more actively in it. Furthermore, gamification is employed in the application to prompt participation in earthquake education.

Keywords—earthquake education, earthquake awareness, earthquake survival ability, earthquake survival confidence, foreigners intending to visit Japan, 'FOE+G' learning model, cross-platform application

1 Introduction

Japan is a country prone to natural disasters. Natural disasters such as earthquakes, typhoons, floods, etc., frequently occur yearly. Strong earthquakes and potential tsunamis are the most dangerous natural disasters in terms of unpredictability and destructibility. Japan is an earthquake-prone country with about 2,000 yearly earthquakes and has experienced dozens of devastating earthquakes in history (from the Japan Meteorological Agency). For example, the 2011 Tōhoku earthquake (9.0–9.1 Mw) and subsequent tsunami resulted in missing and casualties of over 18,000 (from the National Police Agency of Japan). Only physical disaster countermeasures, such as seismic retrofitting and breakwater, to save lives from devastating earthquakes are far from enough. It depends on people's preparedness and behaviour whether they can survive a strong earthquake. In other words, people must acquire adequate knowledge and skills to survive the next possible devastating earthquake. Thus, earthquake education is particularly important for individuals to enhance their ability to survive earthquakes. Engaging in public education about an earthquake greatly affects how individuals prepare and mitigate future earthquake occurrences [1]. Furthermore, earthquake education teaches people how to respond to earthquakes properly and even go through the tough post-earthquake period.

As of December 2021, the Immigration Services Agency of Japan publication accounts that Japan's foreign population exceeded 2.76 million. It is expected that foreigners may keep swarming into Japan after the COVID-19 pandemic. However, many people living in non-earthquake-prone countries may have little awareness and experience with earthquakes and inadequate earthquake knowledge and evacuation skills. Such foreigners may be unable to survive strong earthquakes in Japan. Therefore, earthquake education should be provided to foreigners intending to visit Japan.

Japan has been working to perform disaster education for foreigners currently living in Japan, including earthquake education. Disaster lectures and evacuation drills regularly organised by the government, universities, communities, or other organisations are available. For example, a course at Nagoya University delivered disaster risk reduction education for international students [2]. Handbooks, broadcasts, and TV also provide disaster information and prevention knowledge. Besides, research on how to improve disaster risk reduction and education for foreigners in Japan keeps ongoing. Cultural background and exposure to information about local hazards affect the ability to identify and assess risk, which increases the likelihood that foreign residents will prepare their households for emergencies [3]. Research on the reaction of international students to the great earthquake on 11 March 2011 attempted to improve disaster management strategies. Based on the research findings, suggestions for future disaster planning are advanced, as well as a discussion on the challenges of information provision during crises [4]. However, despite numerous efforts, earthquake education for foreigners is not as effective as it is for the Japanese. In addition to busy work or study, low earthquake awareness or language difficulty may demotivate some foreigners to participate in earthquake education. From this situation, it is expected that earthquake education for foreigners intending to Japan, i.e., earthquake education in a comparatively settled time before they visit Japan, will be accepted as an alternative to increase earthquake education opportunities.

The research in this paper focuses on how earthquake education for foreigners intending to visit Japan can be improved using ICT. Receiving earthquake education in advance enables sufficient time and opportunities to gain earthquake survival ability and build confidence in encountering possible earthquakes. Two research goals are set: RG1, helping enhance earthquake awareness in advance; and RG2, facilitating the mastery of primary earthquake surviving knowledge beforehand. A learning model called

'FOE+G' is proposed to achieve the research goals. In the model, 'FOE' means Frequency of Occurrence of Earthquakes in Japan, and 'G' indicates gamification.

The first important step is to help build earthquake awareness to improve earthquake education. People not living in Japan will hardly access detailed information about earthquakes and will not have earthquake awareness even if they are interested in Japan. This situation is in contrast to people who live in Japan because information about earthquakes via TV news, net news, mobile Apps, etc., is frequently received, and they have already been equipped with solid earthquake awareness. Therefore, it is essential to enhance earthquake awareness by 'FOE' to people intending to visit Japan, who should understand the frequency and be motivated to learn to survive strong earthquakes. Furthermore, gamification is expected to make earthquake education more interesting and increase engagement. Consequently, an ICT prototype system was designed and developed based on this learning model.

The remainder of this paper is organised as follows: Section 2 is a review of related research work; Section 3 is the learning design; Section 4 is the introduction of the mobile application prototype; Section 5 is the experimental results and discussions; Section 6 is the conclusion and future work.

2 Related work review

ICT-based systems are not fresh stuff in disaster (including earthquake) education and prevention [5]. However, ICT-based disaster education, as a complement to conventional methods, has advantages in terms of accessibility, traceability, personalisation, knowledge sharing, user experience, etc.

Mobile applications for disaster education enable knowledge access anywhere and anytime, owing to the popularity of mobile devices and the Internet. Considering the wide acceptance of social media among young people, an application with the help of Twitter conducts disaster prevention and mitigation education among them [6]. Furthermore, a mobile learning application is available for children to improve their earthquake education via an interesting game-based method [7].

Simulation systems play a role in disaster education due to the development of AV/VR technology. Using virtual-reality or augmented-reality technology and some wearable intelligent devices, some systems can simulate disaster scenarios. For example, the system simulates earthquake scenarios to assist evacuation drills [8]. Additionally, this system simulates tsunami scenarios and evacuation tasks using mobile devices [9]. Compared with the traditional evacuation drills, such systems create an immersive experience for users, making drills less time-consuming tasks. Besides, some systems support traceability by logs or other types of records. In the case of failure, the evacuation drill process can be traced back to determine the cause and to make improvements. Currently, many international students with uneven earthquake crisis awareness and knowledge are studying in Japan, and video-based learning is a popular approach to delivering disaster education. However, filtering meaningful information in long videos is time-consuming. A user-responsive video learning tool supports dividing long videos into meaningful chunks for faster skimming and re-watching and figuring out students' preferences/attention and retention process inside the video parts, which helps conduct disaster education among international students [10].

3 Learning design

3.1 Learning model

The learning model includes five elements: 'FOE', earthquake awareness, gamification, motivation, and learning. These five elements are divided into two categories. 'FOE' and gamification belong to 'Trigger-Variable', and the others are classified as 'Learner-Variable.' The structure of this learning model is shown in Figure 1, rectangles represent elements of 'Trigger-Variable', round rectangles represent elements of 'Learner-Variable', and arrows represent a role of 'enhance.' A detailed explanation of the elements is given in Figure 1.

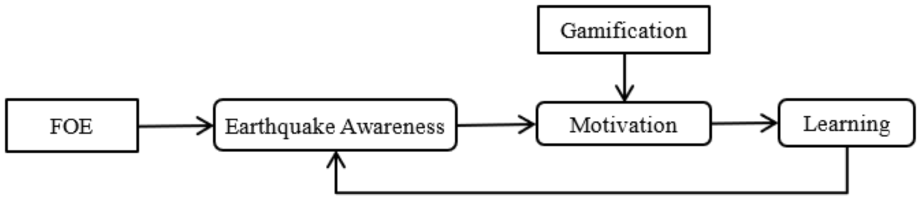

Fig. 1. Learning model structure

FOE. In this learning model, 'FOE' is an arousal event of earthquake crisis with the following logic: Earthquake Occurrence -> Notifying Earthquake Reality (in Japan) -> Arousing awareness. In other words, every time an earthquake occurs, the reality (earthquake occurrence) is delivered to the target audience, and the earthquake awareness gets awakened. This process is called an arousal event, i.e., 'FOE.' Frequent earthquakes in Japan convert 'Japan is an earthquake-prone country' from an abstract concept to dense arousal events, gradually changing people's psychological tendency towards earthquake crisis and helping build awareness in advance.

'FOE' is one type of motivation source for learning in this model. It is currently presented mainly in the form of notifications in the prototype application.

Gamification. It is defined as the use of game design elements in non-game contexts [11]. It is also defined as using game elements and game-design techniques in non-game contexts [12]. In brief, gamification is learning from games, learning what makes the games successful and engaging, and then applying some of those techniques to non-game fields. Gamification may affect users' psychological tendencies and get motivated to inspire specific behaviour. In the educational field, gamification is also popularly used to increase the fun and make learning more engaging [13]. A literature review of forty related articles from 2016–2021 concludes that the use of gamification plays a significant role in improving student learning outcomes, imposing effects on students' engagement, motivation, interest, enjoyment, satisfaction, and innovation in learning activities [14]. Disaster education, including earthquake education, is more likely omitted due to not being compulsory, despite knowing the importance. The introduction of gamification to this learning model is expected to make earthquake education more engaging and encourage active participation rather than boring. Gamification has been applied in disaster management and education [15]. Implementing gamification in disaster education can complete the solution to fulfilling the disaster planning process for residents. Gamified mobile application employed for flood emergency planning shows that gamification can increase user effectiveness regarding time on information and knowledge about disaster risk and disaster preparedness [16]. Gamified applications related to disasters are efficient modes for raising community disaster awareness. The possibility of using gamified applications to increase community awareness through virtual platforms is emphasised, with relatively less space, cost, and time-consuming environments [17].

Gamification is another type of motivation source for learning in the model.

Earthquake awareness. Earthquake awareness is a type of crisis awareness, which can be regarded as the cognition of earthquakes and the resulting psychological needs for earthquake risk aversion. Earthquake awareness potentially affects the attitudes and behaviours towards earthquake education. Increasing earthquake awareness promotes better learning engagement, and earthquake expectations and preparedness could be predicted by earthquake awareness. Awareness and perception of risk are among the most crucial steps in the process of taking precautions at an individual level for various hazards [18][19]. For foreigners intending to visit Japan, it is an important prerequisite for improving the earthquake education situation to build earthquake awareness, which imposes a long-term impact on stimulating participation in earthquake education. Accordingly, helping raise earthquake awareness is one of the research goals.

Figure 1 shows that the element 'FOE' works on 'Earthquake Awareness.'

Motivation. This element here in the model, in brief, refers to the enthusiasm and initiative to participate in earthquake education. From Figure 1, 'Earthquake awareness' and 'Gamification' work on the element 'Motivation.' As mentioned, earthquake awareness is the cognition of earthquakes and the ensuing need to avoid earthquake risks. These needs prompt seeking effective approaches to reduce such risks, i.e., motivation. The employment of gamification helps maintain a motivating situation.

Motivation helps a positive attitude toward learning (earthquake education).

Learning. This element means behaviour to participate in earthquake education. In this model, 'Learning' is one of the research goals. It is propelled by 'Motivation.' Meanwhile, learning reversely boosts earthquake awareness, forming a virtuous circle.

3.2 Research questions

Two research questions (RQ) are proposed based on the two research goals.

- RQ 1. To what extent do FOE and G contribute to improving earthquake education situation for target audience in terms of raising earthquake awareness?
- RQ 2. To what extent do FOE and G contribute to improving earthquake education situation for target audience in terms of knowledge acquisition?

4 Mobile application prototype

This prototype system has a central part as an application, with an attached server. The server mainly performs functions such as: retrieving seismic information from the Japan Meteorological Agency (JMA), pushing earthquake messages to the application via WebSocket, retaining seismic information, managing users, and sending notifications to the Apple Push Notification service (APNs) or Firebase Cloud Messaging (FCM) of Google, among others. The application mainly implements seismic information subscription to the server, information displaying and reviewing, notification processing, gamification, learning materials, and multilingual support. The system architecture is presented in Figure 2.

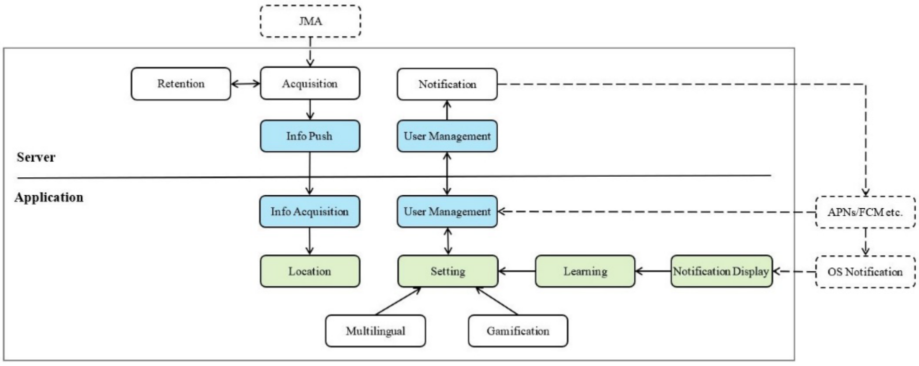

Fig. 2. System architecture

The dashed round rectangles represent external functions, and the dashed lines indicate the interaction between the system and external functions. Rectangles marked in light blue indicate the interaction layer modules between the server and application. Rectangles in light green indicate the UI layer modules in the application. The remaining rectangles belong to the lower-level processing modules.

4.1 Application constitution

The application has been developed based on Flutter [20] and Dart development language [21], and it is cross-platform to be available for iOS and Android operating systems. Here the following sample screenshots were taken on an Android smartphone.

Information Acquisition. The application supports the WebSocket protocol, which enables the server push function. When the application launches, it makes a subscription to the server. Then, the application listens to the server for new seismic messages, whether they are active or in the background.

Location. It supports displaying and preserving the seismic information from the 'Information Acquisition module.' No more than three locations are allowed to be present. Each place has a card with the location name and the number of total earthquakes, the number of earthquakes having a magnitude equal to or greater than 3. Figure 3 shows how this module works.

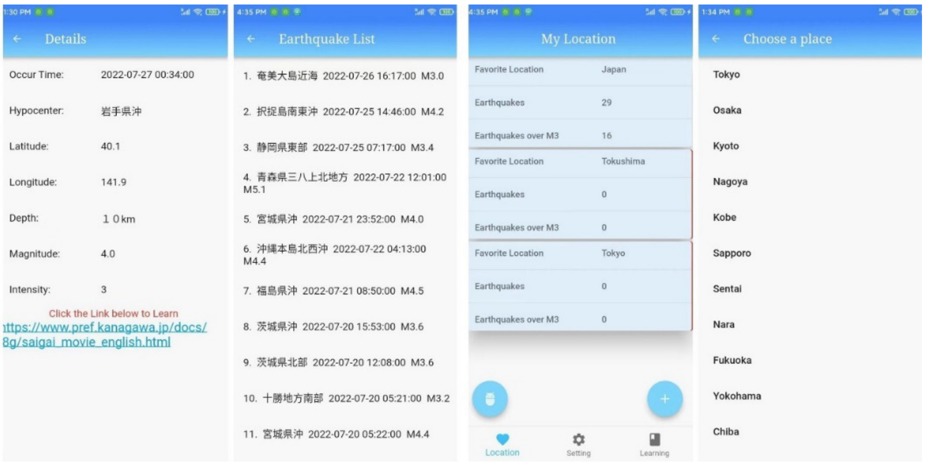

Fig. 3. Information display and retention in location module

On the page 'My Location,' the first in the list of locations defaults to Japan, i.e., users manage up to two concerning places. Users can remove a place from the list by swiping to the left, or add a new one by clicking the round button at the bottom right, which navigates to the page 'Choose a place.'

Clicking the round button at the bottom left, navigates to the earthquake message intention page titled 'Earthquake List,' and click any item to view the details, as shown on the page titled 'Details.'

Setting. English and Simplified Chinese are available. Setting the threshold (by seismic magnitude) to trigger a notification is supported. Besides, user personal information is shown, including username, rewards, study, etc. User information and settings synchronise between the 'Setting' module and the 'User Management module.' Figure 4 shows the 'Setting' page and subpages.

The first screenshot in Figure 4 is the 'Setting' page, and others are subpages navigated by clicking items orderly on the 'Setting.'

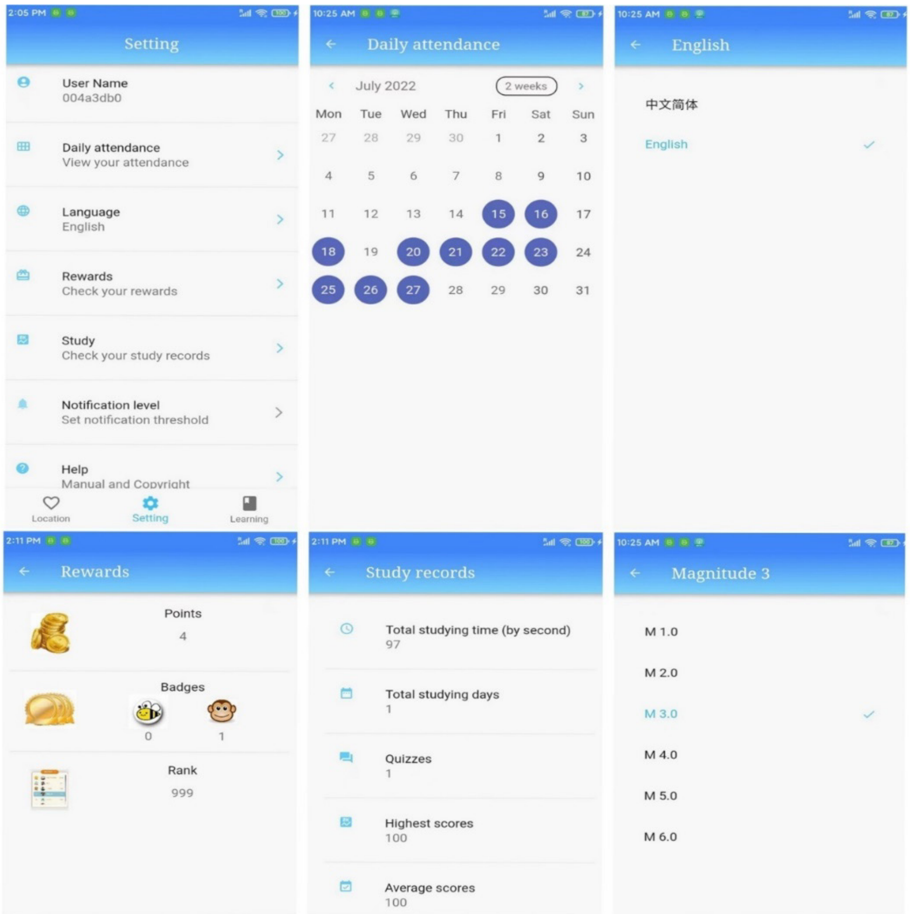

Fig. 4. Screenshots for settings and subpages

Learning. The application also provides rich learning materials in both contents and forms, including scenario earthquake knowledge (named 'Text' type), learning links ('Link' type), pictures ('Pic' type), video links ('VLink' type), and quizzes ('Quiz' type), enabling learning anytime and anywhere. Figure 5 shows the five types of learning materials available in the application.

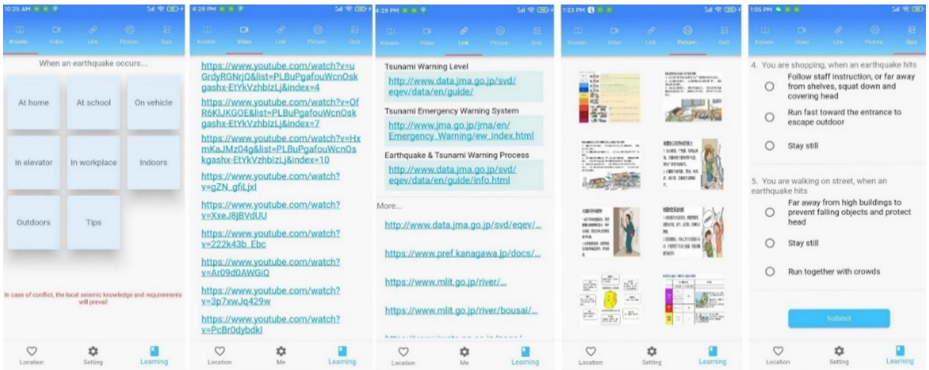

Fig. 5. Learning materials

Notification display. This module takes charge of responding to the user tap when the OS pops up a notification and displays it in the application.

Notification is the instance of ‘FOE’ in the application. Users are aware of the frequent earthquakes in Japan through notifications even if the application exits. Besides earthquake information, each notification has a tip of a random type of earthquake knowledge. Therefore, user attention is drawn to earthquake notifications, which also present learning opportunities. In such a situation, high levels of attention enable effective learning. Consequently, this is how notifications contribute to earthquake education awareness and participation.

Figure 6 shows how a notification works. The first screenshot shows that the OS pops a notification, and the second shows the response page after tapping on the notification. Besides earthquake details, a URL to the learning tip is attached. Clicking the URL will navigate to the corresponding page. Users are also reminded to navigate to ‘Learning’ for more learning materials.

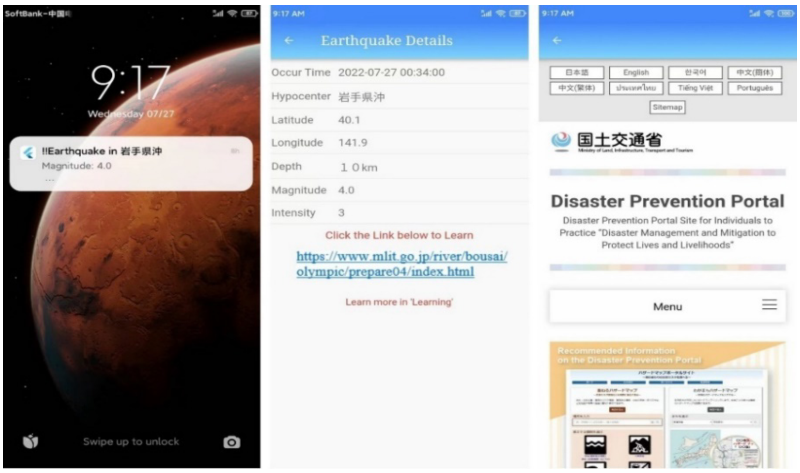

Fig. 6. Notification working mode

User management. This module processes the local and server synchronous storage of personal information. When user status gets changed, such as learning status and rewards are updated, or the notification threshold is reset, the new values are locally written and posted on the server synchronously.

Besides, this module is also responsible for retrieving and updating the device's unique identity from APN/FCM, etc., and posting the identifier to the server to locate the target application and send notifications.

Gamification. Table 1 shows the gamification, including game elements and mechanisms, employed in the application. Point and badge are the most common game elements. Daily attendance has recently become popular, encouraging people to conduct specific missions daily. This application, for example, is designed for a particular page to be accessed once a day, which may remind users to use the application and contributes to customer adherence to the application. These types of game elements may facilitate learning directly or indirectly.

Table 1. Game elements and mechanisms

Game elements	Game mechanisms
Point	Rewards, feedback
Badge	Rewards, feedback
Daily attendance	Challenge, achievement, chance

The rules for gaining points are as follows: 1. Launching the application gains one point once a day; 2. Viewing a notification gains one point; 3. Learning the tip on a notification gains one point; 4. Learning for at least 1 min gains one point once a day for each type of learning material; 5. Daily attendance gains one point per day; 6. Keeping daily attendance up to specified days gains a box with random points, no more than the number of consecutive attendance days.

Two types of badges exist: 1. Bee badge, representing diligence; 2. Monkey badge, representing intelligence. The rules for gaining badges are as follows: 1. Full marks in a quiz earn a monkey badge; 2. Daily attendance up to specified days (5, 10, 15, 20, 25, and 28 respectively) gains a bee badge.

Figure 7 shows partly the gamification used in the application. The first screenshot indicates gaining a point after learning the Text material for at least one minute. The second is for the Link material. The third shows earning a Monkey Badge when users get full marks in a quiz, and the fourth shows the daily attendance.

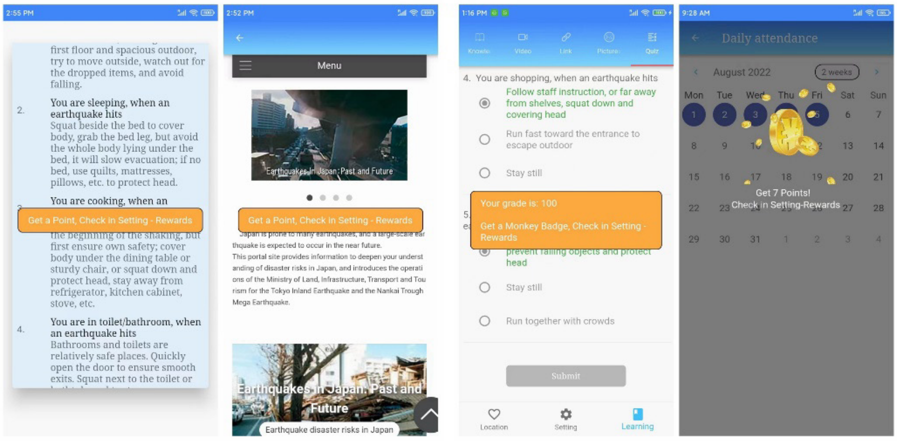

Fig. 7. Gamification in the application

Multilingual. Multilingual support is required because the target audience is foreign users. According to a survey, the Japanese language may be a barrier for foreigners in accessing sufficient disaster information [22]. Therefore, multilingual support should be a tool to work to serve multicultural students [23]. The application currently supports simplified Chinese and English. The default language of the application initially follows the device language. If this language is not supported currently in the application, English is the default language. A preferred language can be chosen from the supported list on the 'Setting - Language' page, shown in Figure 4.

4.2 Server

Additionally, a server has been developed to support the application, and it is based on the Spring Boot framework and implemented using the Java development language. The current version of the server supports 200 concurrent accesses and keeps improving.

As shown in Figure 2, the server supports acquiring earthquake information from JMA and retaining earthquake information within a certain period. Push earthquake information to the application through the WebSocket protocol after the application subscribes to the server. The user management module supports personal information and setting preservation. In the user management module, a unique device identifier and notification threshold are combined to trigger notifications to APNs/FCM, etc.

Additionally, user data during the experiment were temporarily recorded.

5 Experiment

An experiment was conducted using the prototype application to answer the research questions.

5.1 Settings

Participants. Considering the large population of possible learners, thirty-eight participants intending to visit Japan were recruited in China. Before the experiment, every participant agreed on the practical terms (e.g., the application installation into their smartphone and a 4-week experimental period). The results of an anonymous pre-questionnaire distributed among participants showed that the age distribution was 33, 4, and 1 participant in the age groups 18–25, 26–30, and 31–40, respectively. The results also revealed the following participant features:

- Thirty participants never experienced a large earthquake.
- Eight participants had no earthquake knowledge, twenty-eight had limited, and only two knew well.
- Twelve participants knew nothing about surviving earthquakes in Japan, and twenty-six knew only a little.

From these features, many participants fit the targeted learners because they are believed not to acquire enough knowledge and skill to survive earthquakes.

Participants were divided into the following groups while minimising the participant features' differences.

- Group FG (N = 13): Participants installed the application with notifications of FOE (F) and Gamification (G) functions - experimental group.
- Group F (N = 13): Participants installed the application with the F function - experimental group.
- Group C (N = 12): Participants installed the application without any F or G function - control group.

All applications are the same except for the F/G functions. The grouping of all participants was transparent in that they did not know they were in one of the three groups and would be using applications with different functions.

Procedure. Before entering the experimental period, participants were provided with the app manual (different among groups) and a short time for trial use. All participants simultaneously entered the experimental period from 21 April to 18 May 2022. During the experimental period, participants were not forced to use the application.

Participants were defined as follows by their behaviour to the application.

- Non_user: Participants did not use the application during the experimental period.
- User: Participants had used the application during the experimental period at least once.
- Learner: Participants had learning behaviour by tapping a learning tip carried on a notification or viewing learning materials in the application.

Additionally, the following data types were collected and recorded on the server.

- N_Learn: The total amount of time learning by navigating to 'Learning' in the application.
- D_Learn: The total duration (sec) of each learning when navigating to 'Learning' in the application, from the start (when learning material is presented) to the end (when learning material is closed).
- T_Learn: The number of learning times and duration for each type of learning material (i.e., text, picture, link to external learning material, link to external video, and quiz).
- L_Days: The number of days when participants have learning behaviour.
- N_Resume: The number of times resuming the application (by participants).
- N_Notif: The number of notifications (for groups FG and F).
- N_Notif_Learn: The number of times learning by clicking learning material via a notification (for groups FG and F).
- N_Points: The number of points gained using the application (FG group only).
- N_Monkeys: The number of monkey badges gained using the application (FG group only).
- N_Bees: The number of bee badges gained using the application (FG group only).
- N_Attend: The date distribution of daily attendance (FG group only).

After the experimental period, all participants were given a post-questionnaire consisting of five-point Likert Scale questions and other surveys to evaluate the application and collect user feedback. Then, two months later, an online test was conducted to examine the situation of knowledge retention among groups.

5.2 Results

Participant behaviour. The collected data revealed that nine participants were non-users: two, one, and six in Groups FG, F, and C, respectively. Group C had more non-users than the other groups, which means lower participation. Table 2 shows the data that intuitively reflect the difference in earthquake education participation levels among the three groups.

Table 2. Summarised data on participation levels

Group	Non_user	User	U_Rate*	Learner	L_Rate**
FG	2	11	84.62%	8	61.54%
F	1	12	92.31%	9	69.23%
C	6	6	50.00%	4	33.33%

* User percent to total participants.
** Learner percent to total participants.

Table 3 shows the collected data on learning behaviour, including the mean values of the number of learning times and durations (by second), the number of total learning times and the total learning duration for groups.

Table 3. Summarised data on learning behaviour

Group	N_Learn	Mean*	D_Learn	Mean**	Mean***
FG	159	12.23	1617	124.38	202.125
F	195	15.00	1747	134.38	194.11
C	59	4.92	688	57.33	172.00

* Mean value of N_Learn
** The mean value of D_Learn for all participants in each group
*** The mean value of D_Learn to Learners in each group

The number of days with learning behaviour is 19, 12, and 6 in groups FG, F, and C, respectively. Figure 8 shows the date distribution of learning behaviour and the number of learners daily.

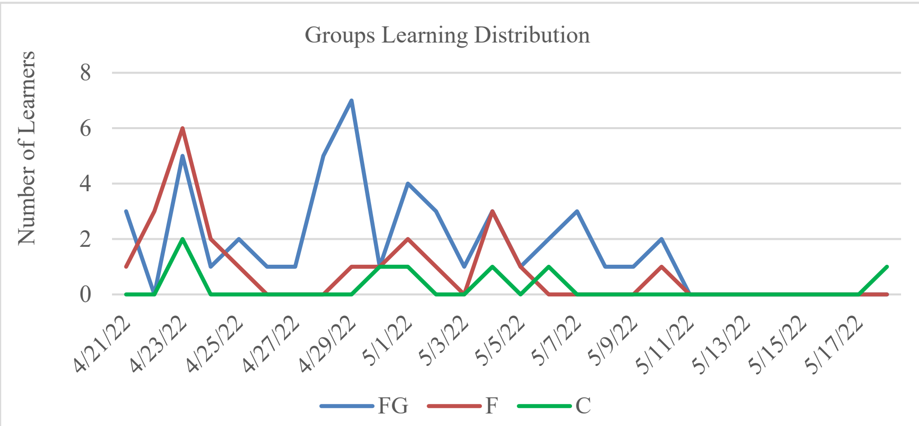

Fig. 8. Learning behaviour distribution on the date

The number of application resuming times, i.e., how frequent users wake up to the application, was recorded for each group, which is an aspect of the customer stickiness to the application, shown in Table 4.

Table 4. Application resuming times

Group	FG	F	C
N_Resume	156	70	20

Different learning materials were recorded, which may help determine user preferences for learning materials and adjust weights accordingly. Tables 5 and 6 show the number of times and durations for types of learning materials (T_Learn), respectively.

Table 5. Learning times of materials

Group	Total	Text*	VLink*	Link*	Pict*	Quiz*
FG	159	71 (44.65%)	19 (11.95%)	17 (10.69%)	21 (13.21%)	31 (19.50%)
F	195	67 (34.36%)	30 (15.38%)	14 (7.18%)	18 (9.23%)	66 (33.85%)
C	57	25 (43.86%)	6 (10.53%)	4 (7.02%)	8 (14.04%)	14 (24.56%)

* The numbers in brackets are the percentage of times of the corresponding type to the number of total times in each group.

Table 6. Learning duration of materials

Group	Total	Text*	VLink*	Link*	Pict*	Quiz*
FG	1617	811 (50.15%)	67 (4.14%)	14 (.87%)	46 (2.84%)	679 (41.99%)
F	1747	644 (36.86%)	40 (2.29%)	21 (1.20%)	387 (22.15%)	655 (37.49%)
C	688	144 (20.93%)	6 (.87%)	7 (1.02%)	165 (23.98%)	366 (53.20%)

* The numbers in brackets are the percentage of the learning duration of the corresponding type to the total learning duration in each group.

During the 28 days experiment period, a total of 31 notifications were clicked, 20 by group FG and 11 by group F. Group FG learnt notification knowledge tips 13 times, while group F learnt them nine times. The distribution of notification clicks and learning is shown in Figure 9.

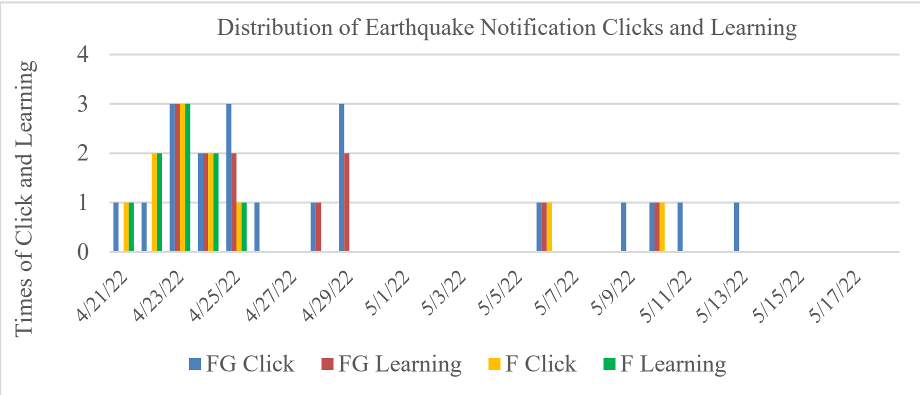

Fig. 9. Distribution of notification click and learn

For group FG, the use of gamification is shown in Table 7.

Table 7. Gamification in group FG

Group	N_Attend*	N_Points*	N _Monkeys*	N _Bees*
FG	42 (8)	180 (11)	24 (6)	1 (1)

*The value in brackets indicates the number of participants in the corresponding game element.

Participant impressions to application. In total, 29 responses to the Likert Scale questionnaire were received, 6 in group N, 12 in group F, and 11 in group FG. Some of these respondents had not learnt about the system during the experiment. However, before the experiment, all participants had a short trial, so all answers could be considered valid.

As shown in Table 8, the Likert Scale had five surveying items for evaluating the three Apps, covering usage, ease of use, ease of learning, and user satisfaction.

Table 8. Results of the Likert Scale on the application

Question	FG	F	C
Q1. The application is easy to use	3.91	4.00	3.83
Q2. The application has rich learning materials	3.64	3.58	3.67
Q3. The application helps enhance earthquake awareness	3.91	3.75	3.00
Q4. The application helps master earthquake knowledge	3.82	3.83	3.67
Q5. Overall, the application is satisfactory	3.82	3.58	3.50

Surveys on notification and gamification. Table 9 shows the evaluation of groups FG and F to use notification (FOE) in the application.

Table 9. Results of the Likert Scale on notification

Question	FG	F
Q1. Do you agree that notifications help enhance your earthquake awareness?	4.09	3.75
Q2. Do you agree that tips on notifications help you master earthquake knowledge?	4.18	3.92
Q3. Do you agree that notifications prompt you to learn earthquake knowledge?	4.00	3.75
Q4. Do you agree that frequent notifications are acceptable?	3.18	2.92

Table 10 shows the evaluation of group G towards the employment of gamification (G) in the application.

Table 10. Results of the Likert Scale on gamification

Question	FG
Q1. Do you agree that gaining points prompts you to learn earthquake knowledge?	4.09
Q2. Do you agree that gaining badges prompts you to learn earthquake knowledge?	4.09
Q3. Do you agree that daily attendance prompts you to use the application?	4.18
Q4. Do you agree that daily attendance reminds you to gain earthquake knowledge?	4.18

Knowledge retention situation. an online test was conducted among the same participants in three groups two months after the experiment examined the participants' knowledge retention situation. The test assessment included 25 multi-choice questions (single-correct or multi-correct choices) on basic knowledge of earthquake survival. In total, 36 responses were received, 12 in group FG, 13 in F, and 11in C. The responses are two types: 'Learner' and 'Non_learner.' 'Learner' represents participants who have learnt earthquake knowledge by this application in the previous experiment, and 'Non_learner' represents participants who have not learnt earthquake knowledge by this application. The results are shown in Table 11.

Table 11. Results of the knowledge retention test

Group	Non_learner	Mean Score*	Learner	Mean Score**	Mean Score***
FG	5	62.4	7	84	75
F	4	64	9	84.44	78.15
C	7	63.43	4	78	68.73

* The mean score of Non_learners
** The mean score of Learners
*** The mean score of the total responses in each group

5.3 Discussion

Research questions were discussed and concluded based on the experimental and survey results.

RQ 1. To what extent do 'FOE' and 'G' contribute to improving earthquake education situation for target audience in terms of raising earthquake awareness?

Discussion. The post-survey results in Table 8 show that the mean values of Q3. are 3.91(in 5 points), 3.75, and 3.00 in groups FG, F, and C, respectively. Groups FG and F improve significantly compared with group C, while groups FG and F differ slightly. The results of Q1. in Table 9 reveal that participants in groups FG and F hold a relatively positive attitude that notification increased their earthquake awareness, 4.09 and 3.75, respectively. However, there were no obvious differences between the two groups.

Conclusion. 'FOE' has relatively significant effects on raising foreigners' earthquake awareness, while that of 'G' is not very significant.

RQ 2. To what extent do 'FOE' and 'G' contribute to improving earthquake education situation for target audience in terms of knowledge acquisition?

Discussion. Three aspects are under consideration in evaluating the results of learning.

1. Participation
   Table 2 shows that groups FG (84.62%, 61.54%) and F (92.31%, 69.23%) have obvious improvements in terms of the participation of both Users and Learners than those in group C (50.00%, 33.33%), while the difference between groups FG and F is slight. Fig. 8. shows that groups FG and F perform better than group C in the number of study days and the number of active learners per day. Comparing Fig. 9., at the time points of 23 April and 29 April, notification clicking and learning were

more frequent. Meanwhile, Fig.8 shows that there are also two peaks of learning behaviour on the two days. As a result, 'FOE' helps increase engagement and stimulate learning behaviour to a certain extent. It is also shown in Fig. 8. that group FG performs better than group F, with learning behaviour lasting longer, indicating that gamification somewhat works to keep participants motivated for a long time and increases the level of individuals' participation. However, it does not contribute much to the participation of the whole group FG.

2. Learning behaviour

   Table 3 shows that groups FG (12.23, 124.38) and F (15, 134.38) have better performance on the mean value of learning times and duration than those in group C (4.92, 57.33), while the differences between groups FG and F are slight. Table 9 Q2 and Q3 results show that the groups FG and F harbour relatively positive attitudes that FOE helps learn 4.18 and 4.00 for group FG, 3.92 and 3.75 for group F, respectively. The results of Q4 in Table 9 show, however, that participants in groups FG and F did not hold a positive attitude towards frequent notifications, 3.18 for group FG and 2.92 for group F. More than half of the participants considered only one piece per day acceptable. Even though notifications affect user learning attitudes and behaviours, the frequencies of notification clicking and learning are not as expected, as shown in Fig. 9.

   Besides, from Table 3, the mean learning duration in terms of Learners in group FG (202.125) is slightly longer than that in groups F (194.11) and C (172), which indicates that the employment of gamification benefits individual learning performance in group FG. Table 4 shows that group FG has significant differences in the application resuming, which shows that gamification helps motivate users in the long term and increases the user stickiness to the application. Table 7 presents the usage of game elements. The post-survey results in Table 10 also show that users keep a positive attitude that gamification is helpful to continue learning. However, motivation and stickiness have not improved learning behaviour significantly. According to the post-survey results, it might be attributed to the fact that some learning materials were inaccessible in the experimental area.

3. Learning results

   The results of Q4 in Table 8 also show that users hold a relatively positive attitude that the application helps master basic earthquake knowledge. The knowledge retention exam results in Table 11 show that the mean scores of 'Non_learner' in the three groups have no obvious difference. In each group, the mean score of 'Learner' was significantly higher than that of 'Non_learner', meaning learning by using the application was effective in all groups. Additionally, the mean scores of 'Learner' in groups FG and F are higher than that in group C, which indicates that groups FG and F have better knowledge retention than groups C, and 'FOE' and 'G' contribute to better knowledge acquisition and memory. There was no significant difference in the mean scores of 'Learner' between groups FG and F. The mean scores of the total responses in groups FG and F are higher than those in group C, which shows that benefiting from 'FOE' or 'G', groups FG and F have better learning results overall than group C.

Conclusion. 'FOE' contributes significantly to raising group participation and has obvious effects on improving learning behaviour. Gamification does little on group participation. However, it has certain effects on improving individuals' participation and learning performance within the group and maintaining learning motivation. There is no difference between 'FOE' and 'G' in the evaluation of learning results.

Besides, the experimental data collected revealed user preferences on the types of learning materials. Tables 5 and 6 show the learning times and duration for each type of learning material and the corresponding percent. The type 'Text' and 'Quiz' are the most popular in the three groups. However, the types 'Vlink' and 'Link' are rarely used. A furthermore survey figured out that the main reasons included 'avoid unknown URL due to security,' 'inaccessible,' 'load the URL very slow,' 'watching video is time-consuming,' 'watching video is costly in case of no Wi-Fi,' etc. These data and surveys help customise the learning materials facing different target audiences and adjust the weight of types of learning materials to better user experience.

6 Conclusion

This research improves the current situation of earthquake education for foreigners intending to visit Japan. For the target objects, two research goals are set: 1. help build a good earthquake awareness in advance; 2. help master the basic earthquake survival knowledge in advance. A learning model called 'FOE+G' is proposed to achieve the goals, and a prototype application is developed based on it. The experiment verified that the application based on the learning model achieves the two research goals.

Additionally, the experiment itself has limitations. For example, the sample size of the subjects is small. Besides, some services in the experimental area are unavailable, resulting in a poor user experience. Likewise, the UI design of the application is unprofessional enough.

The future work, according to the experimental results and user feedback, will implement the notification mechanism more flexibly to strike a balance between user acceptance and valid warning. Besides, improving the classification of learning materials, expanding learning materials, and localising learning materials according to learning objects to avoid services or websites being unavailable, thereby improving user experience, are all on the plan list. Furthermore, according to the learning objects, reasonable gamification elements and mechanisms will be adopted to turn the learning motivation and customer stickiness into learning behaviour.

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8 Authors

Meiqin Liu is currently a doctoral student at the Graduate School of Advanced Technology and Science, Tokushima University, Tokushima, Japan. Her research focuses on the disaster education based on ICT systems for foreigners intending to visit Japan and living in Japan (email: c501947008@tokushima-u.ac.jp).

Hiroyuki Mitsuhara received the B.E. and M.E. degrees from Kindai University in 1998 and 2000, and then he received the Ph.D. degree from Tokushima University in 2003. He is currently an associate professor at Tokushima University. His interest includes interactive learning systems, game-based learning, VR/AR, and disaster education (email: mituhara@is.tokushima-u.ac.jp).

Masami Shishibori received his BS Degree in 1991, his MS Degree in 1993 and PhD Degree in 1997, from Tokushima University, Japan. He is currently a full professor at Tokushima University, Japan. His research interests include multimedia processing, information retrieval, and natural language processing.

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