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Exploring Application of an ICT-Based Disaster Education System for Foreigners in Japan

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Abstract: In Japan, a disaster-prone country, foreigners may fail to survive in disasters because they lack disaster-related knowledge, so disaster education for foreigners living in Japan is necessary. However, many foreigners are unwilling to spend time on disaster education. To improve this situation, gamification is employed. Gamification is to use game design elements or mechanisms in non-game contexts. For example, in the educational field, gamification makes learning easy and attractive, which motivates participants and encourages engagement in learning activities. This paper explores an information and communication technology–based system with application of gamification in disaster education for foreigners living in Japan.

Keywords: Foreigners in Japan, disaster education, gamification, ARCS+G motivation model, ICT-based disaster education system, cross-platform app

1. Introduction

Japan is attracting an increasing number of foreigners from all over the world with its natural and cultural environments. According to statistics from the Japanese Ministry of Justice, the number of foreigners residing in Japan increased dramatically from around 2 million to more than 2.6 million between 2011 and 2018, and the rising trend is continuing. The large number of foreigners have brought new social problems into the country. One of the important issues is disaster education, particularly how foreigners will survive during disasters.

Japan is a disaster-prone country. However, Japan has generally had low numbers of casualties caused by disasters, especially by earthquakes. Japan's comprehensive and advanced disaster education is one of important reasons contributing to the low casualties. In Japan, even among kindergarteners, disaster education, including disaster knowledge, survival techniques, and evacuation drills, is conducted regularly. Therefore, the Japanese know how to quickly get to designated sites or safe places by proper methods.

However, disaster education for foreigners living in Japan is not as effective, and it is unclear how it should be improved. Unlike the Japanese, most foreigners have neither disaster awareness nor disaster knowledge relevant to their adopted country, and they have no understanding of how to survive when encountering disasters in Japan. Even if disaster lectures and experience activities are organized regularly in universities, the popularity of disaster education among international students is not satisfactory. It can be inferred that general foreigners in Japan are in the worse situation than international students on receiving disaster education because they have fewer opportunities to be exposed to disaster education and knowledge.

Such foreigners may not survive disasters, which may contribute to serious social problems. This is a negative factor in Japan's efforts to attract more foreigners. Thus, it is indispensable to popularize disaster education among foreigners, to enhance their disaster awareness, to impart disaster knowledge, and to help them build confidence in meeting possible disasters. To solve this problem, an information and communication technology (ICT)–based disaster education system is designed and developed in this study.

Complicating this problem, disaster education can be boring, and it is not compulsory for adult foreigners. As a result, people are reluctant to invest time in disaster education, which reflects their lack of disaster awareness. Considering this situation, gamification is employed in the presented disaster education system, which is expected to make the education more engaging to encourage foreigners' participation.

Considering the following properties of earthquakes:

1. Unpredictability. Earthquakes cannot be predicted accurately yet and may hit anytime or anywhere. The unexpected nature of earthquakes means many people fail to prepare for this type of disaster.
2. Great hazard. The destructiveness of strong earthquakes and possible sequent tsunami is frightening. For example, in the Tohoku district off the Pacific Ocean, an earthquake occurred in 2011 that, with the sequent tsunami, resulted in a missing and death toll of more than 15,000 people.

In Japan, earthquakes strike with a high frequency. Based on these considerations, this paper focuses on disaster education related to earthquakes. If not specified, disaster education in the following sections refers to earthquake education.

2. Fundamental Ideas on Earthquake Education

2.1 Study Outline

In this study, earthquake education is divided into three learning phases that foreigners enter in sequence: (1) preparation phase, (2) practice phase, and (3) influencer phase. The first phase, the preparation phase, means people start accessing earthquake knowledge in their home country before visiting Japan. This is necessary to help build awareness of earthquakes. For example, if foreigners intend to visit Japan, they should know that there is a high frequency of earthquakes in Japan.

The second phase, the practice phase, involves gaining practical knowledge after arriving in Japan. For example, it is important to know detailed shelter information, to know where and what types of shelters are in the community, and to participate in evacuation drills and other exercises that help people get to the nearest evacuation site during an earthquake.

The third phase, the influencer phase, involves learning to become influencers, i.e., instructors or facilitators. Foreigners with disaster education can act as influencers to impart earthquake knowledge to those who intend to visit Japan, to help them build earthquake awareness and confidence, or to nationals in their home countries to promote earthquake education. The three learning phases are shown in Figure 1.

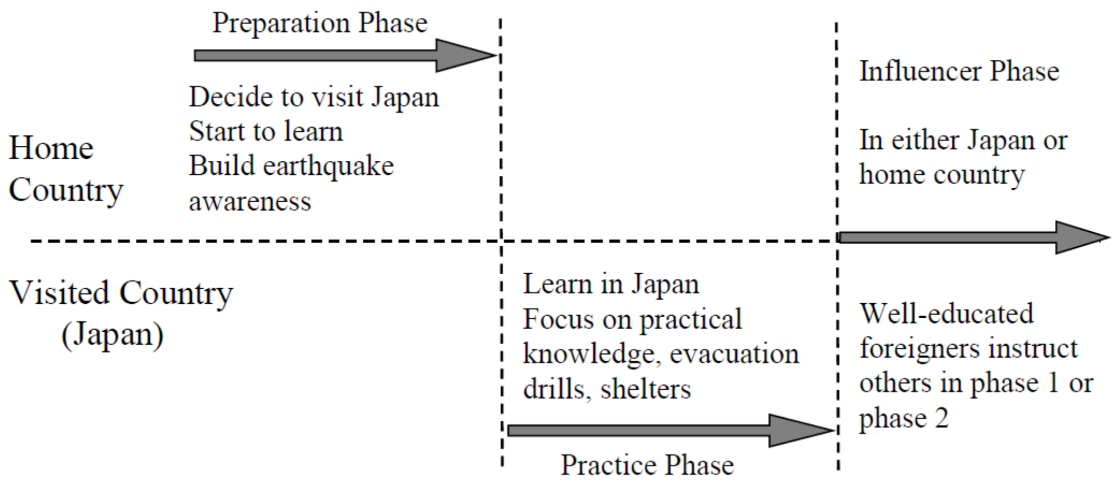


Figure 1. Three learning phases by timeline.

2.2 ICT-Based Disaster Education

In disaster education, disaster knowledge and evacuation drills are indispensable. However, in conventional disaster education, arranging a disaster lecture or organizing an evacuation drill is time consuming. Furthermore, such evacuation drills cannot create an immersive experience, and participants may not be serious about learning because they know the drill is just a drill and not real.

ICT-based disaster education, as a complement to conventional methods, is in a boom phase (Rahman et al., 2016) (Leelawat et al., 2018). Compared with conventional disaster education, ICT-based disaster education has several advantages. With the diversification of electronic equipment, different ICT-based systems have emerged and play an increasingly important role in disaster education. Some ICT-based systems obtain effective and instant disaster information by using portable devices and the Internet. In particular, by using virtual-reality or augmented-reality technology, as well as some wearable intelligent devices, some systems can simulate a disaster scenario and create an immersive experience for users (Kawai et al., 2015) (Mitsuhara et al., 2016). Backtracking is also an important property in disaster education. Some ICT-based systems record all procedures of evacuation drills, which enable facilitators to check and improve participants' missteps when evacuation drills fail. This increases the success of drills in real evacuations.

This paper concentrates on the first phase of research: beginning earthquake education when foreigners are still in their home countries. An ICT-based system, combining with the application of gamification, will help fulfill the requirements.

2.3 What the System Is Like

The system consists of two parts: server side and client side. The server side supports the WebSub open protocol, and the client side is designed and developed as a cross-platform app for smartphones.

Besides high efficiency and backtracking, this system has other advantages, such as the following:

1. Accessibility. As a cross-platform app, the client side allows the system to be unrestricted by time and space. Disaster information and knowledge can be easily accessed.
2. Timeliness. WebSub improves the polling mechanism that lets the server side receive almost real-time seismic information and alarms.

Explanations of the system, including WebSub and the cross-platform app, are given in section 3.

2.3.1 Achieving the First Phase

In this phase, disaster education mainly focuses on two aspects: (1) improving foreigners' earthquake awareness and (2) helping foreigners acquire earthquake knowledge.

For the first aspect (i.e., improving foreigners' earthquake awareness), a parameter called frequency of earthquakes (FOE) is introduced into the system. The FOE is the number of earthquakes occurring in Japan within 1 year. It can be seen clearly that the number is in the thousands. Every year, each time an earthquake occurs in Japan, the FOE will increase by 1, and earthquakes with a seismic magnitude of 3 or greater will also be counted and displayed. For example, in 2018, the FOE was 2,179, which meant Japan experienced 2,179 earthquakes, and the number with magnitude 3 or greater shocks was 256. It is clear from the FOE that earthquakes happened 6 times per day on average in Japan and that those of magnitude 3 or greater occurred every 1.4 days on average. Through these intuitive data, the "Japan is an earthquake-prone country" concept will become concrete instead of abstract. If the system was in use in 2018, users' smartphones would be overwhelmed by earthquake warnings, which promotes foreigners to change their views and builds earthquake awareness.

For the second aspect (i.e., helping foreigners acquire earthquake knowledge), the system provides a learning module that includes various materials as text, pictures, videos, links, quizzes, etc. Earthquake information and knowledge, as well as corresponding measures to help survive an earthquake, can be accessed easily. Quizzes help to check whether users have a good command of the earthquake education.

2.3.2 User Customization

User-customized settings are available. Settings based on destination are supported, placing emphasis on the seismic information for specific places. For example, if a Chinese woman is about to visit Tokushima, then Tokushima can be set as a favorite place; meanwhile, a Malaysian man going to Hiroshima can mark Hiroshima as a favorite place. If an earthquake occurs in Tokushima, the Chinese user will receive a warning message with a ring or vibration, including detailed earthquake information and learning links, and FOE of Japan and Tokushima will be increased by 1; meanwhile, the Malaysian user will receive only a simple prompt message. Similarly, if an earthquake happens in Hiroshima, the situation will be reversed. If an earthquake hits Tokyo, both users will only receive a simple prompt message. The example is shown as Figure 2.

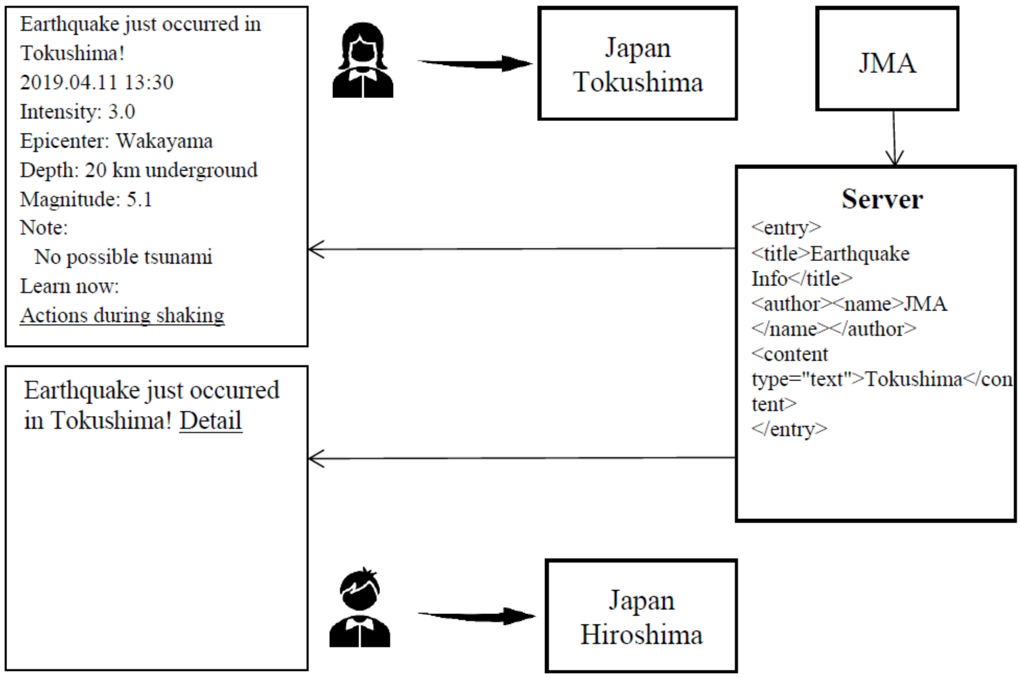


Figure 2. Example for user customization based on location.

Customized setting that use a specific seismic magnitude as the message-receiving threshold is also supported, allowing the users to receive only earthquake messages of the specified magnitude or greater. Multilingual support is also available. The appropriate language can be chosen for those who have difficulty understanding Japanese.

2.3.3 Motivation Model Employed in the System

The system conforms to the so-called enhanced ARCS+G learning motivation model (Amir Fazamin et al., 2014). ARCS stands for attention, relevance, confidence, and satisfaction (Keller, 1987). In simple terms, the ARCS motivation model refers to paying attention to related issues and then benefiting from positive feedback to build confidence and acquire satisfaction. In the enhanced model, G refers to gamification.

Gamification is the use of game design elements in non-game contexts (Deterding et al., 2011) (Werbach & Hunter, 2012). The definition contains three key points: design elements, game mechanism, and non-game context. Gamification is learning techniques from games and thoughtfully applying them to non-game situations. Gamification is being widely in many fields, including Internet, medical or health care and finance (Cudney et al., 2015) (Robson et al., 2016) (Yang et al., 2017) (Hiroyuki & Masami, 2017). In the educational field, gamification has also been playing a role (Hanus & Fox, 2015) (Roy & Zaman, 2018) (Yildirim, 2017). In disaster education, gamification is expected to help more foreigners living in or coming to Japan receive disaster education. Common game design elements include badges, levels, points, leaderboards, virtual currency, characters, maps, challenges, competitions, and collaboration. Game mechanisms include rewards, achievement, progress, self-expression, and community.

In this system, a growing FOE may urge users to pay more attention to earthquakes and realize that Japan is a country with frequent earthquakes, which meets the attention component of the ARCS+G motivation model. Each time an earthquake occurs, users have the opportunity to learn about earthquakes, which meets the relevance component of the ARCS+G model. The more users learn, the more relevant knowledge they obtain, the more confidence they gain to survive earthquakes, and the more satisfaction they receive from the positive feedback resulting from their confidence, which meets the confidence and satisfaction components of the ARCS+G model. The gamification, including some basic design elements and game mechanisms that are explained in detail later, introduced in the system is expected to contribute to user satisfaction.

3. System Prototype Design and Gamification

3.1 System Prototype Design

This system consists of two parts: (1) the server side, which mainly takes charge of the user management module, message pushing, and subscribing to and pulling earthquake information from the Japan Meteorological Agency (JMA), and (2) the client side, which oversees the user management module, learning and quiz management module, earthquake information processing module, and multilingual support. The system architecture diagram is shown in Figure 3.

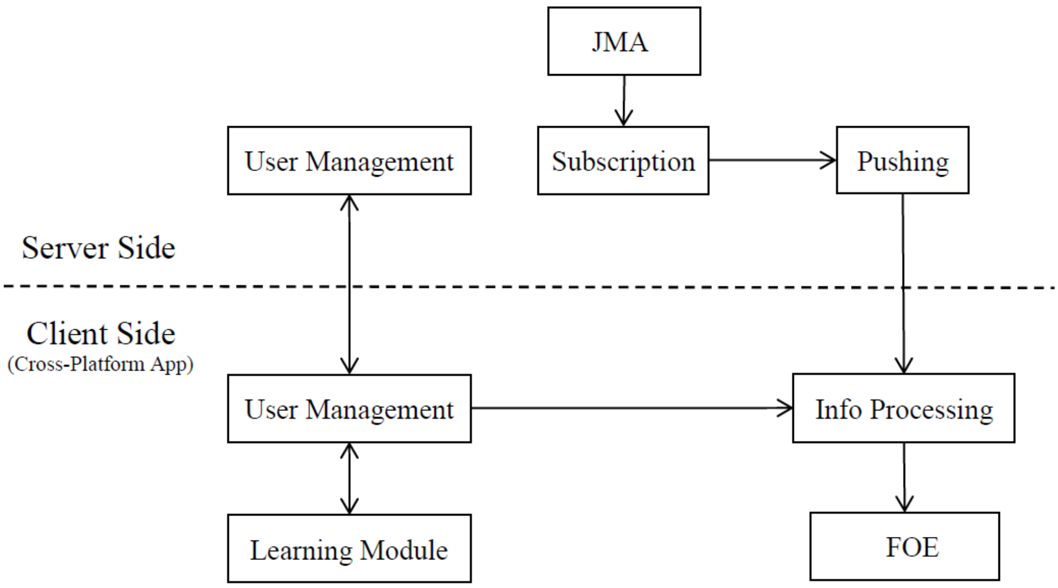


Figure 3. System architecture diagram.

3.1.1 Server Side

In this system, the server is implemented in Java based on the Spring Boot framework, and it supports 100 concurrent users in this version. The server side achieves the following functions:

1. User management module. This module is mainly for managing personal information, such as user signup with username and password or a unique device serial code; user sign-in status; user profile, including favorite location and language; user rewards as points, badges, and a leaderboard (PBL), which are explained later; and user learning record, with total learning duration, quiz scores, etc.
2. Earthquake statistics. The earthquake information processing records details of all earthquakes occurring in Japan, giving the epicenter, occurrence time, magnitude, etc.
3. Multilingual support. On the server side, the translating function supports multiple languages. The raw seismic information from JMA is in Japanese, which hinders those who

have difficulty understanding Japanese. Therefore, the server side keeps a user list, recording each user's setting language. The raw messages are translated to the language of each user's setting before they are pushed to the user.

4. Subscription module. A subscription service is also available that is responsible for obtaining seismic information from the JMA website. Subscription to the earthquake topic from the JMA website occurs via WebSub (previously known as PubSubHubbub), which is an open standard for communication between publishers and subscribers. See Figure 4. WebSub improves polling, so when an earthquake occurs, the server obtains almost real-time seismic information in extensible markup language (XML) format and pushes it to users.

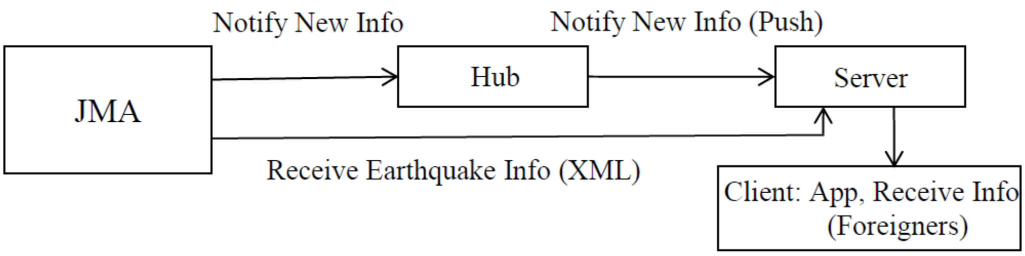


Figure 4. WebSub flow diagram.

5. Pushing module. A pushing service is available. After obtaining new earthquake information, the server pushes messages at different levels to users according to the epicenter and each user's setting location. Detailed seismic information, including magnitude, epicenter, depth, and tsunami warning, as well as some related links that can increase earthquake knowledge, are pushed to those whose setting location is the same as the earthquake site. Those whose setting location is different from the epicenter receive only simple earthquake notification messages.

3.1.2 Client Side

In this system, the client part is in the form of a cross-platform app that supports iOS and Android operating systems. The app fulfills basic functions, including the user management module, FOE statistics and display, learning module, and multilingual support:

1. The user management module focuses on user signup, sign-in, personal settings, and saving the user profile, as well as user learning status, similar to the server.
2. The message processing module receives and parses earthquake messages from the server.
3. The FOE module takes charge of FOE statistics and display. The receiving message is divided into two types. One type of message is the local earthquake message, i.e., an earthquake occurred in the same area as the setting location, which contributes to both local FOE and Japan FOE by adding 1. Another type of message contains information on earthquakes happening elsewhere; then, only the Japan FOE increases by 1. Earthquakes with the specified magnitude or greater are also counted, including the frequencies of both in Japan and in the setting location.
4. The learning module provides various learning materials, including text, videos, and pictures. Users can obtain earthquake information, i.e., the FOE in Japan, and earthquake knowledge that may help them survive earthquakes. It also provides quizzes, helping users to check whether they have good earthquake knowledge.
5. With the multilingual function module, multiple languages are supported on the client side. A preferred language can be chosen, which may help those who have difficulty understanding Japanese improve their earthquake education. In addition, the setting language is recorded in the server to push messages in the same language.

After it is released, it will be possible to download and install the app from the Apple App Store or major Android stores, allowing users to explore disaster education in their own country before arriving in Japan.

3.2 Gamification Applied in the System

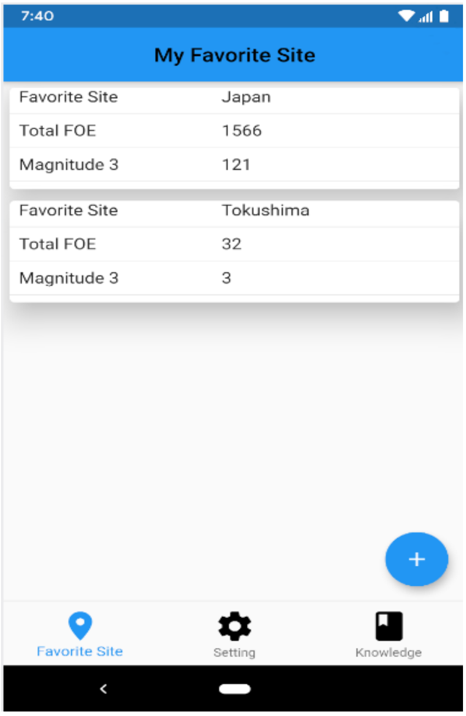
In this paper, some basic game design elements known as PBL are employed. These elements are known as reward and achievement mechanisms. At the beginning of earthquake education, proper reward and achievement mechanisms are considered effective approaches to attract users. After realizing the importance and necessity of earthquake education, users will be willing to learn. In the follow-up work, some new game elements and mechanisms will be designed and applied to stimulate learning motivation so as to maintain long-term engagement.

In general, the rules of applying PBL in the system are the more often people use the system, the more points they obtain, the more types of badges they gain, and the higher their rank. The specific rules are as follows:

1. Awaking the app earns 1 point, no more than 1 point per day.
2. Browsing the pushed message earns 1 point, no more than 1 point per day.
3. Reading learning materials for at least 5 minutes can earn 1 point, at most 2 points per day.
4. Completing a quiz can earn 1 point, at most 1 point per day.
5. High accuracy in the quiz of more than 90% will gain an extra point.
6. Using the app for at least 5 days in a week will win a bee badge for hard work.
7. A 100% score on a quiz earns the fox badge for cleverness.
8. Each week, based on number of badges, first place on the leaderboard is rewarded by a mystery chest box that includes a random number of points between 1 to 5, as well as the title of Survival Master.

How these points can be used is under consideration, such as redeeming them for small gift or a discount for meal in a university café.

Two app snapshots are shown in Figure 5.



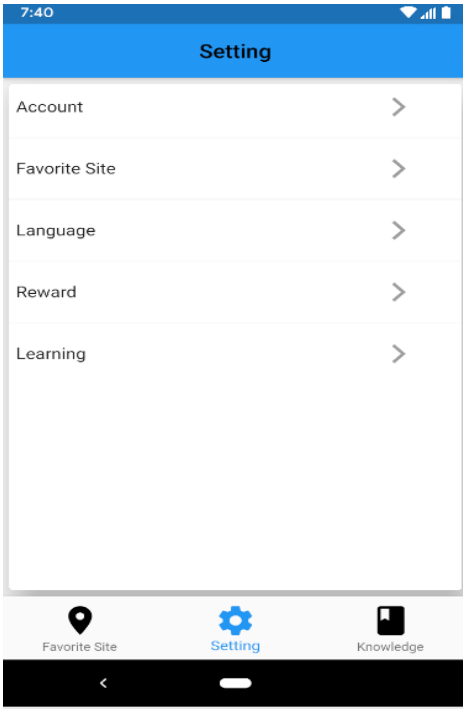


Figure 5. App snapshots for FOE and user customization.

4. Summary and Future Work

Previous research on the application of gamification in education was concentrated in the classroom or on special education for special groups, with experimental samples of around 25. Whether gamification can play a role in the open nonmandatory education field combined with ICT has been explored in this paper. It proposed that gamification in earthquake education, combining it with ICT, is expected to have excellent performance in this field.

This paper described the fundamental ideas and developed a system prototype. In the near future, the system, including the cross-platform app and server, is expected to be completed. After being launched in the iOS App Store and major Android app stores, an open experiment in which number of samples and time are unlimited will be conducted. Statistics will be analyzed periodically to verify the role of gamification in earthquake education combined with ICT.

In future work, the second phase, the practice phase, will be carried out. The practice phase focuses on users' practical learning. Practical information, such as an online earthquake evacuation drill and detailed information about nearby shelters, will be provided. New game design elements, like maps and challenges, as well as a new learning theory and model, will be introduced into the system. In addition, the server program and configuration will be improved to increase the concurrent number of users.

References

Amir Fazamin, W. M., Hamzah, W., Ali, N. H., Saman, M. Y. M., Yusoff, M. H. et al. (2014). Enhancement of the ARCS model for gamification of learning. *Proceedings of 3rd International Conference on User Science and Engineering (i-USEr2014)*, 287-291.

Cudney, E. A., Murray, S. L., Sprague, C. M., Byrd, L. M., Morris, F. M. et al. (2015). Engaging healthcare users through gamification in knowledge sharing of continuous improvement in healthcare. *Procedia Manufacturing, 3,* 3416-3423.

Damage Situation associated with 2011Tohoku district - off the Pacific Ocean Earthquake. Retrieved from http://www.npa.go.jp/news/other/earthquake2011/pdf/higaijokyo_e.pdf

Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011). From game design elements to gamefulness. *Proceedings of the 15th International Academic MindTrek Conference on Envisioning Future Media Environments* - MindTrek 11, 9-15.

Hanus, M. D., & Fox, J. (2015). Assessing the effects of gamification in the classroom: A longitudinal study on intrinsic motivation, social comparison, satisfaction, effort, and academic performance. *Computers & Education, 80*, 152-161.

Kawai, J., Mitsuhara, H., & Shishibori, M. (2015). Tsunami Evacuation Drill System Using Smart Glasses. *Procedia Computer Science, 72,* 329-336.

Keller, J. M. (1987). Development and use of the ARCS model of instructional design. *Journal of Instructional Development, 10(3)*, 2-10.

Leelawat, N., Suppasri, A., Latcharote, P., Abe, Y., Sugiyasu, K., et al. (2018). Tsunami evacuation experiment using a mobile application: A design science approach. *International Journal of Disaster Risk Reduction, 29,* 63-72.

Mitsuhara, H., Iwaka, K., Kozuki, Y., Shishibori, M., Inoue, T. et al. (2016). Penumbral tourism: Place-based disaster education via real-world disaster simulation. *Proceedings of 3rd International Conference on Information and Communication Technologies for Disaster Management (ICT-DM2016).*

Mitsuhara, H., & Shishibori, M. (2017). Virtual Currency as Gamification for Learning in a Disaster Museum to Increase the Number of Revisitors. *Proceedings of 25th International Conference on Computers in Education, ICCE 2017 - Main Conference.* 746-754

Rahman, M. U., Rahman, S., Mansoor, S., Deep, V., & Aashkaar, M. (2016). Implementation of ICT and wireless sensor networks for earthquake alert and disaster management in earthquake prone areas. *Procedia Computer Science, 85*, 92-99.

Robson, K., Plangger, K., Kietzmann, J. H., Mccarthy, I., & Pitt, L. (2016). Game on: Engaging customers and employees through gamification. *Business Horizons, 59*(1), 29-36.

Roy, R. V., & Zaman, B. (2018). Need-supporting gamification in education: An assessment of motivational effects over time. *Computers & Education, 127*, 283-297.

WebSub. Retrieved from https://www.w3.org/TR/websub/

Werbach, K., & Hunter, D. (2012). *For the win: how game thinking can revolutionize your business*. Philadelphia: Wharton Digital Press.

Yang, Y., Asaad, Y., & Dwivedi, Y. (2017). Examining the impact of gamification on intention of engagement and brand attitude in the marketing context. *Computers in Human Behavior, 73*, 459-469.

Yildirim, I. (2017). The effects of gamification-based teaching practices on student achievement and students attitudes toward lessons. *The Internet and Higher Education, 33*, 86-92