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The Role of Serious Games in Disaster and Safety Education: An Integrative Review

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Abstract: One of the critical elements of catastrophe preparedness is a training of the disaster responders and society. However, conducting a live disaster training is costly and labor intensive. Hence, serious game (SG) may offer a possible solution as a method of disaster and safety education. Besides, the advancement of games for education and training has been increasingly used for decades. SG provides a challenging and realistic environment that can mimic actual setting of crisis and disaster situation. Furthermore, there are numerous of SG and applications that have been researched for disaster and safety training. Toward sustainable education and training in this field, it is important to clarify the potential of SG that can improve disaster awareness and skill. Therefore, this paper discusses SG's role for disaster and safety training using an integrative review methodology. A process of the integrative review consisted of five steps to obtain the results, that is, identification of problems and purposes, definition of search strategy, assessment and analysis of the findings. The search criteria were applied to various electronic article databases relevant to information technology, disaster or emergency, and training. This integrative review found the key factor of SG for disaster and safety training. We finally conclude SG has a potential to deliver the disaster awareness through a virtual environment that could motivate learners to have a broader skill and knowledge to prepare the appropriate actions when a disaster occurred.

Keywords: Serious game, disaster, and safety training, integrative review.

1. Introduction

Disasters can be destructive, leading to the emergence of environmental devastation and loss of property, physical and psychological effects, and personal catastrophes. There are numerous human-made and natural disasters which strike both developing and developed country. For example, the disaster of forest and land fire occurred in Indonesia especially in West Sumatra and Central Kalimantan 2002 to 2015, (Miettinen, Shi, & Liew, 2016). The forest and land fire were mostly caused by the carelessness of the palm oil and pulp industry that ignored the nature protection. It had a significant impact on smog pollution, decreased the level of health, and damaged ecosystem (Hayasaka, Noguchi, Putra, Yulianti, & Vadrevu, 2014; Kirana, Sitanggang, & Syaufina, 2016). Other calamities are natural disasters that affected the countries in various ways. A natural disaster is the aftermath or sequences of incidents. It can interrupt and force the lives and livelihoods of people affected by natural events including tornado, landslide, flooding, earthquake, volcano eruption and tsunami (Berz et al., 2001). However, all types of the disasters will have the capacity to consume social and physical assets. Therefore, not only the disaster responders but also the society need adequate preparedness and response approaches. Hence, they can minimize the impacts of disasters such as climate change, increasing urbanization, and poverty that influences factors to expand the frequency, severity, and complexity of disasters. Preparedness for such disasters is serious for families, societies, emergency manager including disaster first responders, but many of them stay unprepared. As contemporary, the disasters perform to underline the necessity for personal responsibility, local management, and continuity plans to ensure the ability to respond to and recover from major events without a doubt. On the other hand, in the recent years, serious game (SG) and simulation have been massively adopted as an important additional apparatus to the training. By the

empirical evidence, it has been proven that SG can be used to improve motivation (Annetta, Minogue, Holmes, & Cheng, 2009), learning, and retention (Girard, Ecalle, & Magnan, 2012). According to the need of providing an alternative way for disaster preparedness, SG would be a possible tool to fulfill this demand.

This paper presents an integrative review to evaluate the critical role of SG in disaster and safety education. One of the study goals is to examine the learning outcome by measuring the evidence of game assessment. Also, the review shows that there are plenty of SG intended for disaster responders and staffs. In contrast, SG for societies, in particular for students or children is limited. Hence, it can be concluded that there is the necessity of such SG for developing their awareness to the disaster preparedness. The rest of this paper is ordered as follows. Section 2 will briefly review the terminology of SG and explain the definition of disaster and safety training. Section 3 will describe the five steps of the integrative review method defined by Whittemore and Knafl (Whittemore & Knafl, 2005). Section 4 will show the results of the review and analyze the key factors of SG role for disaster and safety education. Finally, this paper will conclude the integrative review of SG role by presenting findings of SG potency for preparing disaster responders and society to deal with the catastrophe impacts.

2. Serious Games and Disaster Training

2.1. Disaster and Safety Education

Disaster can create various risks for responders and society in the impacted area. Preparing before a disaster occurrence plays an important role to ensure them to have the essential skill, knowledge, and equipment to solve the disaster issues. It also trains the feeling about know-how to keep themselves protected when a disaster happens and how to escape from the impacted area. These concepts of disaster preparedness and response guide the potential survivors about how to prepare and how to be aware when the disaster occurs. Japan is an example of the country leading in the disaster preparedness. The regular exercise and campaign how to deal with the catastrophe situation are well organized regularly. It involves not only disaster responders to maintain the response skill but also persuade society to be aware of the disaster which occurred recurrently (Tomio, Sato, Matsuda, Koga, & Mizumura, 2014). Thus, engaging in a regular simulation would foster the necessary instincts to respond instantaneously in disaster situations. The expert said that through recurrent training and simulation practices, disaster responders and society would be able to increase and maintain their skill until an actual disaster happened. (Wahyudin & Hasegawa, 2015).

2.2. What is the serious games?

Games are artifacts to provide learners a competitive activity with a particular goal and context within a set of rules. SG is one of the game genre but combines practical aspects with an original amusement use. In other words, SG uses the terminology and technology of games, which implement for education (non-entertain) purposes. In recent decades, SG has been popularly used for many educational setting such as in health (Sardi, Idri, & Fernández-Alemán, 2017), and medical (Graafland, Schraagen, & Schijven, 2012). According to the increasing of gaming technology, SG also adopts the new paradigm, not only for learning by playing but also for encouraging learners to have high motivation and engagement in their learning processes. Games would expand their benefits if they can involve the learners in all situations within particular characteristics. Also, SG empowers the learners' characteristics to assist that the learners acquire appropriate knowledge with the precise learning experience through the seamless integration of entertainment and learning (Gee 2003).

However, the main disparity between games for entertainment and SG for educational goal is the outcome of SG itself. In users' side, an entertainment game intention is mostly as an amusement toy. Hence, for developers, a successful game development can be examined by how popular the game among users, and how much revenue can be collected. In contrast, a game for educational purposes can reach the success position if the game can raise the magnitude of learners' learning outcome and revive its function for forthcoming learning uses. Michael and Chen stated that SG as a

tool for educational purposes should be able to present the required factors indicating that the learning process has occurred (Michael & Chen 2005). Hence, SG would be reliable for educational apparatus if it could stipulate a scaffold assessment of the learners' achievement and progress tracking of their learning exerts. It is correlated with the Corti's postulate that SG could reach the popularity as an industry if the learning experience is measurable, quantifiable, and definable (Corti, 2006). SG is principally attentive on learning rather than entertaining (Miller, Chang, Wang, Beier, & Klisch, 2011). In conclusion, by combining gaming and learning, SG represents an intense interest in the educational research field.

3. Aim and Method

The purpose of this paper is to present an integrative review of the use of SG in the disaster and safety education. It is to examine the empirical evidence of the role of SG in this field. The integrative review is a way to allow various approaches (i.e., investigational and non-investigational research) to have a potential play and a greater role in evidence-based practice. As described in section 2, SG is one of the promise methods for delivering learning contents to invite learners to be aware of the disaster situation and its impact. Whittemore and Knafl proposed five steps of the process to do the integrative review. The first step is to identify issues related to the use of SG for training by answering what the role of SG for such issues is. The second step is to define the purpose of review which is a depth analysis of utilizing SG in this field. The third step is to determine a search approach to find appropriate academic evidence of SG for disaster and safety training. The fourth and last steps are assessment and exploration of data and the presentation of the findings (Whittemore & Knafl, 2005). To realize these steps, some search criteria were defined as follows. Title and abstract of articles should be focused on term serious game or game-based learning, application of various game technology, and as much as possible excluded articles on simulation. The simulation was excluded from the search criteria due to the reason that there is no explicit win/lose state. Simulation is the learner is not trying to win and no scoring. The learners are also not competing against anyone else or cooperating to beat the computer opponent. Another criterion was that article should be published in the indexed journals during 2010 – July 2017. It was to make sure that the effective training of disaster using game claimed in the article proofed by the empirical evidence and judgment by the expert review. The article criteria then applied to various electronic databases relevant to information technology, disaster or emergency, game development, education, and training. They are PubMed, Cambridge, Science Direct, ERIC, Springer, IEEE, ACM, Willey, EBSCO, and SAGE. However, the search keyword was contained the following words or phrases of (computer game OR digital game OR serious game OR video game OR game-based learning) AND (learning OR training OR education OR exercise) AND (disaster OR emergency OR safety OR incident) and also searched for other articles of interest cited in the articles that we selected. Data were mined from all articles, including game name and development technology, learning purpose and target, game mechanic, and the presence of validation studies.

4. Results

The procedure to get the game model which will be reviewed was started by selecting the title and abstract which supposed to satisfy the criteria. From this step, 30 articles relevant to the inclusion criteria, focused on disaster or emergency purpose, were collected. After rigorous reading, six articles were selected to include in the review as shown in table 1.

4.1. Learning target and purpose

4.1.1. For Disaster Responders

Disaster Readiness Through Education (DREAD-ED)
The DREAD-ED game trains learners to deal with an evolving emergency situation. The game harnesses SG for training communication between members of disaster response and management. As a member of the disaster management team, the learners have a role with a unique ability to tackle issues that occur in emergency response. It allowed 3-6 learners to play the game in the same session to simulate communication between the team members. Even though the DREAD-ED evolution involved student participants, however from the description of learning target and purposes, DREAD-ED can be assumed that this game is more suitable for professional disaster commanders. (Haferkamp, Kraemer, Linehan, & Schembri, 2011).

Table 1: Brief information of reviewed articles

Author and Year of Publication	Game Technology	Learning Focus
(Haferkamp et al., 2011)	PC-based simulation named DREAD-ED	Improving Communication among staffs of crisis management, i.e., Decision makers at command and control room.
(Rauner, Niessner, Leopold-Wildburger, Peric, & Herdlicka, 2014b)	PC-based management game called Advanced Medical Post (AMP)	Training the emergency policy makers for vehicle and patient scheduling, and staff and material planning on mass casualty incident (MCI)
(Charlier, 2011; Ferracani, Pezzatini, Seidenari, & Del Bimbo, 2014)	Virtual reality called EMERGENZA	Training medicine personnel in emergency situation
(Knight et al., 2010)	PC-Based game called Triage Trainer	Allowing learners to play through a major incident scenario, triaging casualties when they discover them.
(Radianti et al., 2015)	Smartphone game application named ISCRAM Game (IG) App	Training the rescue team to evacuate victims out of the burning apartment.

(Kawai et al., 2016)	Derived from the location based game using a tablet called Real World Edutainment (RWE). It is equipped with head mount device to perform marker less augmented reality (AR)	Train students' awareness of disaster situation.
(Tsai, 2015)	PC-based game for flood protection adopting persuasive technology called GIL	Train students a practical experience in flooding disaster.

Advanced Medical Post (AMP)-management game
AMP is a policy management game addressed to train the emergency staffs in general incident including human-made and natural disasters so that they could assist the policy maker. Learners will be asked to perform as an incident commander that has a duty to manage the resources of emergency response. It was including staffs of the disaster responders for triage and treatments room, as well as managing transportation from on-site medical care room in the hospital (Rauner, Niessner, Leopold-Wildburger, Peric, & Herdlicka, 2014a).

Triage Trainer
The game was designed for the training of triage sieve accuracy in major incident casualties. As a first responder, learners should immediately identify victims that appear in the game scene. Triage trainer has a particular scenario where the learners should analyze the situation in bombing event in a crowded urban area. This explosion scene caused a chaos situation with the destroyed building structure and number of victims. The learners should response this situation by selecting some action on the scene to determine the decision such how to save the victim life by choosing the priority of triage and evacuation (Knight et al., 2010).

ISCRAM Game (IG) App
Utilizing advanced sensors that have been embedded in most of the recent smartphones, IG App is dedicated to collected users' movement, location, and environmental situation. By doing so, the collected data could be passed to others users, especially the disaster responders, through communication technology. Such process allows the useful data to be used by the responders' team to monitor and to track the team members' movement and could assist them to make decision in disaster location. Hence, the team members could share situational awareness and information within groups to design a strategy of evacuation in the harmless promising way (Radianti, Ben Lazreg, & Granmo, 2015).

4.1.2 For Society

Game-based Evacuation Drill (GBED)
GBED is one of the reviewed game intended for community, especially student. It was derived from real world edutainment (RWE) game (Mitsuhara, Sumikawa, Miyashita, Iwaka, & Kozuki, 2013). GBED is equipped with the advanced technology, i.e., a head-mounted display (HMD) to perform marker-less augmented reality (AR) game. GBED trains the learners with the capability of motion tracking. By empowering branched story line, GBED presents the digital artifacts related to the learners' location represented by GPS data (Kawai, Mitsuhara, & Shishibori, 2016).

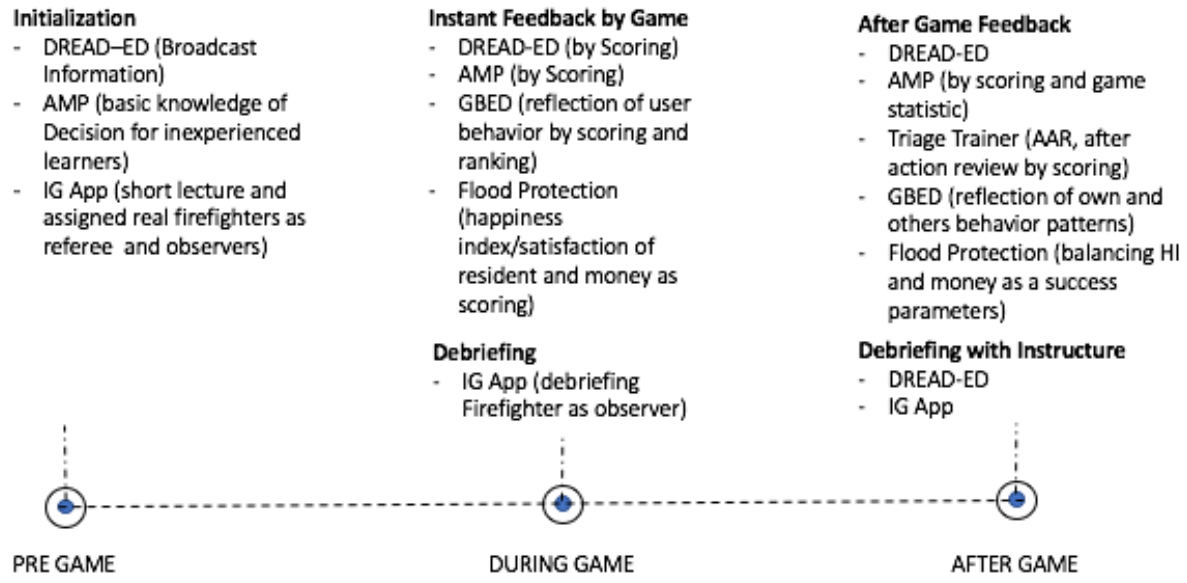
Flood Protection
This game is inspired by the famous Tower Defense for disaster education. By mean of learning by doing principle, PC-based flood protection game was developed to promote learners' learning motivation. Hence, the learners can change their implicit or explicit performance to find the best solution of flooding disaster issues. As the concept of the tower defense, the learners should protect their zone including the industrial, residential and commercial area from the flood. The game promotes the learners to act as a decision maker like a mayor of a city with authority for preventing flooding disaster. To anticipate the disaster happened, the learners should understand how to control the established engineering methods and resources to fight against flooding before and after it occurs. This game also trains how to keep the conservation of water resources and to know what are the policies should be campaigned to inhabitant as the preventive action before the disaster occurs. (Tsai, Wen, Chang, & Kang, 2014)

4.2 Game Mechanics

Mechanics are some behavior, actions and control mechanisms offered to the learners within a game context. Together with the game's content (levels, assets and so on) the mechanics support overall gameplay dynamics (Sicart, 2008). The game mechanics are a distinctive part of the serious game in this review. Hence, to assess the game mechanics of the reviewed serious game are describes as follows. However, with all games, there is a necessary standard feature to encourage learners for reflection, such as scoring and debriefing as shown in Figure 1.

4.2.1 DREAD-ED

The game starts by a television broadcast informing a disaster (e.g., a great fire near chemical depot and flooding). At this point, learners asked to determine the category of hazard level of damage and impact with the following choice: 'perfect' to 'disaster' with the value of 1 to 6. DREAD-ED train learners how to make effective communication among personnel especially when there is a need to exchange personnel. With the effective communication and sharing information each other, learners would have the ability to reduce the hazards. A high-achieving group will excel at receiving the right personnel to the right learners at the right time to control the disaster. To provide a stressful decision making for learners, the opportunity for effective communication and collaboration will be controlled by a limited time.



4.2.2.AMP

Learners act as disaster commander and assign the inexperienced responders to triage, treatment, and transportation of patients. To rescue as many patients as possible and to quickly clear the incident site, the priority at the beginning of a game should be given to the triage. Afterwards, the treatment of the patients, especially of the severely injured ones, should be the focus of the player's attention. Towards the end of the game, transportation of the patients to the hospitals becomes more and more necessary.

The learners learn how to improve the treatment of the patients and their transportation to hospitals by allocating insufficient medical staff to the corresponding activities at the AMP. The primary decision-making goal focuses on saving human lives as the highest priority. A lower priority is given to the clearing of the incident site, except if the incident happened at a critical infrastructural point (e.g., airport, train station). AMP equipped with main statistics for each game run including patient-related and staff-related outcome measures. Thus, at the game end, the learners could assess his/her success regarding quick treating patients and afterward transporting them to hospitals.

4.2.3.Triage Trainer

The Triage Trainer designed to permit learners to play through a major accident scenario, triaging survivor as and when they discover them. The game is enabling learners to practice and experience the triage sieve process. The game scenario is a bomb has just exploded in a busy urban street; the scene shows the expected infrastructural destruction along with some casualties located around the scene. The learners are acted as the first-responder at the location, told that the area is harmless to enter, and tasked with labelling each victim with the suitable priority. To navigate in the game scene, learners use the mouse to click the position of the survivor. When learners access the survivor location, they can evaluate the survivor status by selecting its icons to perform the proper medical checks. When the necessary checks have been completed, the learners choose the priority action through the priority icon. Once tagged, the learners continue onto other survivors. Each scenario encompasses three to ten survivors.

When all survivor in the scene have been prioritized, the learners will get with an after-action review (AAR); it allows the learners to examine their accuracy on tagging and following the correct steps for assessment for each casualty. A cumulative score for both tags and steps is also given. A more focused level of feedback also presented, it was to explain the learners' performance for each survivor in detail, which implies how and where errors were made.

4.2.4. IG App

The IG App game is a part of Disaster in My Backyard (DIMB) Game project that designated for search and rescue. The DIMB game was packed into four levels with increasing challenges around a realistic crisis (flooding) scenario. The IG App game was inserted into the third level of the DIMB game. This scenario was the 'fire level' where "rescue teams" would have to evacuate a 5-story apartment building.

In the preparations, there were six dummies as victims on different floors. These dummies are modeled after a human being and designed to serve as a substitute for the real person. Two assigned individuals posing as firemen would conduct the on-site briefing to the "rescue teams" before the evacuation process. These firefighters provided an IG App, which the groups could use to determine which areas it was safe to go. These firefighters would also act as observers and referees, deciding if a player would die or not, e.g., because of entering the fire zone for too long. Smoke was spread to add lifelike, convincing fire effects, using a standard smoke machine device. In the game implementation stage, there were three "rescue teams" that would conduct the designated search and rescue task. Each team leader held the smartphone with the IG App. In this stage, the learners interacted with the app in the fire level. A short briefing on a "firefighter" role was conducted in advance of the rescue action. The briefing primarily highlighted the understanding about the layout in the app with the corresponding real building, reminded the learners about the meaning of the color code, and about the number of victims to save.

4.2.5. GBED

GBED equipped with HMD that learners can learn through experiences while simultaneously viewing digital contents according to the storyline. GBED has the game component as follows. AR content: In experiential learning, digital materials should be associated with the real world (e.g., locations). Although the use of RWE can satisfy the association requirement, it can be strengthened via augmented reality (AR), which superimposes virtual objects (digital contents) onto the real world via a digital media interface. Some AR-based edutainment systems have been released previously. The storyline: Game has branches an evacuation scenario according to a learners' response to single-choice questions. However, due to difficulties of answering the question using HMD, hence learners could response the question by their eye direction. Reflection: After experiential learning, a learner could reflect their experiences and behavior (including the behavior patterns) to strengthen multi-perspective knowledge stabilization.

4.2.6. Flood Protection

The learners asked to be the decision makers, for example, the mayor of a city that suffers from flooding. The primary purpose goal of this game is to understand how to manipulate the existing engineering approaches and resources to fight against flooding before and after it occurs and to instill the knowledge of modern water conservation methods and policies into students. The learners should protect multiple areas, including residential, commercial, or urban industrial zones from flooding. They also need to install appropriate construction items to prevent the city from flooding. The key to victory depends on how well the learners manipulate the available resources.

Multiple protection regions: The game includes three areas: residential, commercial, and industrial. Each region has its properties such as population, tax rates, and flood resistance. These designs simplify the reality while maintaining the balance of the game without involving complicated political issues.

Multiple evaluation indicators: The happiness index (HI) and money are defined as the two most important indicators for the assessment of a single game play; HI represents the satisfaction level of the residents. As a decision maker, citizens' satisfaction is the primary concern. When the HI drops to zero, the learners fail the game. Learners will need to balance the HI and money while manipulating the arrangement of the different flood protection approaches.

Various disaster mitigation methods: A positive approach, Learners have to save resources for positive approaches and must consider pre-construction activities. Passive approaches, learners use passive approaches as temporary and emergency approaches.

Sequential levels: Game equipped by six levels of difficulty and challenge that have a unique and different map. By providing these various challenges, learners will have more choice in decision-making processes.

4.3 Validation Studies

4.3.1 Assessment of DREAD-ED.

This game measured the decision-making ability of learners within two trials. Each experiment involved 10 participants that divided into two categories, i.e., five students acted as inexperienced disaster responders, and the remaining were expert emergency managers. The selection of the participants with different background was to make sure that they can use the game for building their soft skill by comparing the effectiveness. The general conclusion of both trials of DREAD-ED gave the empirical evidence that this game could improve the social skill of the participants on the aspect of critical thinking how to make reflex the decision. Another useful information obtained the game assessment was that the expert participants used their experience in disaster to solve the game task. Compared to inexperienced students getting stressfully and faced troubles to make the same decision.

4.3.2 Assessment of AMP-Management Game

AMP-management game deals with a complicated process of AMP in an emergency location. This complex problem including how to prioritize the triage and treatment of the casualties and how to care and deliver them (to, within, and from AMP). Assessment of the AMP management game conducted in three trial sessions involved 96 participants, including students, practitioners from health care services, and researchers in investigating the potential of the AMP management Game. Each experiment started by an explanation of the theory, how to do AMP and how to use the AMP management game for understanding the AMP process. Then, the participants were invited to play the AMP management game. After playing this game, they were asked to fill the questionnaire set divided into two categories. The first category consisted of the questions for collecting the participants' opinions about evaluation to measure their improvement of decision-making ability. The second category involved the questions in measuring their rating to the game efficiency and effectiveness of rescue treatment in the AMP. The general results from all conducted trials gave the evidence that game could improve the participants' performance how to do AMP. However, the participants with the medical practitioner background received benefit from the game and felt comfortable to conduct the AMP procedure.

4.3.3 Assessment of Triage Trainer

The evaluation of the triage Trainer game involved 96 participants with the background of clinicians including nurses, paramedics, and doctors. The participants then received different treatment. Half of them have used the Triage Trainer game, and the remaining used card-sort exercises to understand the triage concept. The finding of this assessment showed that the participants exposed by SG got a more significant improvement to do the accurate triage all the casualties using the triage sieve. The general conclusion from its findings was that gaming could integrate effectively into existing courses. Using SG, the learners would get more benefits of the training compared to the traditional way.

4.3.4 Assessment of IG App

The evaluation involved 19 participants who were asked to play the IG App combined with the debriefing after playing the game. They were also requested to fill up the question about their opinion as to whether they liked and disliked the game. Another question was about the quality of debriefing and the usefulness of the application. The general conclusion of the assessment, notwithstanding with the limitation, there was the constructive impression of the IG App session could enhance the learners to make a decision based on real-time fire information.

4.3.5 Assessment of GBED

The evaluation of GBED involved students from 17 high schools that participated in university campus tour. However, due to safety reason, they used Oculus rift only in indoor trial and accompanied by an instructor. Before and after trying the GBED game, they were asked to response a set of the questionnaire consisted of five degrees Likert statement and some free descriptions to measure the capability of GBED. The findings of this assessment gave the conclusion that GBED could improve the visual reality of disaster and encourage the learners to engage in disaster study.

4.3.6 Assessment of Flood Protection

The assessment involved 33 students of ordinary high school comprised of three different grades. They were divided into 11 groups of 3 participants. Before the participants experienced to play Flood Protection on the desktop PCs, they were asked to fill the set of pre-test question that measured their experiences on disaster drill in their life. To collect post-test, a suitable software was used to record the process of playing the game including mouse tracking and screen capturing, student facial expression and voices. The assessment findings provided three necessity evidence, i.e., the participants' motivation data showed the degree of their motivation was high. Base on the evidence, it

can be concluded SG implemented for disaster training at the ordinary school level could improve their motivation to study the protection of flood incident (flooding). Also, learning disaster using the game encouraged the learners' curiosity to know the method of flood protection, such as by applying the concept of green environment.

5 Conclusion

The six SGs with different learning focus and development technology show that developers or researchers should define the suitable technology and learning approach to achieve the learning goal of the educational game. All of the SG study conducted for different learning focus and target, from ordinary student to disaster first responders and management staffs, shows that SG can be applied for inexperienced and experienced learners. However, in an emergency training, the necessity of the learners to get instant feedback is undoubted. With the immediate feedback, the learners would have experience how to make a mistake and receive the instant advice to solve the problem from its action. SG can fulfill such necessary feature of live training. Hence, SG is a proven way to train disaster responders and also society about disaster awareness.

On the other hand, the conducted integrative review gives the evidence that SG does not intend for student and children so much. Hence, it is promising to do research and development to provide students and children have an alternative game to train their ability according to the disaster preparedness. Based on this fact, the research will continue to measure the possibility of developing children's awareness to the disaster impact employing the mobile serious game.

6 Limitation

The conducted review has a weakness that causes the findings bias. The limitation is due to a difficulty to access articles in inclusion because of inadequate article database subscription. However, even though the review is insufficient, it could give a new insight for us to continue the research and development of SG used in disaster and safety education field.

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