Effective Balance of Characteristic Factors in Serious Games: A Case Study of Evacuation Simulation Game

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Abstract:

Serious games, which are games designed for a specific purpose rather than pure entertainment, have begun growing in popularity in recent years. In order to develop serious game which can obtain more effectiveness in study, the balance of characteristic factors in games should be considered. In this study, the authors classified the characteristic factors into three factors, "objectives", "interaction", and "quantification", and a structure model of the game was shown based on these factors. The evacuation simulation games were developed as a case study because the goal and interaction are very simple and easy to understand. The developed game contains three stages in which each stage has a different balance of factors. The goal was to finish evacuation and sub-goals are less time consumption, route findings, life savings, and risk reduction. The user experiment was done by using the developed game in which each stage has a different balance of factors. The result showed that the game items should be added to entertainment, and effectiveness and interest in games are balanced to ones in paper-based study. More experiment and analysis are required to derive effective balance in factors in future research.

Keywords: serious game, evacuation simulation, game factor

1. INTRODUCTION

The enhancement of activities intended for preventing and reducing disasters are now required during ordinary times, due to the frequent occurrence of large scale disasters in the recent years. Training for anticipated disasters is considered vital in verifying the soundness of emergency measures implemented when a disaster occurs, as well as in raising disaster awareness of residents. An evacuation training is ordinarily conducted in order to learn about the evacuation behavior in advance, but contents of such programs are comprised primarily of verification for evacuation routes under limited circumstances, for which anticipated phenomena are defined in advance. In reality, there is a limitation on how often such activities can be implemented as well. This study aimed to deal with such issues, by applying serious games intended for learning about evacuation behavior.

On the other hand, digital games are evolving and spreading rapidly with the progress of computer technologies. Their availability has also increased in the recent years, with the spread of smartphones. Studies on serious games intended for resolving social problems by using digital game technologies have recently been making great strides. Many studies on evacuation behavior that use computers, however, are primarily concerned with evacuation simulators that use agents to perform simulations (Adam et al, 2012) or utilize virtual reality environments (Freund et al., 2005; Mol et al, 2008). As such, there have not been many examples of developments for digital games that are intended for actually learning about the evacuation behavior of users. No study has so far been conducted with a focus on game characteristics that are required for serious games, as viewed from the perspective of game design.

The authors have so far been developing a game for learning about evacuation behavior of a role playing type, which is based on a digital game (Kikuchi & Makanae, 2014). This study aims to sort out characteristic elements of games that are required for serious games and provides a summary of evacuation behavior learning game constructed based on such elements and verify the effectiveness of learning using such a game in an experiment.

2. CHARACTERISTIC ELEMENTS THAT CONSTITUTE SERIOUS GAMES

A continued use of the game by users is necessary in order to allow for an effective function of a serious game for learning. Securing highly entertaining game features that are perceived as fun by users is essential in motivating users to use such games. Clarifying elements required for such games and developing a game that definitively encompasses all such elements was considered necessary to achieve all that. This study therefore investigated literature that defined aspects of playing and games (e.g. Crawford, 1982; Salen & Zimmerman, 2003), then selected characteristic elements that are present only in games. Authors sorted out the definitions on games and playing according to elements that are included in games or playing, then categorized them into the following seven elements:

1) Freedom: Freedom is secured for players of the game.
2) Rules: Games have rules.

3) Entertainment: Games are entertaining.
4) Unreality: Games are executed in environments that are separated from reality and no harm comes to humans in reality.
5) Objectives: Games have objectives (goals).
6) Interactions: Games respond to actions taken by players.
7) Quantification: Feedbacks are quantified.

The four elements 1), 2), 3) and 4) are elements that can exist even in simple playing, according to Caillois (1961). This means that the remaining three elements, which are 5) Objectives, 6) Interactions and 7) Quantification, may be considered elements that characterize games that are not just merely play, although these individual elements may also be found in play. All of these three elements are incorporated in case of games, however, and the mutual relationships among these elements can be considered to characterize individual games.

The basic structure model of games that are based on these three elements is shown in Figure 1. A game design, conducted based on this model, was conducted by this study, to clarify characteristic elements that are incorporated into serious games.

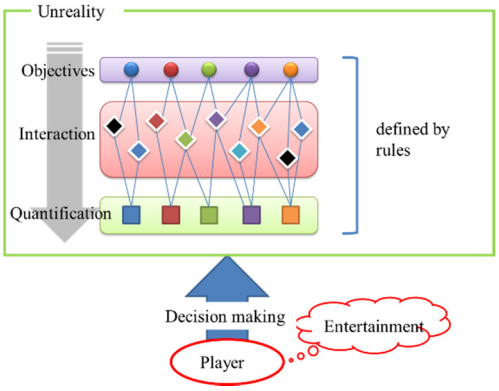


Figure 1. The basic structure model of games

3. DESIGN AND PACKAGING OF EVACUATION BEHAVIOR LEARNING GAME

3.1 Setting of Characteristic Elements in Game

A game comprised of three stages, in which the distribution of the three characteristic elements selected in Section 2 were varied, was constructed to verify effectiveness. The game used in this in-stance was a three-dimensional progression of a game for learning about evacuation behavior, which was based on a two-dimensional mapping, constructed by the authors' previous study. Targeted users of the game were users of ordinary facilities, who are presumed to become evacuees when a disaster occurs. Contents of features that were incorporated into respective characteristic elements for the purpose of the game are described below:

(1) Objectives

The objectives represent the goals in the game aimed for by the player. A primary objective, which is at the core of the game, as well as secondary objectives, which are not directly associated with the primary objective, exist in the game. The game can no longer remain functional when the primary objective is lost, but the characteristic of the secondary objectives is such that the game can remain functional even when secondary objectives are excluded.

The primary objective of {completing evacuation} was set for the game developed by this study, while {rapid evacuation, selection of routes, rescue of human lives and elimination of threats} were set as the four secondary objectives.

(2) Interactions

Interactions represent elements of various actions and results generated by actions taken by the player and fed back to the player. Among interactions there are elements that are linked to multiple secondary objectives. These with links to multiple objectives that demand decision-making on the part of the player are believed to have a positive impact on the fun of the game. The actions taken by the player on the map, for instance overcoming obstacles or rescuing those in need, are fed back to the player.

(3) Quantification

Quantification is an element that expresses outcome or impact of actions taken by the player and is an element that

affects the design of the user interface (UI) of the game. This game quantifies elements, such as the outcome of evacuation or breakthrough of obstacles, as well as number of people rescued during evacuation and final evaluation for the play, which are incorporated in the game. Such information is fed back to the player as needed, through the UI.

3.2 Stage Composition and Map

The constructed game is comprised of three stages that have different distributions of characteristic elements. Targeted facilities, furthermore, are defined by a hierarchical map, which has an arrangement of the start, goal and objects. The game structure diagram and the map, which show the objective and the secondary objectives and the interactions in the three stages that have been set, as well as the relationship between quantification of respective elements, are shown respectively in Figure 2, Figure 3 and Figure 4.

a) Stage 1

The only objective in this stage is the completion of evacuation. No secondary objectives are set and this game is only about moving through passage ways to reach the goal. No obstructions have been set in order to limit the number of elements.

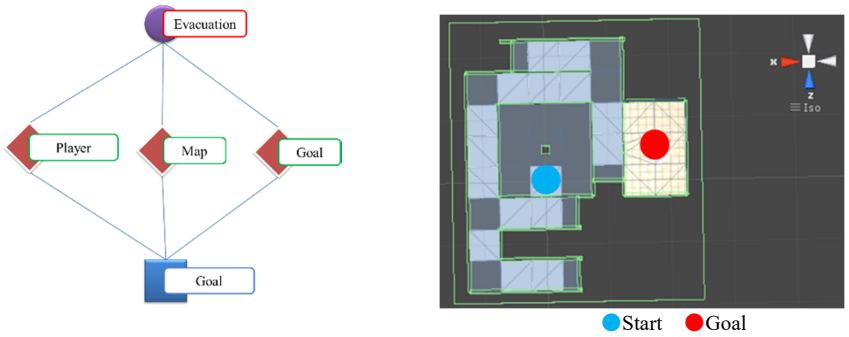


Figure 2. Game structure and map in Stage 1

b) Stage 2

This stage is based on Stage 1 and secondary objectives of {rapidness and routing} have been added. The elapsed time since the start of the stage is displayed on the screen and shortening of time taken to arrive at the goal is promoted as a time challenge. Furthermore, obstructions that can inflict damages to physical capacity of the player have also been arranged on passage ways, to prompt prudent route selection.

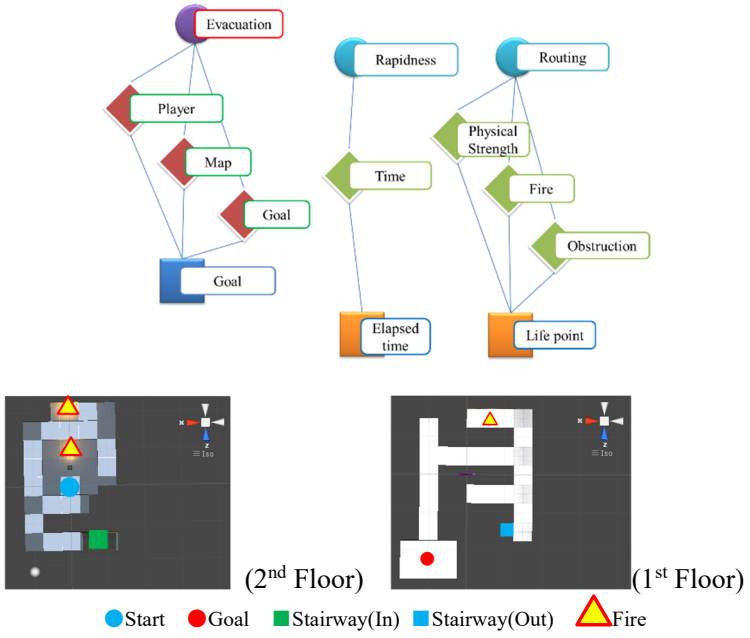


Figure 3. Game structure and maps in Stage 2

c) Stage 3

Two more secondary targets {rescue of human lives and elimination of threats} are added in Stage 3, on top of what had been set in Stage 2. This stage is comprised of two parts, the first half, in which advance disaster prevention measures are implemented, and the second half, in which measures are implemented following an earthquake. Individuals targeted by this game are presumed to be users of ordinary facilities as described in Section 3.1, however, they are also expected to play a role in managing the facility, in order to ensure that they learn about advance measures, knowledge pertaining to disasters and rescues, as well as positions of objects. A player performs inspections and implements aseismic measures on fire extinguishers, vending machines and other objects in anticipation of an earthquake and fire disaster during the first half. Similar to Stage 2, the player is expected to evacuate while being mindful about conserving physical capacity and in the course of evacuation, also rescue injured individuals that are arranged on the map.

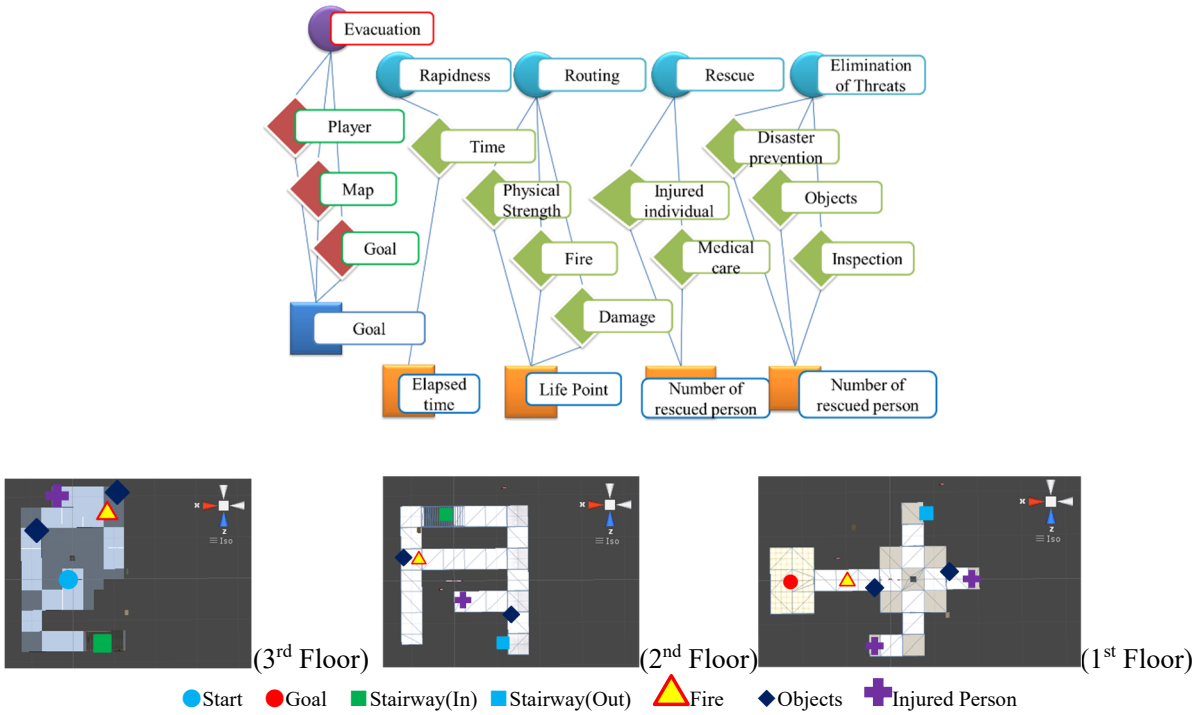


Figure 4. Game structure and maps in Stage 3

3.3 Packaging of Game

The stages defined in Section (2), as well as events that correspond to respective stages, were incorporated to build a single game application. When the application starts up, the stage selection screen is displayed. A game that corresponds to the selected stage is started and once the goal is reached the end screen is displayed. In case of Stages 2 and 3, the display can also transition to a game over screen when the value of the physical capacity of the character played by the player becomes 0 or lower.

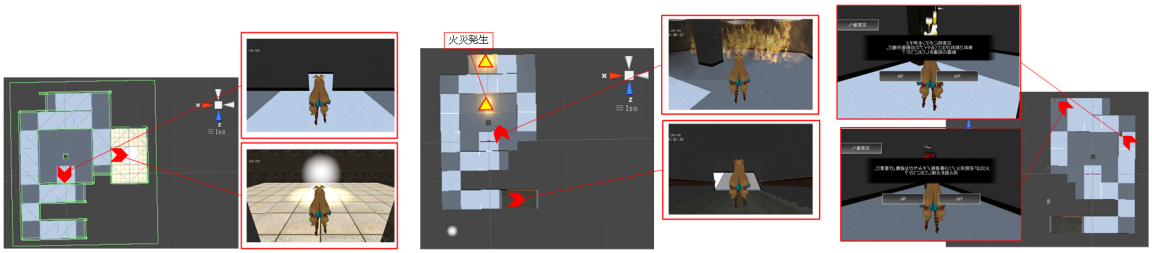
The Unity developed by Unity Technologies was used for the development environment of the game. The Unity is a game developing environment and operates on Windows OS from Microsoft, as well as Mac OS X from Apple and facilitates easy development of applications intended for various platforms. An application that operates on PCs and smartphones was constructed during our development.

3.4 Incorporating Events

Objects arranged on the map in Stage 1 are comprised by the playing character and a ball of light that represents the location of the goal. When the character touches the ball of light, the goal is determined to have been reached and the end screen is displayed (Figure 5 (a)).

In Stage 2, flame objects have been arranged in addition to the objects from Stage 1, which have the function of reducing the physical capacity value of the player when touched by the player.

The first half of Stage 3 is the segment where advance knowledge is acquired and preventive measures are implemented. The mechanism of this stage is such that the player makes a round with-in the given space and touches fire extinguishers, as well as vending machines and other objects that are subject to disaster prevention measures, to acquire disaster prevention knowledge and implement advance disaster prevention measures (inspections). After these measures have been implemented an earthquake occurs and the game transitions to the second half. The mechanism of the second half is such that the player selects emergency treatments for injured individuals that are arranged on the map and evacuate towards the goal.



(a) Stage 1 (b) Stage 2 (c) Stage 3

Figure 5. Screenshots with maps in each stage.

4. VERIFICATION ON LEARNING EFFECTS OF GAME

4.1 Setting of Characteristic Elements in Game

A set of written tests before and after the game play, which was intended to measure the learning effects, as well as a survey intended to obtain evaluations of the game were conducted in order to clarify the learning effects of the game developed by this study, as well as to identify a suitable distribution of characteristic elements. Furthermore, a learning session using a written text was per-formed as a comparative experiment for the learning effects, and each experiment was preceded and followed by tests to compare learning effects, since the implementation of advance measures in preparation for the disaster, knowledge and emergency treatment of injured individuals were set as learning contents of the game.

Test subjects were 20 students and teaching faculty members from Miyagi University, who were randomly divided into two groups, one group comprised of ten members for playing the game and the other group comprised of ten members for studying with a text. A written test was conducted be-fore and after respective learning sessions and a survey was conducted after the learning sessions to investigate the fun of learning and aspects of element distributions. The text prepared for the text learning was made up of sentences and the five minutes, considered roughly the same duration as a playing session for the game, were allotted for learning by reading the text.

The written tests conducted before and after the experiment consisted of questions about knowledge concerning earthquake and fire disasters (Q1 to Q5), as well as questions about emergency treatments (Q6 to Q9).

Furthermore, test subjects who played the game were asked to respond to a multiple choice question with two possible answers to rate the fun aspect of each stage as "Fun" or "Boring," while they were also asked to evaluate the number of game elements by choosing one of "Less is desirable," "Keeping current number is desirable" and "More is desirable." Furthermore, test subjects who learned from studying the text were asked to respond to a multiple choice question with two possible answers to rate the fun aspect of the process as "Fun" or "Boring," while they were also asked to evaluate the amount of text by choosing one of "Less is desirable," "Keeping current number is desirable," and "More is desirable."

4.2 Experiment Results and Considerations

The change in the number of respondents with correct answers is shown in Figure 6. An improving trend of the learning effects was seen with all items among the participants of both the game and text learning, but in terms of respondents with correct answers after learning, the number of items for which those that learned from text exceeded those that learned from the game was three, while the number was one for those who learned from the game. They were in contention for six items. Those who learned from the text therefore had a slightly higher learning effect.

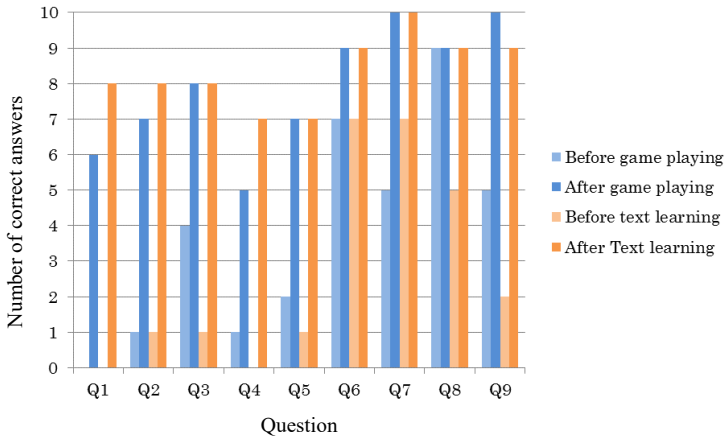


Figure 6. The change in the number of respondents with correct answers

The tabulated results for the fun aspect of game learning and text learning are shown respectively in Figure 7. The responses provided by those who took part in the game learning with regards to the fun aspect of the experience was positive with half of the participants for Stage 1 and Stage 2, while all but one responded positively for Stage 3. Half of the participants also responded as having had fun with those who participated in the text learning, showing roughly same ratio as Stages 1 and 2 of those who participated in the game learning. The number of secondary objectives added between Stages 1 and 2 as well as between Stages 2 and 3 was two in each case, while the number of interactions was 4 and 5 respectively. While the difference between the numbers of added elements was not significant, the increased number of secondary objectives and the interactions intensified the complex conditions in which the players were required to engage in their player actions, which is believed to have enhanced the fun aspect of the game. As a result, while the game learning was slightly inferior to the text learning with respect to the learning effects, we believe we captured the characteristic of the game, which offers fun in learning.

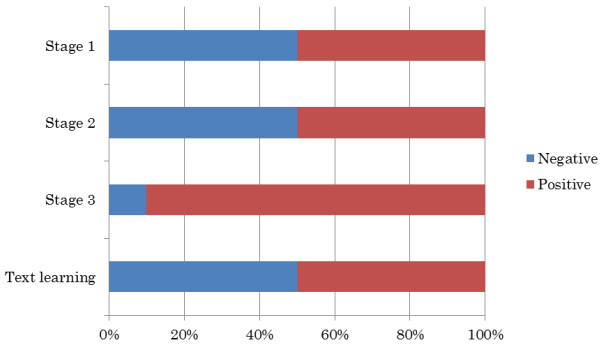
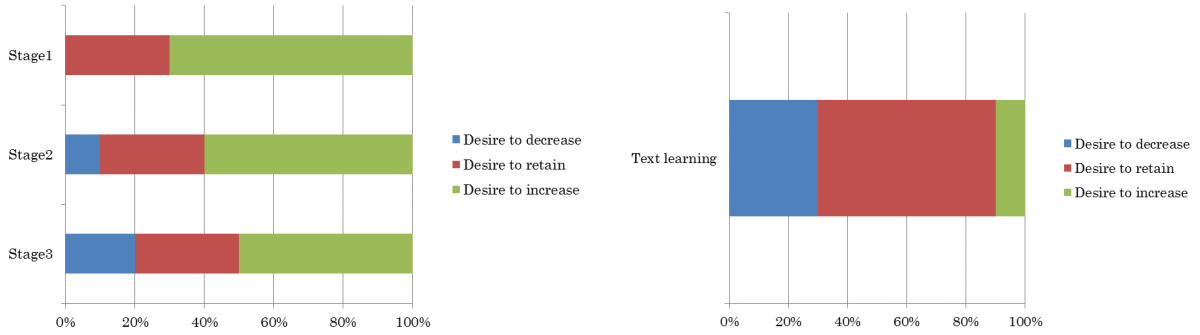


Figure 7. The fun aspect of game learning and text learning

The tabulated results on the evaluation for the number of game elements, provided by test subjects that experienced learning with the game, are shown in Figure 8(a). The number of test subjects who desired to have the number of elements increased in Stage 1 was seven, with the remaining three indicating that the current count should be retained. The number of test subjects who desired to have the number of elements increased in Stage 2 was six, while three were for retaining the current count and one for decreasing the number. Furthermore, the number of test subjects who desired to have the number of elements increased in Stage 3 was five, while three were for retaining the current count and two for decreasing the number. There was a trend of a decreasing number of participants desiring to have the count increased and an increasing number of participants desiring to have the count decreased as the stages progressed. The proportion of those who desired to have the count increased was still quite high even in Stage 3 and the development of the game has not yet reached a point where a balance is reached between those who desire an increased count and those who desire a de-creased count. This suggests that the game that was constructed for this instance still did not have sufficient number of game elements and that there was yet some room for adding more game elements. On the other hand, the tabulation results for the evaluation on

the amount of text used for the text learning is shown in Figure 8(b). There was a large number of participants who desired to have the current amount retained or decreased, which implies that the learners did not desire to have any more amount of text learning to be increased. All these indicated to us that in game learning it is still possible to further increase the number of game elements and it would be possible to include more learning items and contents than this time, which offers a potential for achieving learning outcomes that exceeds that of the text learning. It would be necessary to develop a game with an increased number of game elements and continue with the verification of its learning effects.



(a) Game learning (b) Text learning

Figure 8. The evaluation for the number of elements

5. CONCLUSIONS

A serious game for the advance learning of evacuation actions to be taken in an event of disaster was developed and its learning effects were verified. The results of the study can be summarized in the following manner:

1) Seven elements were selected as constituent elements of serious games based on an investigation of documents, three of which were selected as characteristic elements of {objectives, interactions and quantification}, which are attributed only to games, which were used to indicate a basic structure model.

2) An example of game development, involving an evacuation action learning game comprised of three stages which were formulated by adjusting the distribution of the three elements selected as characteristic elements of the game, was presented.

3) A comparison experiment with text learning was conducted, in order to clarify the learning effects of the evacuation action learning game. Although the learning effect of the game was slightly inferior to that of the text learning, the game was shown to have a potential for learning that utilizes the essential characteristic of the game, which is fun in learning, as well as the potential for further improvement of learning results by increasing the distribution of game elements, were shown as a result.

An experiment involving arrangements of maps and objects for a virtual facility was conducted by this study in the development of a serious game. sharing the design methodology for games intended for evacuation action learning and developing games intended for facility spaces that actually exist and these must be applied to actual evacuation action learning, since our study revealed that learning effects. Furthermore, the application of serious games in the field of construction is still in the developmental stage and as such, it is essential to proceed with a study on the potentials of their applications as well.

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