Explore Through the Past: Gesture-Based Mobile Game for Children Observing Geological Layer Exhibit at History Museum

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Abstract: Geo-Science education enables children to enjoy observing and investigating environment around them. In particular, physically experiencing geological formations in a museum or other settings can enhance the effectiveness of geo-science education. Mobile devices are widely spread and have been used in various areas. However, during their usage, the physical movements of learners are restricted. Restriction in physical movements leads to reduction in enjoyment. Therefore, our study developed an action game wherein learners interacted with a digital object on a mobile device through a character controlled by their body movements. Our experiment result shows children found the game engaging and educational and were willing to try again. The game was easy to use and natural, suggesting it increased interest in the exhibit. The results suggest the use of gesture-based learning experiences can increase interest and make learning about geological formations in museums more effective.

1 INTRODUCTION

1.1 Introduction

Geo-Science education makes children more interested in the environment around them and enables them to enjoy observing and investigating things that interest them. It provides a variety of knowledge about the environment, such as past crustal movements and environmental changes, the organisms that inhabited the environment, and how our ancestors lived in the past. As a first opportunity to learn geology, observational studies are required in the elementary school curriculum. However, it is difficult for children to gain an essential understanding of geology through classroom learning alone (Ford, 2005). Although students visiting outcrops directly for observation and learning is desirable, in this highly urbanized environment, children can visit only a limited number of outcrops easily and safely. Meanwhile, Geoparks are becoming increasingly popular around the world as places where geology can be studied (Arima, 2016). One problem with geoparks, however, is that in addition to safety, the learning experience is largely dependent on the prior knowledge of the individual. The museum is much more convenient, safe, and has stable resources for geological learning. A stripped section of a geological stratum installed as an exhibit can provide an experience similar to actual observation and learning. However, most museum exhibits are valuable academic materials, which are often fragile and lack durability. Therefore, many museums prohibit visitors to touch the exhibits, only allowing them to observe. Hence, exhibitors must read the exhibit panels and recognize the labels attached to understand the contents. However, many geological contents are inherently unobservable because of the scale of time and space, making observations extremely complex and difficult for children to understand (Trend, 1998). It is difficult to be interested in an exhibit based on its appearance alone, and the background and history of an exhibit are important too (Gerven et al., 2018). Consequently, geological exhibits are difficult to captivate children's interest.

For intrinsic motivation through an even more intense learning experience, learning while having fun is effective (Henderson et al., 2007). Learning games are effective for such learning experiences. Children have been found to believe that problem solving and exploration in games helped them learn (El Mawas et al., 2019). Gamification can create a

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playful and engaging learning experience through an interaction style separate from viewing, reading, and listening. Gamification on vulnerable and chronologically obscure exhibits in museums enables us to make complex concepts easier for children to understand better. It can spark interest and enhance learning in the museum (Acquah and Katz, 2020). Satoyama forest management game is a simulation game that can experience hundreds of years of forest management. Children understood the concept of forest managing, overcoming the complexity due to the scale of time (Yago et al., 2021).

1.2 State of the Art

The use of mobile terminals enables experiencing gamification in wide areas, such as museums and outdoors. Location-based mobile game for local history and cultural heritage sites using widely used mobile devices (Luiro et al., 2019) have been studied. However, simply interacting through touch screen with content displayed on a screen limits the physical movements that are important in learning.

Learning is more effective when body movements are involved in the learning process (Gee, 2008). Embodiment leads to better learning outcomes than in the non-physical learning in classrooms settings (Vazou et al., 2019). Integrating physical activities by asking children to imitate the movement of animals to had positive effects on children's understandings and memory on geology concepts (Mavilidi et al., 2016), and foreign language vocabulary learning (Schmidt et al., 2019). With motion tracking sensors such as Microsoft Kinect, physical movements can be used to directly interact with digital contents. The Angle-makers helps children understand angle by tracking both arms and calculating (Georgiou et al., 2020). Museums settings have utilized this to introduce full body interactive installations. By using gestures and body movements to control exhibits, visitors experienced more engagement and joy. UKIO-E game allows children to have conversation with painters of Japanese traditional arts using gestures and voices (Tamaki et al., 2016). Belong allows children to interact with dinosaurs with multiple gestures (Tokuoka et al., 2017). In both games, children's interest significantly increased. However, learners' use of gestures in gamification experiences with mobile devices have not been considered enough. By incorporating physical actions into game-based learning using mobile devices, we aim to make learning more effective while maintain versatility.

In this study, we describe the development of a mobile gesture-based action game that enables learners to learn about vulnerable geological formations through fun and playful physical actions. Here, we develop a game in which the contents of a geological strata cross-section are displayed, and the user can interact with the contents by manipulating the characters through physical gesture actions. The proposed system consists of tablet devices alone and built-in accelerometer was used to achieve the gesture recognition. Through this system, the learner observes the geological strata while moving his or her body. In this study, we focused on the effects of physical movements on learning, and the experiment was conducted with such purpose. This paper describes the outline of the proposed system, the experiment, and the results of the questionnaire survey.

2 GAMIFICATION OF GEOLOGICAL LAYER EXHIBIT

2.1 Overview

In this study, an action game that displays digital information and requires physical action is used to enhance the geological strata exhibit in a history museum into a highly interactive and exciting experience.

The game allows students to learn about geological formations from the bottom to the top along a chronological sequence of strata formation. The formation of geological strata often takes several hundred years, a scale of time that cannot be experienced in ordinary life. For example, the 4-meter-high, 6-meter-wide stratum in Figure 1 shows the lower part of the stratum, the oldest part that dates back to the 13th century, and the upper part that dates back to the 17th century.

Figure 1: Geological Strata Exhibit at Museum.

The learner climbs a game stage course reconstructed the strata by controlling a small character along a chronological sequence from a start point in the lower layer, which is the older strata, to a goal point in the upper layer, which is the newer layer. In the process of climbing, game displays contents matching the artifacts in the stratum, dialogues of characters to enhance the immersive experience, and brief descriptions of the stratum according to the location of the artifacts. The learner climbs a course by using the characteristics of the displayed contents and aims at the goal. The learner can observe the numbers of digital contents and the artifacts in the stratum as shown in table 1 at the same time to learn the chronology of the excavated artifacts and their positional relationship in the strata. The system setup is shown in Figure 2.

Table 1: Artifacts in Geological Layer.

Category	Number of contents
Building Surface	8
Road Gutter	6
Plate	3
Bone	3
Burnt Soil	4

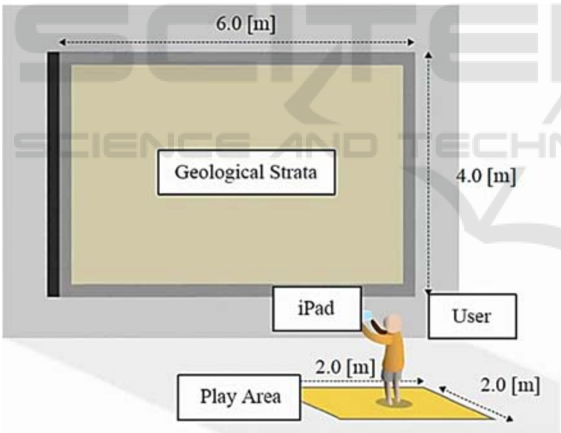

Figure 2: System Setup.

The game is played by the learner holding the device and scanning the strata exhibit with the camera. When the system recognizes the exhibit, a character and course are superimposed on the exhibit. The player can control the character by tilting the device, shaking it up and down, and tapping the screen to reach the goal. The game experience flow is shown in Figure 3 and Figure 4.

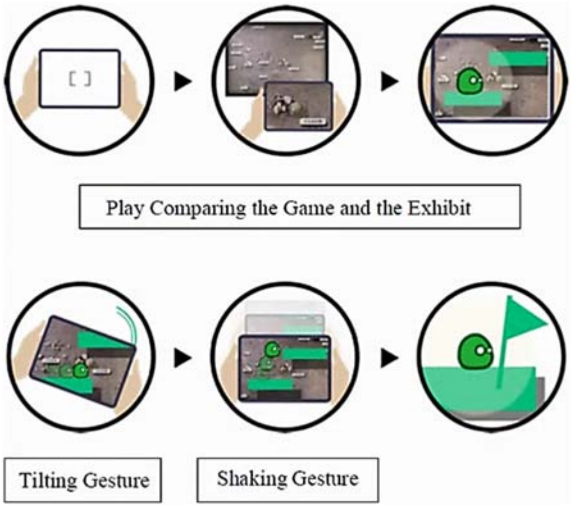

Figure 3: Experience Flow.

Figure 4: Game Flow.

2.2 Creating Exploration Experience

An understanding of a geological time scale is an important element in learning about geologic strata. Children understand the environmental changes of the Earth in ancient times, but they think in terms of two rough time divisions, “very old age” and “old age” rather than specific years (Trend, 1998). To simplify children’s understanding of geological strata, this game does not use specific ages but divides the strata into three major layers: the old, middle, and upper strata. The learner can freely climb from the bottom to the top of these three layers. The exhibit of the virtual space is darkened so that the learner can experience the adventure of exploring the places of interest to them. The character is shown glowing, and the excavated artifacts can be seen only by controlling the character. Figure 5 shows this scene.

Figure 5: Character Lighting up the Geological Layer.

The excavated items contained in the stratum are difficult to observe with the naked eye because of their small size compared to the size of the exhibit and because they have lost their original appearance because of weathering. For example, Figure 6 shows an excavated item on display. On the left is a pot made of clay, and on the right is a dolphin spine. Although they are labelled, recognizing the items is very difficult. Especially for children.

Figure 6: Excavated Items Displayed.

For children, the museum experience can be strongly felt by linking their direct experiences with the exhibits (Piscitelli & Anderson, 2001). Therefore, we selected content that local children would find familiar. For the building surface, we chose artifacts familiar to the local residents of the city of Fukuoka, where the museum is located. To make it easier for the children to recognize, items are illustrated, as shown in Figure 7.

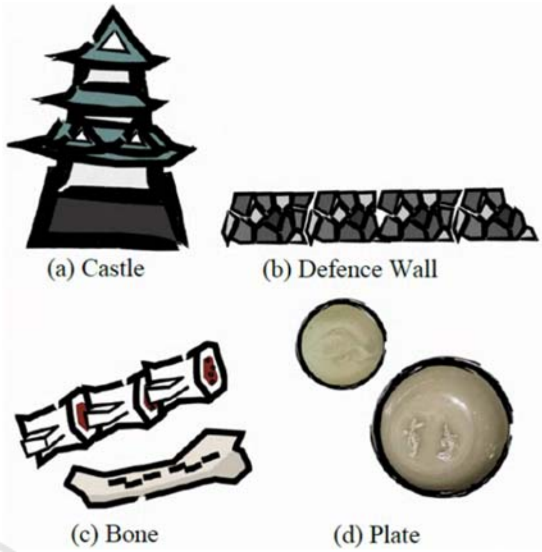

Figure 7: Illustration Content Shown in AR.

2.3 Climbing up the Layers Using Body Gestures

This system requires that the device reads the learner’s movements and translates them into the actions of the digital character on the screen in real-time. This allows learners to have an immersive experience of learning geological strata by controlling the characters displayed on the strata through their physical movements. We used the acceleration sensor value built into tablet devices to measure the learner’s movement. The acceleration of the terminal in the z-direction is measured, and when a tilt of more than a certain amount is detected, it is converted into the character’s horizontal movement speed in proportion to the acceleration. As shown in Figure 8, the character moves horizontally when the learner holds the device horizontally and tilts it. The character moves faster in proportion to the tilt of the device.

The game also includes a jumping motion because of the nature of the game’s strata-climbing game. Tapping the screen moves the character to jump vertically. The longer the tap on the screen, the larger the jumping motion.

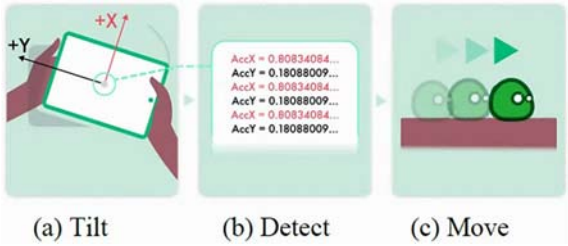

Figure 8: Tilting Mobile Tablet to Control Character in Game.

3 EXPERIMENT

3.1 Experiment Method

The proposed system was evaluated by 24 visitors (17 boys and seven girls), ranging from the first grade of elementary school to the second grade of high school. The evaluation was conducted at the Fukuoka City Museum. Participants were a mixture of siblings and single visitors, and only one iPad was provided for each experience. Participants played the game for around 15 minutes after a brief explanation, and the completion of the experience was optional. Figure 9 shows the game being played by a single participant and Figure 10 shows multiple participants playing it simultaneously.

Figure 9: Single Participant Playing the Game.

Figure 10: Participants in a Group Playing the Game.

First, participants briefly observed the strata. Thereafter, they moved to a designated position in the center at the front of the stratum, holding the iPad with both hands, and experienced the game. The participants followed the guidance displayed in the game and freely controlled the characters by moving their iPads. Participants soon got used to the game and enjoyed playing it regardless of the number of people in the group. Finally, after completing the game, a simple questionnaire was used to evaluate the game. The questionnaire consisted of 12 questions, four questions were about the game, three were about fatigue, four were about the strata exhibit and a free answer section. Each question was scored on an 11-point scale from 0 to 10, with 0 corresponding to “not at all disagree” and 10 to “strongly agree.”

3.2 Results

The responses to the questionnaire are described as follows: scores from 0 to 3 were classified as negative responses, from 4 to 6 as neutral responses, and from 7 to 10 as positive responses. The number of positive responses and the number of neutral and negative responses were analyzed using a direct probability computation method. Questionnaire results are presented in Table 2.

First, the evaluation of the game was summarized. The following four questions were asked: “Was the game fun?” “Was the game easy to understand?,” “Would you like to play more?,” and “Did you feel a sense of accomplishment?” Positive responses far exceeded the neutral and negative responses. 23 out of 24 participants enjoyed the game, and wanted to keep playing, even though as shown in table 3, some participants felt the game was a little difficult. Next, the evaluation of fatigue was summarized by asking the following three questions: “Does your body feel tired?” “Does your brain feel tired?,” and “Was the character easy to control?” Positive responses to these questions also far exceeded the neutral and negative responses. Comments such as “It was very easy because I only need to move my device” show it was easy to control the character through physical gesture. Finally, the evaluation of interest in and understanding of the exhibition was summarized by asking the following four questions: “Did the game make you want to know more about the contents?” “Would you like to see the exhibition again?,” “Can you imagine the contents?,” and “Do you understand the chronological order?” Positive responses to these questions exceeded the neutral and negative responses. Comments such as “It was easy to understand, and I thought people who do not know about history can also enjoy this.," "I understood Fukuoka city's history" younger participants believed they have gained knowledge from playing this game.

Table 2: Results of Questionnaire.

Question	Positive	Neutral	Negative
Was the game fun?	23	1	0
Was the game easy to understand?	23	1	0
Would you like to play more?	23	1	0
Did you feel a sense of accomplishment?	23	0	1
Does your body feel tired?	21	1	2
Does your brain feel tired?	14	6	4
Was the character easy to control?	15	2	7
Did the game make you want to know more about the content?	23	0	1
Would you like to see the exhibition again?	19	5	0
Can you imagine the contents?	19	5	0
Do you understand the chronological order?	17	6	1

Table 3: Free answer field.

Age	Answer
7	It was fun.
8	It was fun.
9	It was entertaining.
9	It was very easy to understand and very fun.
10	Jumping was hard, and when I succeeded, I was very happy.
10	It was easy to understand, and I thought people who do not know about history can also enjoy this.
10	I understood Fukuoka city's history.
11	It was very easy to control the character. I want difficulty level selection.
11	It was very easy because I only need to move my device.
11	It was fun.
12	It looked like a real thing.
13	It was interesting, I thought there was a problem with the wall-jumping.
13	It was difficult but fun.
13	I was hoping for something a little easier.
13	It was difficult but interesting.
14	It was interesting.
16	I liked the fact that I was able to have fun and cooperate with my friends when we got through the fire part.
17	It was interesting because of the special way of operation, but I didn't gain much knowledge.

The results of this study suggest that the use of gesture-based learning experiences can lead to an interest in geological formations and make learning about geological formations in museums more effective way. The nature of the game, which allowed children to acquire information about the exhibit by freely exploring areas of interest sparked children's interest toward geological strata exhibit, motivating children to learn about the geological strata exhibit more, and led to understandings of basic geological formations.

4 CONCLUSIONS

This paper describes the development and evaluation of a game for geological layer exhibit to support geo-science education in a museum. For children to enjoy and learn geological layer exhibit effectively, we developed a game in which children can learn about geological layer by controlling digital characters through a mobile tablet device with physical gestures.

The effectiveness of the system was evaluated using a questionnaire consisting of 11 questions. Positive responses exceeded neutral and negative responses for all questions related to the game, fatigue, and interest in geological formations. The children found the game engaging and educational and were willing to try it again. The game was easy to use and natural, suggesting that the game increased interest in the exhibits. The results of this study suggest that the learning through exploration with use of gesture-based learning experiences can lead to an interest in geological formations and make learning about geological formations in museums more effective. These results establish the possibility of an education using simple gesture motion that provide children with a better play and learning experience.

However, this limitation has been identified in this system. Area based AR marker can be unstable at areas with insufficient light sources. To stabilize the AR at such areas, placing AR markers are desirable. Therefore, in future work, we would like to stabilize the system by placing multiple AR markers on the floor. The goal of this research is to develop an effective system for learning with mobile terminals in museums using body movements. With such a system, we can make museums more enticing and effective for children's knowledge acquisition.

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