Educational Effectiveness and Learner Behavior When Using Desktop-Style VR System

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ABSTRACT

An experimental class using a desktop-style virtual reality system was conducted in a school to examine the educational effectiveness and learner's behavior. The results show that sharing educational materials in 3D promotes discussion in group work.

1 INTRODUCTION

In recent years, expectations for virtual reality (VR) technology are diverse, and its use in different fields like medical and education is continuously being investigated. Several head-mounted displays (HMDs) with wide field and high-definition constituting the core element of VR have emerged. Research and development on HMDs dates to the 1960s [1], but low cost high-performance products only appeared in the market in recent years. Thus, the development of highly realistic and immersive image expression significantly promoted interest in VR recently.

Advances in display technology also caused changes in teaching methods. In other words, the use of Information and Communication Technology (ICT) is being promoted in education, with new devices and media actively used in learning at school. The main ICT devices used by students are tablets, which are used for digital textbooks, digital teaching materials, and thinking tools that support lessons. By promoting the use of tablet devices at schools, opportunities to utilize new media using VR technology like 360° images and stereoscopic 3D images for education are expected to increase. Shibata et al., for example, developed an educational material that allows students to learn the state of historic sites by observing 360° images on a tablet [2] and stereoscopic images on a 3D display [3]. The material provided understanding of historical sites better than obtained from ordinary photographs.

Although VR educational materials exhibit benefits unavailable in conventional educational materials, most of such materials are often adopted for personal use only. In school, in addition to individual learning, it is important to collaboratively understand the learning contents and to resolve issues in as groups. Moreover, it is important that teachers interact directly with students to obtain reliable feedback about their learning status. We therefore used a desktop-style VR system instead of an HMD to explore the usage of VR in education for an actual school classroom.

In this study, we subjectively and objectively analyzed the sharing of 3D objects by student in the space for a group discussion. Concretely, we evaluated the educational effectiveness and health issues of VR usage. We also measured the viewing distance and the working space between the display and the learner.

2 METHODS

We conducted an experimental class to compare the situation with the learner and co-learner viewing in 3D and the situation where the learner viewing in 3D while the co-learner in 2D.

2.1 Participants

The experimental class involved 20 first year high school students.

2.2 VR System

We used the zSpace 300 (zSpace, Inc.) as the educational VR system for this study. This is a desktop-style VR system containing a 24-inch stereoscopic 3D display with a resolution of 1920 × 1080 pixels (Fig. 1). The students viewed the stereoscopic 3D images using polarized 3D glasses. The students held a dedicated stylus exhibiting 6 degrees of freedom, like a pen, were able to naturally rotate their wrist to move and examine objects in the educational materials [4]. The VR system contained two tracking sensors for tracking the user's 3D glasses and stylus, on the sides of the display. Therefore,

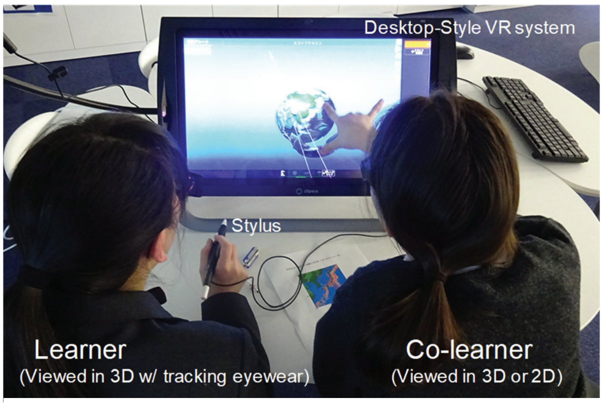

Fig. 1 The desktop-style VR system used in the experimental class.

when a student with tracked 3D glasses tilted his or her head to look around an object, the VR system was dynamically updated to display the accurate perspective of images.

2.3 Conditions

Two students used a VR system collaboratively, with one student as the learner and the other as a co-learner (Table 1). Among the five pairs of students, the co-learners used 3D glasses to collaborate while performing a task (group 1); in the other five pairs, the co-learners used 2D glasses (group 2).

Table 1 Conditions and settings used for the VR class by learners and co-learners

Group		View	Stylus	Head tracking
1	Learner	3D	Yes	Yes
	Co-learner	3D	No	No
2	Learner	3D	Yes	Yes
	Co-learner	2D	No	No

2.4 Educational Materials

We aimed to explore the usage of VR in education through an actual classroom situation. Therefore, we selected appropriate educational materials before conducting an experimental class. After discussing the educational unit and criteria for evaluating the effects of the VR techniques, we selected plate tectonics and earthquake mechanism as the learning content. The earth science content from the VIVED Science module installed in the VR system was used to conduct the experimental class. The students were able to split the plates and observe their overlap (Fig. 2).

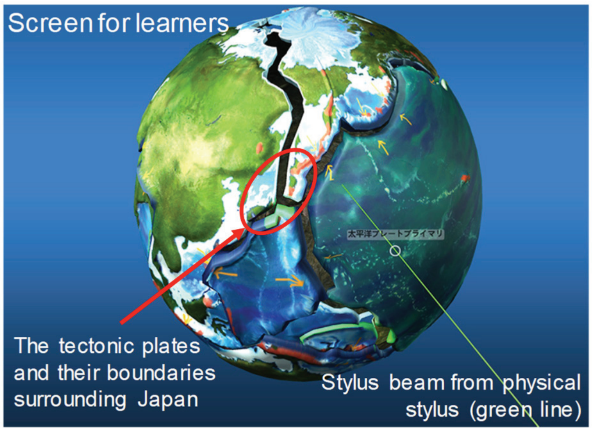

Fig. 2 Screen for learners showing the mechanism of earthquake occurrence.

2.5 Task

The task for group work involved considering the relation between the plates and earthquakes that occurred near Japan. During the group work, students engaged in discussions and filled a worksheet that encouraged the students to write as many thoughts and observations as possible in 3 minutes.

2.6 Evaluation Items

The two evaluations performed include: a questionnaire and learner's behavior.

2.6.1 Questionnaire

After the group work, the students attempted a questionnaire requiring them to assess three categories including learning attitude, things related to the VR use, and health issues like visual fatigue and motion sickness [5]. Each category comprised three questions (Table 2), with students responses rated on a 4-point Likert scale. The number 1 indicates disagreement, 2 indicates slight disagreement, 3 indicates slight agreement, and 4 indicates agreement for the scale.

Table 2 Questionnaire items

Learning attitude
1. How well did you learn about the characteristics of the plates?
2. How well did you learn while talking to your friend?
3. How well did you communicate with your friend about the parts that you wanted to view?
VR usage
4. How easily did you observe the details of the object that you wanted to view?
5. How much did you concentrate on learning?
6. How easily was it to observe the state of the plate?
Health issues
7. To what extent did you not feel well?
8. How much visual fatigue did you experience?
9. To what degree did you feel confused or disoriented?

2.6.2 Learner's behavior

To understand the learner's behavior, we focused on the viewing distance of learner and the distance between the display and the stylus from the learner's operation. The group work in the class was recorded from the side with a video camera. The scale on the camera screen at that time was recorded to measure two distances. After the class, we estimated the ranges of the distance between the learner's head and the screen, and the distance of the stylus from the screen based on the video images.

3 RESULTS

3.1 Questionnaire

Here, we focus on the results of the learners only to compare their behaviors. The detailed results including co-learners were reported in the reference [5]. The responses from the learners using a stylus to the nine questions are depicted in Fig.3, with the scores averaged across the students. The ordinate represents the response to each question from 1 to 4, with 1 and 2 indicating negative responses and 3 and 4 positive responses.

Regarding the learning attitude (questions 1 to 3), learners with co-learners that viewed in 3D exhibited a better inclination for collaborative learning. Concerning the VR usage, the learners who manipulated the 3D object were highly evaluated when their partners also used viewed in 3D. In relation to the health issues, although the overall score was low, the learners who manipulated the 3D object indicated a higher degree of visual fatigue when the co-learners also viewed in 3D.

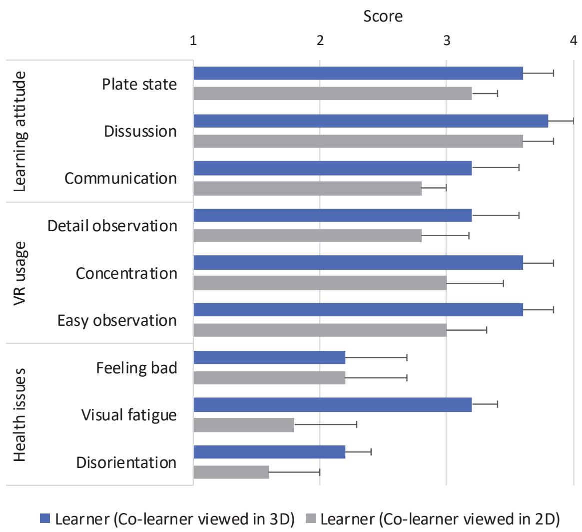

Fig. 3 Results for the learning attitude, the VR use, and health issues from the questionnaire.

3.2 Learner's behavior

The learners manipulated the 3D object while moving their heads freely, regardless of whether the co-learner was viewing in 2D or 3D. Therefore, the shortest and longest distances from the screen were measured for the learner's head and the tip of the stylus to estimate each range. The average range of the viewing distance for learners whose partners viewed in 2D was 35 to 40 cm, while the range for movement of the stylus was 10 to 26 cm (Fig. 4). Conversely, the average range of the viewing distance for learners whose partner viewed in 3D was 44 to 53 cm, while the range for the movement of the stylus was 16 to 40 cm. Thus, learners whose co-learners viewed in 3D had a longer viewing distance and a wider range of movements Therefore, we estimated that the 3D model involved a wide range when the learner and co-learner viewed in 3D, that is, the workspace used for learning was wide.

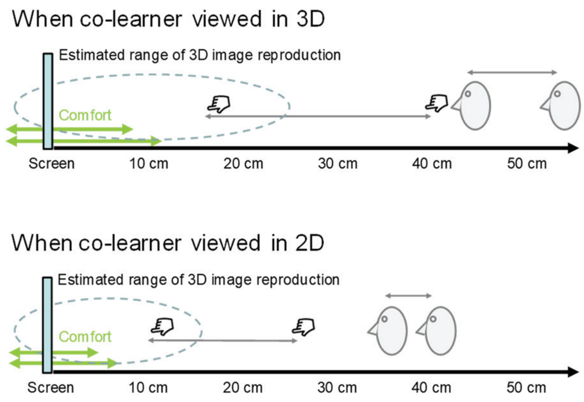

Fig. 4 Results of the range of the learner's viewing distance and that of the stylus movement.

4 DISCUSSION

The results from the experimental class shows that the learners who manipulated the 3D object were evaluated higher overall through the questionnaire when the co-learners also viewed in 3D. The learners' behaviors were different when co-learners viewed in 2D and in 3D.

On the VR system used in the study, only learners were able to manipulate 3D models. If the co-learner wanted to view other parts of 3D model for discussion, they needed to ask the learner to manipulate the 3D model. Regarding learning attitude, manipulating the 3D objects viewed in 3D highlighted a positive educational effect on group work. Thus, we suggest that the manipulation of the 3D model through new technology will enhance collaborative learning, thereby encouraging deep learning and facilitating achievement of learning objectives. In addition, the results from questions on VR usage indicated that the inability to properly share teaching materials in 3D space hinder the benefit of VR. This implies, a VR system that effectively shares cyberspace has a good effect in education.

Regarding the health issues, learners who manipulated the object exhibited a higher degree of visual fatigue when their co-learners also viewed in 3D than when co-learners viewed in 2D. It is assumed that the results could be associated with learner's behavior.

When studying in general, students tend to bring the subject closer to observe detail. A similar situation occurred using the VR system in this study. When the learner and co-learner viewed in 3D, their behavior resembled a real-world observation because they shared the 3D model in real space. However, when the co-learner viewed in 2D, the 2D images were viewed on screen, whereas learners enabled to view the 3D image closer. Thus, a gap is present in the position of the image. Consequently, we assumed that the learners operated by approaching the screen as illustrated in Fig. 4. Learners apparently adjusted the position of the 3D model to establish better communication with the co-learner. The learner, however, was unaware that the partner viewed in 2D unless viewing was discussed in the group work.

Using a 3D space in front of the screen may positively impact learning, but also increase visual fatigue using traditional 3D display technology [6]. Based on a study on the comfort zone in stereo displays [7], the comfort stereo viewing range from screen is 5–7 cm in the condition that the co-learner viewed in 2D, and 8–12 cm in the condition used viewed in 3D, calculated from the viewing distances. This study cannot provide the exact range of the 3D image reproduction. However, from the position of the stylus, it is presumed that 3D images were placed closer to the students when the learner and co-learner viewed in 3D. However, in the experimental class, the viewing time was limited to three minutes, with no complaint of strong discomfort. Importantly, despite the strong potential of VR systems as a learning tool, their use in schools requires careful consideration in terms of 3D expression and time.

Generally, perceived images on stereoscopic 3D displays are often distorted, depending on the mechanism of the conventional 3D displays [8][9]. For example, when the viewer is far from the 3D display, the perceived distance of the reconstructed image is greater and the perceived shape of an object is stretched in depth. However, in case of the VR system used in this study, appropriate images were displayed for a learner based on head tracking. This indicates that the reconstructed images for a co-learner are distorted regardless of 2D or 3D observations. This is an uncomfortable scenario for co-learners [5]. Moreover, depending on whether the co-learner views in 2D or 3D, the learner's behavior and subjective evaluation differed. Therefore, it is necessary to examine in detail the viewing and educational effects.

Additionally, for accurate image representation, the usage of a desktop-style VR system is suitable for only one person. However, it is also worth using by several students because using the VR system to perform group work, the interactive 3D educational materials can enhance understanding of the learning contents and promote collaborative learning.

5 CONCLUSIONS

The experimental class conducted in this study reveal that sharing educational materials in 3D promotes collaborative work in a group. The improved collaboration is attributed to the access to view the 3D image by the co-learner and viewing of the same image as the learner. However, stereoscopic 3D images with high binocular disparity create excessive vergence–accommodation conflict; thus, observers experience severe visual fatigue from prolonged stereo viewing. Therefore, careful consideration of 3D representation and time is imperative for safely using the VR system in education.

Considering the relatively small sample size in the present study, future studies with larger sample sizes are needed.

6 ACKNOWLEDGMENTS

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