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Middle School Science Education Teaching Aids for Industry 4.0

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Abstract. This paper provides an overview of teaching aids the authors developed for middle school science classes using next-generation technology such as virtual reality, augmented reality, and a face-to-face learning management system. Our proposed aids have possibilities for the Internet of Things (IoT), big data (BD), and artificial intelligence (AI), all of which are necessary for the social realization of Industry 4.0.

1. Introduction

Earlier, robots were able to perform tasks only after being given instructions by humans; however, thanks to the advancement of autonomous technology robots are now capable of doing tasks after evaluating situations themselves. This shift is about to have a huge impact on human industry and bring about what is known as Industry 4.0 [1–2]. Such autonomous technology is made possible through advancement in microelectromechanical systems (MEMS)-based sensor technologies and improvements in processing speeds. Industry 4.0 brings with it an industrial transformation due to technological advancements in the Internet of Things (IoT), a sensor technology; big data (BD) obtained through sensor measurements; and artificial intelligence (AI), which finds and analyzes correlations in BD. The resulting industrial autonomy will mean that about half of the tasks traditionally fulfilled by humans are expected to be replaced by robots [3].

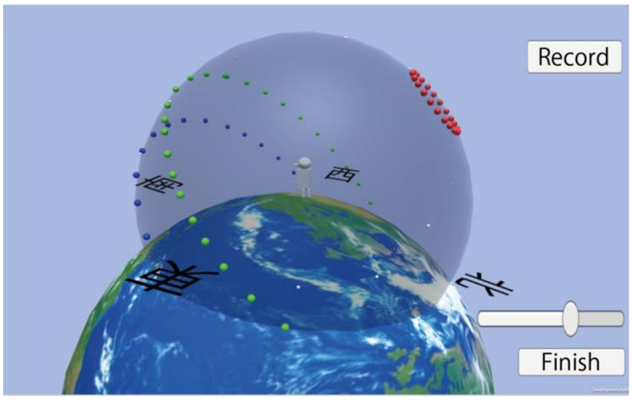
In the future, therefore, people will work in new jobs using IoT/AI/BD that do not exist today. Because people specializing in system engineering will be needed, new training programs, including programming education, must be introduced starting in Japanese elementary schools as soon as 2020 [4]. Such training programs should include not only a shift in educational curriculum, but also the development of teaching aids. To this end, in this paper, we outline some teaching aids effective in compulsory education in IoT/BD/AI technologies and propose directions for developing additional aids in the future.

The remainder of this paper is structured as follows: Section 2 addresses the use of tablet sensors in middle school science education; Section 3 addresses the use of information sharing; and Section 4 proposes ways to utilize IoT/AI/BD based on these technologies.

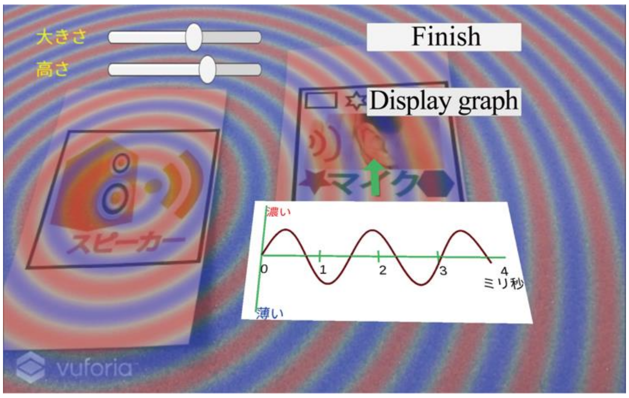
2. Sensor Measurements

Sensor measurements have been used in education since the 1990s and they make it possible for students to perform real-time measurements of scientific phenomena [5–6]. Today, tablets are capable of making various sensor measurements, making such measurements increasingly accessible to students [7–8]. Using tablet devices, it is possible to display measurement results not only as graphs but also through other display methods that help students understand the data in other ways, including through virtual reality (VR) and augmented reality (AR), both of which make it possible to visually describe the world in a way we cannot normally experience. In science class, for example, students are able to visualize phenomena they are unable to see otherwise, thereby facilitating an intuitive understanding of scientific phenomena.

To this end, we developed three VR/AR teaching aids: a VR teaching aid to better understand diurnal motion (Fig. 1a), an AR teaching aid to explain the nature of sound waves (Fig. 1b), and a marker-less AR teaching aid to explain the motion of objects (Fig. 1c).



(a) VR teaching aid for understanding the diurnal motion of a celestial object



(b) Marker-based AR tool for understanding the propagation and receipt of sound

(c) Marker-less AR teaching aid for understanding the motion of objects

Fig. 1. VR and AR applications

2.1 Virtual Reality (VR) Teaching Aid

In our first teaching aid, we measured azimuth orientations using tablets' interior gyroscope sensors and then displayed a virtual image of all directions seen from a single point. VR allows not only for a high-level visual sense of reality but also for changes in spatial and temporal scale. Therefore, VR is suitable when learning about celestial objects that require students to think at a macroscopic scale of space and time, such as diurnal motion (Fig. 1a).

Because detailed specifications of the teaching aid and its effectiveness in learning have been reported in previous studies, this paper merely provides an overview [9]. The VR tool allowed students to observe about 10 hours of real-time diurnal motion in 5 minutes, while they could easily shift their spatial perspective between an overhead view (i.e., observation from space) and an observer's view (i.e., observation on Earth).

We tested the efficacy of this tool with a group of 148 ninth-grade students; all were able to observe diurnal motion using our teaching and felt that VR was useful in facilitating their understanding of the shift in spatial perspective between views. As an example, the use of VR increased the comprehension of the celestial sphere from 53% to 78%.

2.2 Marker-Based Augmented Reality (AR) Teaching Aid

AR allows us to analyze videos shot with tablets' internal cameras in real time and add VR components to the videos. Marker-based AR uses markers as coordinates to display objects we cannot see in real life. In the teaching aid shown in Fig. 1b, we used marker-based AR to display the propagation of sound waves in the atmosphere to teaching students about the nature of sound.

Again, detailed specifications of this teaching aid and its effectiveness have been reported in previous studies [10–11]. We prepared markers for sound transmission and reception and visualized in AR the fluctuations in spatial density associated with sound propagation and the sound reception process. Our teaching aid allowed students to intuitively understand the dynamic shifts as a sound wave travels through space and time.

We then tested this tool in a class and survey of 125 seventh-grade student. Our findings suggest that AR is an effective tool in visualizing the nature of sound and other invisible phenomena. As an example, the use of AR increased the comprehension of the sound wave from 30% to 95%.

2.3 Marker-less Augmented Reality (AR) Teaching Aid

Unlike in marker-based AR, where users set marked coordinates, marker-less AR devices themselves recognize the space and determine the coordinates of the AR display. For example, some methods use time of flight (ToF) measurements and triangulation using a compound-eye camera, while other technology has been developed that recognizes flat surfaces using a monocular camera [12–13].

Because this method enables AR display that reflects an actual space, we used it to develop a teaching aid displaying the ideal mechanical behaviors of mass points in scanned space as shown in Fig. 1c, details of which are reported in previous studies [14]. We evaluated the accuracy of space recognition of a device equipped with a ToF-type depth camera and revealed that marker-less AR could be used in mechanical experiments. We are planning to develop a learning program using this teaching aid and to verify its educational effectiveness in a class.

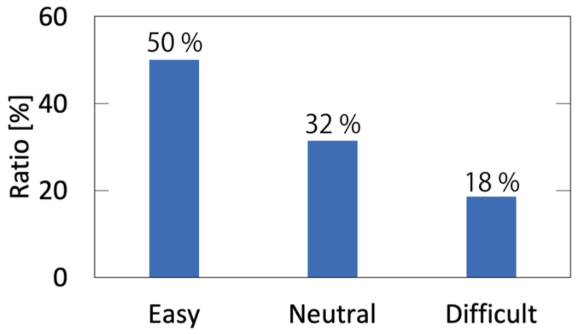
3. Learning Management System

The use of tablets in education has many advantages. Students can communicate information over the internet. Learners can proceed at their own pace using a remote site and by watching online lectures. Video distribution provides one-way communication to learners, while learning management systems (LMS) enable e-learning through bidirectional communication. These tools can help provide a uniform education to schools in remote areas where there are few teachers available. In addition, LMS can also be used in face-to-face classes instead of connecting various remote sites.

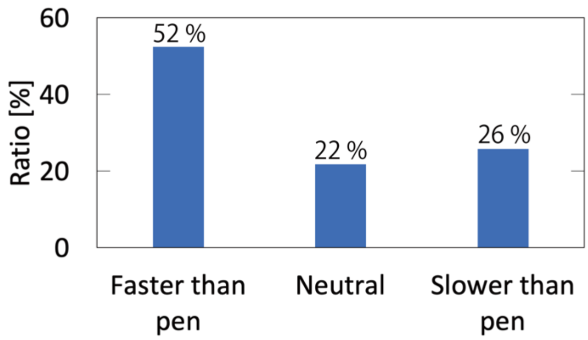
Because of these benefits, Japan now aims to provide tablets to all students and integrate them into compulsory education in the hope that using LMS during face-to-face classes will facilitate the smooth sharing of information among students and between the teacher and students. In this study, we used a face-to-face LMS to verify the increased efficiency of opinion-sharing when learners input their opinions in text format.

To this end, we asked 124 eighth-grade students in four classes at middle school A to use our face-to-face LMS in three sessions of their science class. We provided each student with an iPad, which they used to share opinions in text format using the LMS to set assumptions and discuss the lesson. Students used the iPad's touchscreen keyboard for text input.

The log analysis revealed that students entered an average of 320 Japanese characters in each class. The text input speed could not be evaluated quantitatively, because that time could not be separated from the time required to think about what to enter. Therefore, we evaluated speed of text input using a questionnaire survey after the first session of LMS use. We asked students to provide answers on a 3-point scale about the "difficulty level of text input" and "text input speed" when using tablets (Fig. 2). The results show that about half of the students did not have any trouble entering text using the touchscreen keyboard, and only 20% thought it difficult to enter text using the touchscreen keyboard or that it took more time than using a pen. This suggests that sharing opinions through text input using tablets is possible at the middle school level.



(a) Difficulty level of text input



(b) Text input speed

Fig. 2. Results of our questionnaire survey (N=124).

4. Future Prospects

4.1 LMS on High-speed 5G Mobile Networks

While Section 2 shows that displaying scientific phenomena using VR and AR facilitates students' understanding, Section 3 suggests that such an understanding can be furthered by online communication and incorporating sensor measurements into IoT. In other words, online education using VR and AR is a method of IoT utilization, a research topic that should be furthered addressed in the future.

E-learning that provides education to remote sites through video distribution is growing. While traditionally such e-learning relies on two-dimensional videos shot with a fixed camera and typically involved complex preparations, including the design of studios and teaching aids, such methods do not allow viewers to change their viewpoint. However, the use of VR and AR make it possible to distribute a variety of e-learning materials that are not limited to videos shot with a fixed camera. By distributing 360-degree VR videos shot using a wide-angle lens, students can see not only the image of the blackboard but also the entire classroom, furthering active learning. Distribution of point group data of the space obtained from ToF measurements makes it possible to observe the target object from every angle, which can be utilized in experiment observation. Although a large volume of data must be communicated, we believe that a new way of e-learning can be achieved through the use of high-speed 5G mobile networks.

4.2 Analysis of Big Data (BD) by Artificial Intelligence (AI)

Section 3 shows that sharing of opinions in a text format through the use of a face-to-face LMS is effective at the middle school level. However, a function for categorizing and aggregating opinions is necessary after they are shared. Future research should address the possibility of BD and AI in this role. Equipping the face-to-face LMS with a machine learning function for automatic categorization makes it possible to not only share opinions but also to aggregate them. This should make it easier to handle class opinions and aid in the dissemination of the face-to-face LMS.

5. Conclusion

In this paper, we introduced VR/AR teaching aids using sensor measurements and a face-to-face LMS and explored their implications for science learning. We hope that these tools, as well as their integration with IoT, BD, and AI, can facilitate active learning and experiment observation and connect remote sites. We also hope that equipping the face-to-face LMS with a database function to handle BD and enabling it to categorize data through machine learning would allow the LMS to instantly aggregate learners' opinions, which has been considered difficult in the past.

Acknowledgements

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