Development of Network Instructional Materials using Mixed Reality

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We assumed a practical training format for acquiring skills and understanding knowledge in High School Information I, following Kolb's experiential learning model. We developed network learning materials that leverage the characteristics of merging Mixed Reality (MR) technology's real space and virtual environment. To validate the effectiveness of the developed materials, We compared the extent to which the simulated experience on paper worksheets and the actual practical environment in the main material could provide a learning experience close to real-world practice, assessing the differences in insights.

Key words: Mixed Reality, High School Information I, Kolb's experiential learning model

1. INTRODUCTION

Starting from the academic year 2022, "Information I" has been introduced as a mandatory subject in high schools [1]. In Information I, it is crucial to deepen understanding and acquire skills related to realizing diverse forms of communication, as well as utilizing information systems and various types of data. The chapters on information and communication networks, as well as data utilization, require students to develop both knowledge and skills. With skill acquisition, it is important for students to gain practical experience, reflect on the content they should learn, and foster both knowledge and skills. The Kolb experiential learning model is often discussed as a process to reinforce knowledge through experiences [2]. As an example of incorporating this experiential learning model into the learning unit of information and communication networks, there is a hypothetical section involving exercises on drawing diagrams of home LAN (Local Area Network). While exercises can be easily conducted through lectures, paper, drawing websites, and the like, to further extend students' knowledge and skills, it would be necessary for them to engage hands-on in practical environments using their own abilities. However, setting up fiber-optic lines in high school classrooms and purchasing network equipment is not easily feasible in terms of cost-effectiveness and the burden on teachers.

On the other hand, in recent years, there has been growing interest in the utilization of MR, a technology that integrates the real and virtual spaces, mutually influencing each other in real-time. For instance, TOYOTA has introduced MR in automotive maintenance tasks, developing a system that overlays information such as wiring in 3D onto the actual vehicle, allowing for an intuitive understanding and operation.

In this study, we aim to design and construct network learning materials utilizing MR that enables integrated learning of skill acquisition and knowledge understanding in High School Information I, following the experiential learning model. The goal is to clarify the educational effectiveness of the materials.

2. LEARNING DESIGN IN THIS STUDY

The instructional target for this study is an establishment of a home LAN (figure1). In the learning process, we introduce an experiential learning model that applies ①Concrete Experience, ②Reflective Observation, ③Abstract Conceptualization, and ④Active Experimentation (figure2). In step ①, Participants will apply their pre-existing knowledge to build a home LAN. In step ②, based on the results of step ①, they will identify points where connections were not established correctly, errors that appeared, and explore the reasons and backgrounds behind them. In step ③, thoughts generated in step ② will be verbalized, shared with others, and summarized into opinions. Finally, in step ④, participants will once again perform network construction similar to step ①, based on the insights gained in step ③.

In this paper, we focus on applying MR to LAN construction. By utilizing the spatial recognition capabilities of MR, we can recognize the real-world space and prepare network equipment in a virtual environment. The MR function to merge the real-world space and virtual environment realizes the placement of optical outlets on walls and devices like Optical Network Unit (ONU) on desks. This allows for the placement of virtual devices on real-world desks and walls, allowing students to interact with them as if they were physically touching them. Through collaborative experiences, students can construct networks in an environment where they can operate and learn experientially.

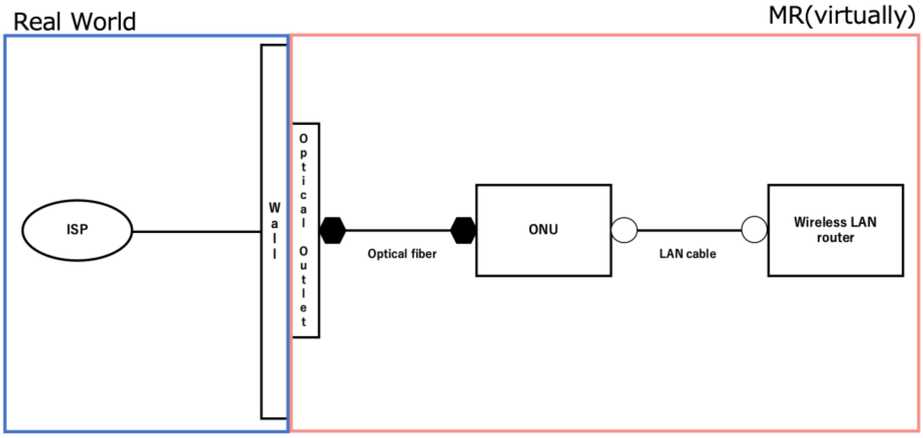

Figure 1　Connection between ISP and home network

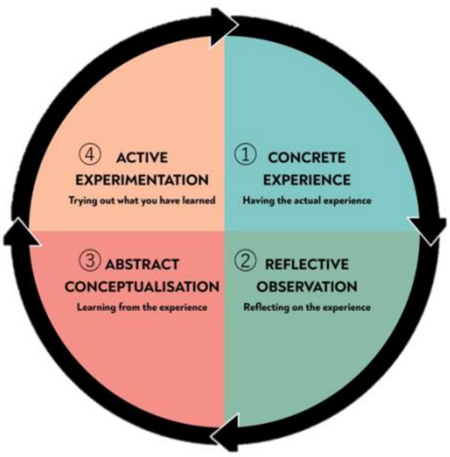

Figure 2　Kolb's Experiential Learning Cycle

3. DEVELOPED LEARNING MATERIALS

In our study-HoloLens2 is employed as the MR device, with Unity used as the development environment.

3.1 Display of Network Equipment Using QR Codes

To realize the placement of virtual devices at any location on walls or desks, we use the "Microsoft.MixedReality.QR." Utilizing the QR code recognition and real-time tracking features of this package enables us to display network devices on QR codes and place them in arbitrary locations (Figure 3). Additionally, the devices prepared for this system include an optical outlet, ONU, wireless LAN router, optical fiber cable, and LAN cable, totaling five types (figure4, figure5).

Figure 3　Display of Network Equipment on QR Code

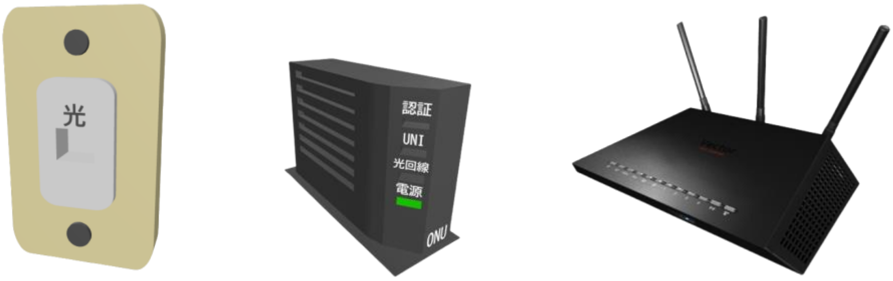

Figure 4　3D Models of Optical Outlet, ONU, and Wireless LAN Router

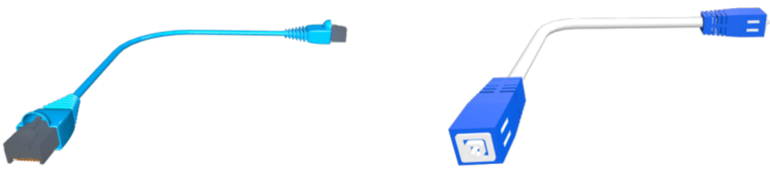

Figure 5　　3D Models of LAN Cable and Optical Fiber Cable

3.2 Placing Network Equipment on Physical Desks in Real Space

We realized the placement of 3D computer graphics (3DCG) network devices on the real-world surfaces such as desks and floors by utilizing the spatial mapping feature of HoloLens 2 and configuring the network equipment in Unity using Rigidbody as a component for "using gravity" and setting up Colliders (Figure 6).

Figure 6　　Placement of 3D CG Network Equipment on a Desk

3.3 Performing True/False Judgments

The developed educational material involves learners connecting network equipment with cables to establish a LAN. It assesses whether the connections are made correctly and provides feedback to the learners based on the assessment results. Correct or incorrect status in the system is determined by two criteria (i.e. (A) checking if cables are inserted into the four connection ports of each network device, and (B) Comparing the answers provided by the system with the user's response).

In section (A), it is necessary to have cables connected to four ports: the connection port of the optical outlet, the Fiber connection port of ONU, the UNI connection port of ONU, and the WAN connection port of the wireless LAN router. If there are fewer than four connections, an incorrect message is displayed at that point.

In section (B), the system enables us to confirm the correct type of cable connections for the optical outlet, Fiber connection port of the ONU, UNI connection port of the ONU, and WAN connection port of the wireless LAN router. If the connection ports are incorrect or the cable types are wrong, a message is displayed.

If both (A) and (B) are correct, the radio wave symbol is displayed on the wireless LAN router. The notification lights on the ONU and wireless LAN router illuminate, and three correct effects indicating the flow of packet communication are displayed, symbolizing that communication can be simulated (figure7).

Figure 7　When the Network is Properly Constructed

4. VERIFICATION

The verification was conducted by comparing the " success" and "understandings" when building a home LAN using this system versus using a paper worksheet. This comparison involved: (a) assessing how learners perceive the experience of learning in an environment close to the practical training setting, and (b) comparing the results based on the respective quantities. The verification involved 14 participants who conducted the network construction experience in pairs.

First, we show the results on the worksheet for (a).

・"I understand the connection order of the devices being used."

・"I have succeeded in connecting to the Internet using multiple devices."

・"I have found that there is a continuous connection from the ISP to the LAN."

On the paper worksheet, many opinions were written about the roles of network equipment.

Next, we show the results on this system for (a).

・"I newly discovered that ONU and wireless LAN router have multiple connection ports."

・"I have learned that there are different types of cables."

・"I have realized that devices I had seen in the real world were actually ONU or wireless LAN routers."

In this study, we simply realized network connection between the optical outlet and ONU, and ONU and wireless LAN router without distinguishing cables. However, it was found that there are dedicated cables for each device when connecting, and there are multiple places to insert the cable. If it is not inserted in the correct place, it can lead to network construction failures. Furthermore, many students obtained new insights, such as realizing that machines they had previously unconsciously observed at home are actually network devices.

At the end, the comparison results of the number of (b) are shown in Table I. From this table, it can be observed that on paper worksheets, the average for each pair was 1.85, whereas with the present system, it was 6.28, indicating an increase of 3.38 times.

Table I Difference in the Number of Realizations and Understandings between Paper and MR

Pair	Paper	MR
A	1	3
B	2	5
C	2	8
D	4	12
E	1	1
F	1	10
G	2	6

A series of the results suggests a higher potential compared to traditional paper worksheets, from the perspective of providing students with materials for understanding and reflection based on specific experiences that may be less visible on conventional paper worksheets.

5. CONCLUSION

In this study, we developed a practical class design for high school Information I, based on Kolb's experiential learning model, incorporating the characteristics of merging MR technology in real space and virtual environments. The network learning materials are developed for enhancing skill acquisition and knowledge understanding. The verification results suggest that the utility of these materials may be higher compared to conventional paper worksheets.

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