A Peer-Teaching Support System for Online Exercises: Prototype and its Evolution

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***Abstract*—Online exercises that deal with hardware, such as Internet of Things prototyping, have few convenient tools for students to share visual information on physical artifacts for peer-teaching. We proposed a peer-teaching support system "ShareHandy," which allows students to share videos of artifacts under development and point out areas of interest in real time using smartphones and PCs. We developed a prototype and applied it to an online Internet of Things prototyping exercise and verified its effectiveness for peer-teaching. As a result, the students could understand each other's problems and give appropriate advice efficiently and accurately. This proves that the system is effective for peer-teaching and improving the overall efficiency of the exercise. However, we found that it has little effect on promoting peer-teaching itself. Based on the findings, we defined the requirements for improved system necessary to promote peer-teaching in the exercises. This paper describes and evaluates the first protype of ShareHandy and provides the requirements for its evolution.**

Keywords-online education; peer-teaching; IoT exercise.

I. INTRODUCTION

Peer-teaching is a learning method for students to teach each other, gaining attention as a way to increase the effectiveness of student learning [2]. Recently, the COVID-19 pandemic has increased the number of online classes and exercises. However, such an online situation makes peer-teaching difficult because of the limited interactions between students [4]. One of the main reasons for this is that it is difficult for students to share the information on their physical artifacts under development visually. For example, in an online exercise where students learn to assemble the same electric circuit, they lose important peer-teaching opportunities, such as sharing one student's work with the teacher and other students, pointing out and giving advice to each other interactively, and reviewing the advised points after that.

To solve this problem, Dorneich et al. [5] provide several best practices to promote effective online team collaboration. Kitagami et al. [6] propose an exercise method of using a virtual camera to share camera images as well as documents, on one screen in a Web conference system, in which students watch the screen image transmitted by the teacher as they proceed with the exercises. However, this method does not allow students to see other students' artifacts while receiving teachers' transmission. Hamblen et al. [7] proposed a method for peer-teaching of hardware assembly in an asynchronous environment using a wiki. Students can interact with each other using the wiki, but only in a non-real-time manner.

We propose a peer-teaching support system "ShareHandy" to solve the problems mentioned above to ease online peer-teaching in a group of students. In the previous work [1], we developed a prototype of the system, which has several functions to share students' physical artifacts visually with each student's smartphone or Web camera: pointing at and drawing on the shared videos, saving the snapshot of the videos with the drawings.

This paper fleshes out the contents of the previous paper to provide detailed discussion, presenting the requirements for the peer-teaching support system, its design and implementation corresponding to the requirements, the evaluation of its usefulness by applying it to a group exercise of Internet of Things (IoT) prototyping held online, and the proposal of additional functions to promote peer-teaching like progress sharing and document pointer.

In this paper, Section 2 presents the details of our proposal system, Section 3 describes the experimental evaluation, results and discussion, Section 4 presents the requirements for its evolution, and Section 5 concludes this paper.

II. PROPOSED SYSTEM

To support peer-teaching in IoT prototyping exercises, it is necessary to have a support system for the students (and the teacher) to share the students' physical artifacts visually. The proposed system provides stream live videos of students' artifacts using their own smartphone or Web cameras, which they can point at and draw additional information on.

The following subsections describe usage scenarios of the proposal system, its functions, and how the functions can be utilized in the scenarios.

A. Usage Scenarios

The target exercise assumes a situation in which each student work individually on the same assignment and several small groups of students are organized for peer-teaching. The students can use the proposed system to discuss and teach each other in the group. In this situation, students may frequently switch their role between tutors (teaching) and learners (being taught).

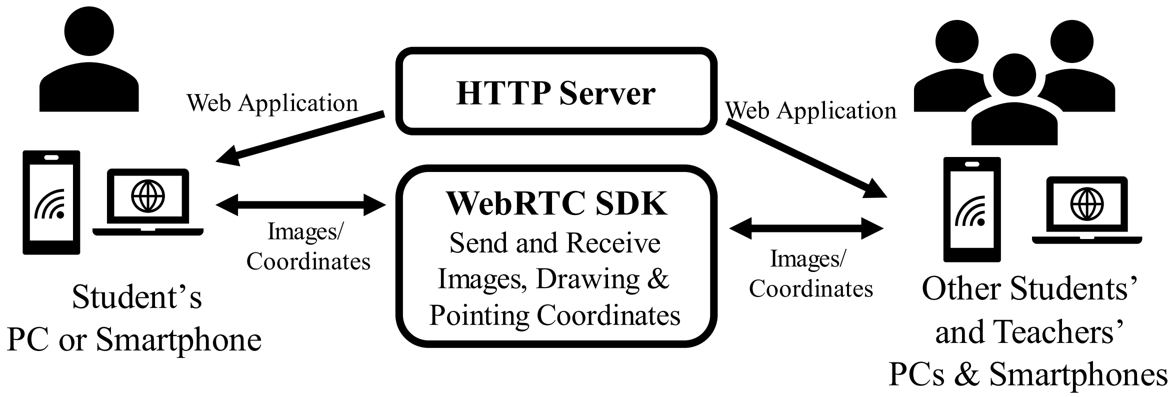

Figure 1. System Structure of ShareHandy

The proposed system is supposed to be used with the Web conferencing system, which handles document sharing and voice communication. The system helps the group members share video of their artifacts under development.

We assume the following usage scenarios of the system:

- Students who have successfully completed the assignment and those who have not finished yet, compare each other's artifacts to find out what to do for solving the problems the no-completed students have.
- A student asks the teacher of his questions, and a session is held to answer them. Some other students interested in the questions participate in the session, and the session proceeds on a question-and-answer basis.

B. Designed functions and how to use in the scenarios

We listed the designed functions and how it will work for above scenarios below.

1) Setting up rooms for group sharing

The system allows users to set up multiple rooms at a time so that users can easily have a space to discuss some topic, which other users can participate in freely when they are interested in the topic.

2) Real-time video streaming

Images of multiple students' work-in-progress artifacts are streamed in real-time by using smartphones or Web cameras attached to laptops. The system can display multiple videos simultaneously so that the students can see and compare each other's artifacts. This allows the tutors to convey, what changes are supposed to occur in each of the correct steps and allows the learners to explain what situation they are in and what their problems are. In addition, the system helps the users recognize the artifacts in 3D, which is not possible with documents or still images.

3) Pausing video and broadcasting still images

The video streaming can be paused to share as a still image. This allows the tutors to have enough time for detailed explanation at the key points and allows the learners to stop at their problematic points to ask for advises.

4) Pointing by participants

Each user has a cursor with a personal identifier, which can be placed at a specific position on the video image to indicate his or her point of interest. This allows the teaching student to clarify the focus points, explain the problems, and give instructions accurately. It also allows the person being taught to show the points to ask.

5) Writing and drawing by users

Users can write texts and draw figures on the streaming videos (including still images) using pointing devices. This allows the tutors to label related locations (e.g., initials and numbers) or to indicate directions by drawing arrows. In addition, the learners can leave notes to be shared.

6) Saving video captures and drawings as still images

Still images of videos with drawing can be stored on the user's device. This allows the learners to review the session afterward.

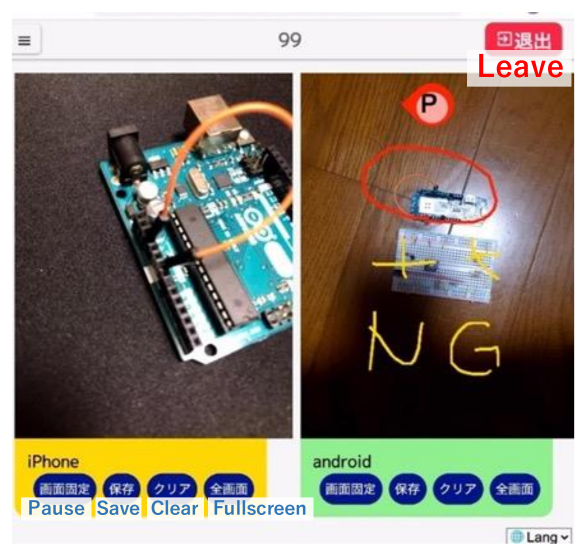

Figure 2. User Interface of ShareHandy and Demonstration

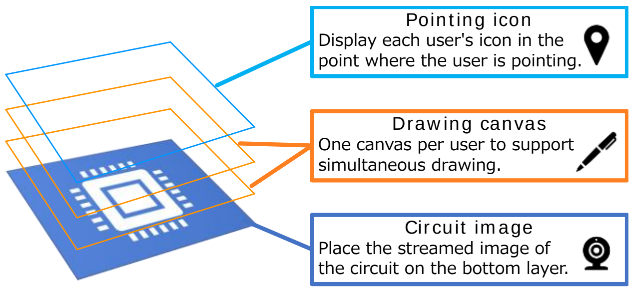

Figure 3. Layered Canvas Function

C. Implementation of the Proposal System

The proposed system has been implemented as a prototype first. The system structure of the prototype is shown in Figure 1.

The prototype is built as a Web application [8], which runs on a Web browser and has the advantage to support multiple operating systems with a single code. This allows it to work on devices like PCs and smartphones, in which users only are required to access a web page to use the application. Moreover, there is no need to install additional applications on the device.

As shown in Figure 1, we use WebRTC (Web Real-Time Communication), which is a platform to enable real-time communication of video, audio, and general data via a Web browser [9]. WebRTC communication allows the users to send and receive videos and images, coordinates of drawings and pointers, and other control signals in real-time.

Figure 2 shows an example of using the prototype in real. Three users participate in the session, and two members share videos showing their artifacts. On the left screen, the pointers of the users (shown with a “P” mark) and drawing data are displayed (shown with the text of “NG”). In this situation, the student shown green needs help, and yellow and red members help him. The drawing color and pointing color are the same as the nametag shown at the bottom of the videos, and students choose their color at the beginning of a session.

Table I. QUESTIONS ON THE QUESTIONNAIRE ADMINISTERED AT THE END OF THE EXPERIMENT

No.	Questions and Options
Q1	What is your position?
Q2	In what situations did you use the system? ・ Teaching each other in the group ・ Creating something with the group member ・ Teaching each other with one-on-one
Q3	Please answer the following questions in four choices: Agree, Almost Agree, Almost Disagree, or Disagree
Q3-1	It was easy to see the other person's hand.
Q3-2	Groupmates understood my situation right away.
Q3-3	I was able to work efficiently.
Q3-4	It was easy to communicate by pointing at the hand.
Q3-5	It lowered the barrier for teaching each other.
Q3-6	I would use this system again.
Q4	Any other comment (Free text)

To draw and point with some members simultaneously in real-time is difficult with one canvas, so we provide the drawable sections by overlaying multiple canvases on a video, which are the same number as the group members. This implemented as Layered Canvas Function, which keeps drawings and images independently and overlay them to display and save as an image, as shown in Figure 3.

III. EXPERIMENTAL EVALUATION

To evaluate the proposed system in Section 2, we conducted experiments by using online exercises.

A. Purpose of the Experiment

The following two research questions are set concerning the effects when students use the prototype in online exercises.

[RQ1] Does this system allow the tutors to convey correct steps quickly and accurately to be done on the artifact to the students taught?

[RQ2] Does this system enable group communication to be carried out smoothly, and as a result, it can promote peer-teaching?

We conducted experiments to investigate these research questions.

B. Method of the experiments

We conducted the experiments with following method.

1) Exercises to be applied

The prototype system is applied to the following two real online exercises, individual exercise and group project-based exercise. Individual exercise is the one following a sample procedure, where every student belongs to some group whose members will communicate within it. Group exercise is Project-based learning style one, in which each group develops a prototype to solve their problem.

2) Subjects' attributes and experimental procedure

We held the experiments with ten undergraduate students and four graduate school students. All subjects were students at Shibaura Institute of Technology and majored in computer science and engineering. We formed the subjects to small groups of three to four people, and we asked the groups to use the prototype freely during the exercises. We did not instruct where and how to use it.

3) Evaluation method

The subjects are asked to answer to several questions on a questionnaire after finishing the exercises. Their answers are analyzed to evaluate the results of the experiments. The questions in the questionnaire are shown in Table 2. In addition to this, the subjects are directly interviewed after the exercises.

C. Result of the Experiment

We received 14 answers from all the subjects. The results of the questionnaire are shown in Figure 4.

- Concerning the answers to Q3-1, 86% of the subjects answered positively to the question, “Was it easy to see the other person’s hand?” In addition, all the subjects felt positive about Q3-2, “The other person quickly understood my situation,” and Q3-4, “It was

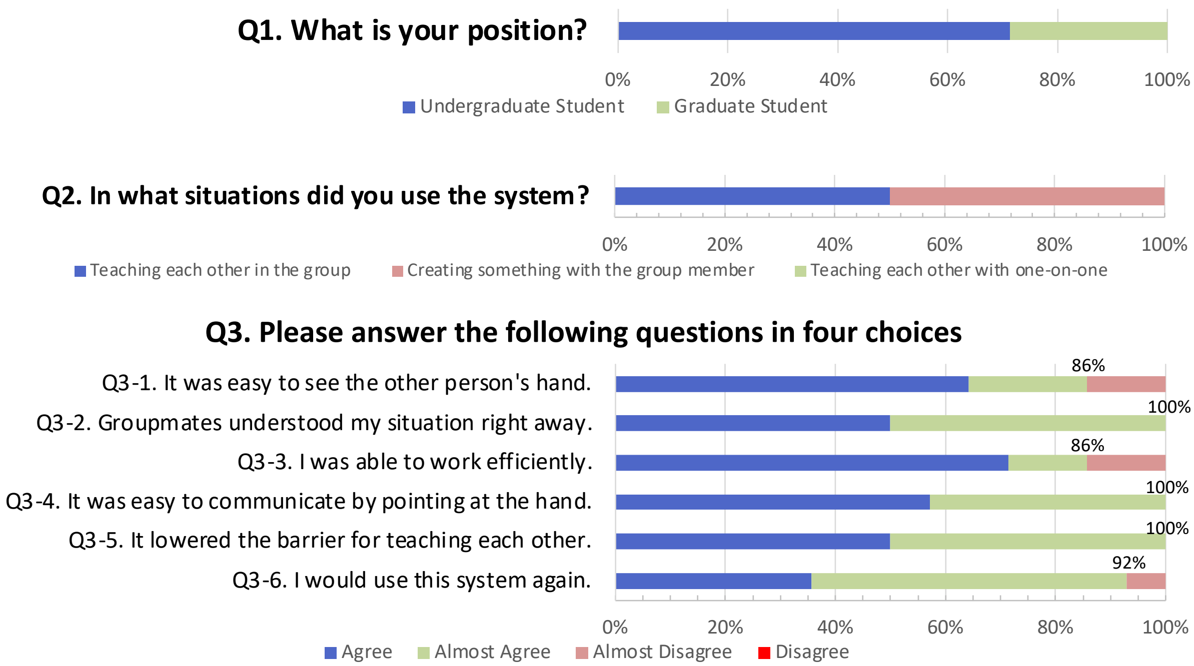

Figure 4. Questionnaire Items & Result of Answers

easy to communicate by pointing with my hand." Furthermore, 86% of the subjects answered positively to Q3-3, "I was able to work efficiently." From these results, we can confirm that the system works as expected and allows the subjects to convey instructions on artifacts efficiently and accurately.

- To Q3-5 of "It lowered the barrier for teaching each other," all the subjects answered affirmatively.

In addition, 92% of the students answered the question affirmatively if they would like to use this system again, suggesting that using this system is helpful.

From the interviews with the students after the experiment, we obtain the following points of their impressions and dissatisfaction.

Positive comments include:

- It is easy to understand how the artifacts are built because they can be easily seen, and their assembling steps can be understood well. (Answered from many subjects).
- Because group members can share their artifacts visually, it is easy to explain them. Some members used it to check if the correct sensor has been selected.

The second comment suggests that we can apply the proposed system to much broader things than we initially expected.

However, we have some negative comments:

- The screen of the smartphone is too small to see the screens of other participants.
- The camera does not focus well, and it is difficult to see small letters.

These comments suggest a need for improvement in both the prototype itself and how to use it (Issue 1).

D. Discussion of the result of the experiments

We found that the proposed system effectively achieves the effects that we targeted in the design of the system from the answers of Q3-1 to Q3-4. Therefore, the system allows all the subjects (including teachers and students) to share multiple hardware visually in real-time and help them communicate (RQ1). Moreover, based on the answers to Q3-5, it can be directly found that the system lowers the barrier for peer-teaching (RQ2).

The overall results from the answers to the questionnaire show the level of satisfaction in using this system is high. This is mainly because there is no other way for students to see others' artifacts and pointing at them in real-time other than the system.

However, the system has not been used often during the exercises, i.e., the frequency to use was lower than expected. Some student commented about it:

- The system is easy to use, but we did not have so many opportunities to use it.
- We did not have so many problems relating to hardware in IoT prototyping.

The main reason for it is that the IoT prototyping used in the experiments does not have so many complicated tasks relating to hardware to require someone's help.

In addition, we found from some interview results that online exercises tend to create an emotional distance between

Figure 5. Image of the prototype of Integrated ShareHandy

students because it does not provide the opportunities to know what the other students have done and are doing now (Issue 2). For this reason, many students are hesitant to ask questions of the other group members and instead possibly chose to solve the problems for themselves.

We concluded through the experiment that further system improvements are needed to reduce students' hesitancy to communicate online in order to close the distance between minds.

IV. IMPROVEMENTS OF THE PROPOSED SYSTEM

Through the experiments of the system, we obtained the results and identified the problems of the proposed system from the questionnaire and the interview. Among them, we focused on the following strategies to activate peer-teaching from the issues showed Section 4.

S1. Reduce emotional distance between members for peer-teaching.

S2. Improve usability [10] when using the system.

A. *Approach to improving the proposed system*

To settle the issues mentioned above, we are planning to develop "Integrated ShareHandy" that comprehensively supports peer-teaching in online exercises. This improvement aims to increase the frequency of use of the system by groups of students by reducing emotional barriers to communication.

For this goal, we set the following additional use case:

- Students who have completed the exercise and students who are stuck on some problems use the system. They go through the exercise to follow the tutors' steps to check each other's work done step by step.

B. *New functions to reduce the emotional distance*

This subsection describes three functions to be required for Integrated ShareHandy.

1) *Sharing exercise documents*

Function: All users share referenced documents, which they can compare it with the video of their artifacts, drawing on and pointing at the documents.

This function is expected to enhance the effectiveness of peer-teaching by allowing all the users being taught simultaneously to see the same document to compare it with their artifacts to find out the problems. This also aims to improve the understanding of those being taught.

2) *Sharing the progress*

Function: The system collects and displays students' progresses.

This function helps students notice some others' delay in progress in the group early, providing them for the opportunities for peer-teaching. The students to be supported can recognize who can help, asking them for support. They can also recognize who has the same level of progress, calling for teaching each other to solve the same problems. In addition, students to provide support can recognize students who probably need help, actively giving offer support to them (S1 in Section 4). We believe that this will increase the frequency to use the system for peer-teaching.

As the other effect of this function, it enables teachers to check students' progress to provide appropriate support.

3) *Authentication for students*

Function: Users can link their multiple logins under their own account IDs to participates in a meeting.

This is convenient when one user logins with multiple devices to participate in a meeting, such as a smartphone for

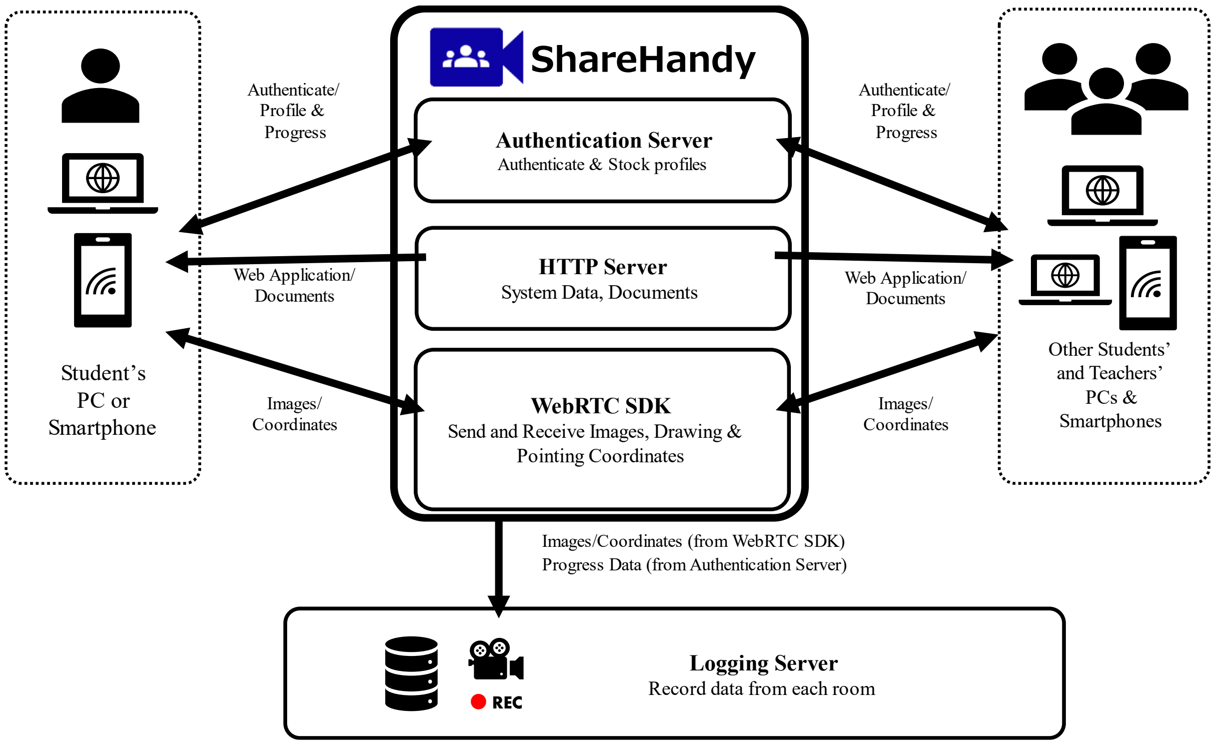

Figure 6. System configuration of integrated ShareHandy

camera functionality only and a PC for viewing and pointing out documents and images (S2 in Section 4).

We will add these three functions in Integrated ShareHandy. Figure 5 shows a prototype image of the Integrated ShareHandy. In the part of 1), users can share exercise documents. In the part of 2), each student's progress is displayed with a donut board over his/her icon as well as numerical value of percentage. This part also shows the name of the document his/her being viewed when the exercise uses multiple documents. In the part of 3) of Section B, the name of the user is displayed, which Authentication Server enables it.

C. *Implementation of added functions*

By implementing these additional functions, we made a few changes to the system configuration, shown in Figure 6.

Firebase was selected to authenticate users and share progress for additional functionality. Firebase are used as not only an Authentication Server but also a Realtime Database server, which stores data that is not handled in a real-time manner like user profiles and progress.

A web application through which students can access documents referred has been implemented.

A computer special for logging will connect to each room, which analyzes audio, video, point locations, and progresses to record users' status and operations when using ShareHandy. The logging system is designed as an independent program from ShareHandy. This is because WebRTC is basically used with Peer-to-Peer network not allowing a host server which can summarize the data for logging. These logs will be used to evaluate the effects and problems of the system on peer-teaching.

D. *Evaluation methods for system and peer-teaching*

We plan to evaluate Integrated ShareHandy in two steps.

The first step is to measure the System Usability Scale (SUS) score. SUS is a tool that is widely used for the evaluation of both hardware and software consideration and its scale measures ten questions, which answer with a five-point Likert scale. Through a questionnaire survey to assess whether the system is sufficient enough to conduct peer teaching, where the SUS score of the system must be more than seventy when the system is considered easy-to-use [11].

After confirming that the system clears the criteria, experiments will be conducted to apply this system to real exercises as the second step. In the step, how to evaluate the activation of peer teaching is important. We believe that it is necessary to compare cases where the improved system is used, where the previous system used and those where it is not used, and thereby to analyze how and how much peer-teaching has been promoted under a quantitative index to investigate the effectiveness of the system for peer-teaching.

To do so, we will use the system record, such as:

- audio and video,
- history of drawings and points,
- students' progresses, and
- the number and the time of teaching sessions

to analyze how peer-teaching took place and how the system effect on it. Also, conversation time other than peer-teaching can be an indicator to check the effect of reducing the emotional barriers.

E. Compare functions between some major systems

We compare main functions to use for exercise between major online meeting systems. Most of major systems like zoom and Microsoft Teams cannot point and draw to video without using screen-sharing, and no way to see the point where members are reading of document. One weakness of the proposed system is that teacher must upload documents to server, and it takes much work than to distribute documents by other system.

V. CONCLUSION

We proposed a peer-teaching support system for online exercises, ShareHandy, which can be used in the context of IoT prototyping where hardware assembly is handled. The system allows students to share videos of artifacts under development and point out areas of interest in real time using smartphones and PCs. Experiments to evaluate its usefulness in improving peer-teaching in online exercises had positive results, suggesting that the system is effective enough to support group work and peer-teaching. However, the frequency to use the system is lower than expected, and it is found that the system is not effective enough in promoting peer-teaching.

Based on the analysis, we planned to develop "Integrated ShareHandy" that comprehensively supports peer-teaching in online exercises, which supports sharing not only their physical artifacts visually but also referenced documents and students' progresses, enabling them to know who can help and work together to activate peer-teaching.

The future work includes to find an effective way to use the system in online exercises and to improve its usability not discouraging its use in pee-teaching. In addition, we will apply the system to more types and number of online exercises and will improve the system for effective peer-teaching.

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