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The Effect of Shared Display Collaborative Mind Tools on One-to-one Collaborative Learning

Chen-Wei CHUNG[a*], Chih-Chung LEE[b], Chen-Chung LIU[b]
[a] Digital Education Institute, Institute for Information Industry, Taiwan
[b] Graduate Institute of Network Learning Technology, National Central University, Taiwan
*jerryjong@gmail.com

Abstract: Most collaborative mind tools are applied in asynchronous learning contexts. In other words, these tools can support students in joint construction of knowledge through the Internet. However, face-to-face collaborative learning may pose new challenges for the design of collaborative mind tools. For example, without a proper arrangement of learning devices, the control of a mind tool may be limited to a single member and this may reduce willingness on the part of other students to share their personal opinions and this may in turn impede the group learning process. This study has adopted a shared display mind tool combining shared display with a one-to-one learning environment to help students engage in collaborative mind activities. The participants were nine graduate students who enrolled in the course “Learning, Collaboration and Creativity" in a middle-sized university in Taiwan. By analyzing activity logs and video, it was found that the shared display mind tool could facilitate information exchange and sharing. This tool can also help students establish shared visual focus and attract the attention of group members. In addition, it elicits ideas from each individual and inspires new search directions, thus enhancing the elaboration of knowledge for new understanding.

Keywords: One-to-one collaborative learning, shared display, collaborative mind tool, peer interaction analysis

1. Introduction

Computer mind tools have been widely applied in supporting teaching and learning [6][8]. It has been shown that mind tools such as CmapTools [5] and Knowledge Forum [13] can help students to organize, judge and link information and knowledge and thus are helpful in improving high order abilities such as critical thinking and problem solving [16]. When such mind tools are applied in collaborative learning, they can promote the externalization of knowledge by facilitating students in judging, linking, and negotiating their own knowledge in a way which develops new understanding of knowledge.

Most collaborative mind tools are applied in asynchronous learning contexts. In other words, these tools can support students in jointly constructing knowledge in non-realtime through the Internet. For instance, Knowledge Forum [13] can facilitate students to exchange resources and ideas in support of collaborative knowledge construction. However, face-to-face collaborative learning may pose new challenges for the design of collaborative mind tools. For example, without the proper arrangement of learning devices, control of a mind tool may be limited to a single member and this may reduce willingness on the part of other students to share their personal opinions, which may in turn impede the group learning process [1]. Furthermore, collaborative learning involves both individual and group activities and would also include rapid transitions between the two activities [10]. For instance, students need to collect and organize information individually and then use the collected information in group discussion to advance their understanding. If the mind tool is used in a shared computer setting where all group members share only a single computer, individual students do not have the opportunity to conduct work independently and develop their own ideas. Therefore, in a face-to-face collaborative learning activity, individual workspaces are needed to support learning autonomy in order that students can generate their own ideas separately and then contribute those ideas in group activities [3].

One-to-one learning environments, which refer to the 1:1 ratio of computing devices and students in educational settings, can potentially address the above-mentioned issues. In such learning environments, each student can use the collaborative mind tool through his/her own computing device. For instance, Zurita & Nussbaum [17] and Manlove, Lazonder, & Jong [11] applied handheld devices in assisting students to perform collaborative learning activities. With the help of the personal computing devices, the group could be more productive due to better communication and interaction. However, individual work and group work taking place during collaboration often occur in parallel. This may impede collaborative learning due to a decrease in activity awareness [14]. More specifically, as each student works only with his/her personal computing device, some group members may not be aware of the learning activities of their partners because of the lack of a visual workspace in a collaborative activity [9].

Shared displays may be used to provide a shared visual workspace in the one-to-one learning environment. The groupware used with shared displays [4, 5] can facilitate collaboration by promoting shared understanding of the workspace and an increasing awareness of partner action, as participants can get close to one another's centre of visual focus with the shared display [14]. At the current development stage, shared displays are applied increasingly to support cooperative work. However, it is still not clear that how these collaborative mind tools, incorporating shared displays in a one-to-one learning environment, may influence collaborative activity.

In response, we conducted a study to investigate student interaction and discourse in the use of collaborative mind tools with the shared displays and personal handheld devices. In order to get a better understanding of student interaction, both verbal and non-verbal communications were analyzed. The former can reveal the detailed processes involved in shared cognition while the latter play an important role in face-to-face communication. For example, eye contact is commonly used as an expression of intention to transmit information to another person and hand-pointing behaviors indicate the direction of attention during human communication [7]. These non-verbal cues are important factors in understanding how students interact when exchanging knowledge [12]. Therefore, this study aims to explore the effect of shared displays and personal handheld devices on face-to-face collaborative learning by answering the research questions below:

1. How may the shared displays facilitate information sharing during collaborative learning in one-to-one learning environments?

2. What role do the shared displays play in non-verbal interaction among group members?

3. How do the shared displays affect verbal interaction among group members?

2. Method

2.1 Participants and the collaborative activity involved

The participants were nine graduate students enrolled in the course "Learning, Collaboration and Creativity" in a middle sized university in Taiwan. Because one of the major goals of the course was to develop collaborative skills in students, they were required to solve open-ended problems collaboratively. To achieve this goal, they were to search the Web and collaborate with each other in forming their individual perspectives of the problem in order to advance their understanding of the problems. During collaboration, students were required to explore all possible solutions to the assigned problems and then to discuss them with each other to achieve a shared understanding. Therefore, sharing information found on the Web and exchanging perspectives with peers were essential during their collaboration.

The nine students were divided into three groups of three, each of which had to generate a perspective on some open-ended problems. The three groups each took part in two collaborative activities. In one of these, the student group used a collaborative mind tool without shared displays (Non-SD) (described later) to explore an open-ended problem: "constructivist approach toward mathematics in Taiwan." In the other collaborative activity, the students utilized a shared display collaborative mind tool (SD) (described later) to investigate another open-ended problem: "low-price computers for education in emerging markets." The students were to explore possible issues and solutions by accessing resources on the Internet. Neither of the two problems has a well-known answer at present. Therefore, an analysis of student interactions during the two collaborative activities could help obtain a better understanding of the effect of the two collaborative mind tools.

Each collaborative activity took 3.5 hours including 0.5 hour for introducing the problem's background and the learning activities. During the collaborative activities, students used their own laptop computers to work on the problems, on which were installed the collaborative mind tools. For instance, group members used their laptop computers to search the Web for material related to the given problem. At the same time they could exchange and share search results with each other using the group mind tools. All collaborative activities and discussions were videotaped by three video cameras on the ceiling for subsequent analysis.

2.2 Collaborative mind tools

To achieve a better understanding of the roles played by the shared displays and handheld devices in collaborative mind tools, this study investigated student interaction assisted by two such tools: one designed based on the shared display (SD) and the other which did not provide a shared display (Non-SD). Both designs used handheld devices as an individual workspace to participate in the learning activity enabled by the collaborative mind tools.

In this study, the collaborative mind tools were used to support exploration activities on the Web. Therefore, they had to assist students in exchanging and sharing search results so that those students could join together to reflect upon the information they had found on the Web. To achieve this goal, this study developed two collaborative mind tools based on mind maps to facilitate such collaboration activities. The mind maps were applied because the use of knowledge maps can improve the quality of argumentation among participants in collaborative learning environments [15]. More specifically, the mind maps functioned as the main workspace in which all participants could amalgamate web search results to reflect upon their own understandings of the problems.

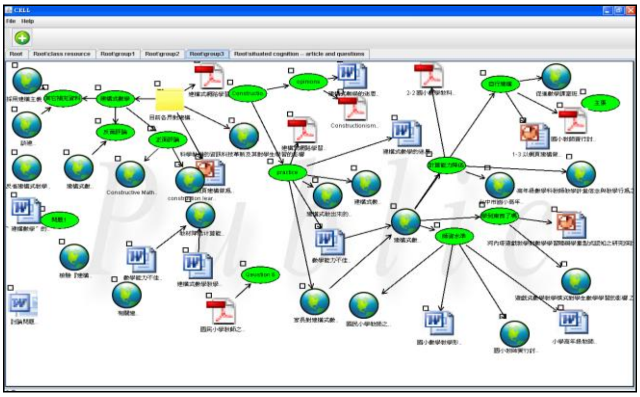

Figure 1. Diverse nodes on the group mind map

Both the Non-SD and SD collaborative mind tools were client/server groupware applications. Figure 1 displays the collaborative mind map constructed by a student group during the collaborative activity. The two mind tools enable students to work individually and collaboratively in the following ways:

- Individual search: Each student can search the Web freely using a personal laptop computer and can contribute any type of web search results as reference nodes to the collaborative mind map. The reference node may include web pages (shown as earth icons), and any type of document files (such as MS Word, MS PowerPoint, and PDF). Each student drags the web search result nodes from his/her laptop computer onto the group mind map.
- Exchange of web search results: Students can easily exchange and share web search results with their peers. They access the shared web search results through their personal mobile computers by double-clicking the web search result nodes on the group mind map.
- Integration and reflection: Students can organize and integrate information collaboratively by performing group mind mapping activities. When they read the web

search results, they can propose an issue, position or argument node (shown as an oval icon) on the group mind map to decompose the exploration topic. Students could also propose ideas on specific web search results by adding a comment node (shown as a square icon) on the collaborative mind map, or propose diverse ideas on a comment node added by others, which led them to further develop a shared understanding, refine a concept, or generate a new idea. In the meantime, students can clarify the relationship between these resources (i.e. web search results, concepts, and comments) on the group mind map by linking these resource nodes.

The Non-SD and SD collaborative mind tools have a different design in terms of the usage of the shared display. Therefore, a comparison of the interaction between students can be made to explore the influence of shared displays on collaborative learning. More specifically, the Non-SD collaborative mind tools allowed the students to perform mind mapping activities only on their own laptops. In contrast, the SD collaborative mind tool contained a shared display with which students could work together on their mind maps while also individually editing the mind map with their own laptop computers. Each group took part in the exploration activities with both the Non-SD and SD collaborative mind tools, therefore, a total of six collaborative mind maps were generated by the three groups. Their mind mapping behaviors with the collaborative mind tool were logged. The log files and the mind maps were analyzed to reveal the effect of shared displays on collaborative learning.

3. Results and discussion

3.1 The effect of students' visual focus

We were interested in how eye contact affected collaborative learning. This study analyzed video and activity logs generated during collaborative learning. It was found that group members discussed their teamwork in depth though the shared display. At the same time, group members modified the content of their proposed nodes and uploaded new search results on the shared display. For example, figure 2 shows that all group members looked at the shared display to discuss their group work. Such discussion demonstrated that they were elaborating their understanding of the problem. It also found that members B and C viewed position nodes 2 times and proposed 2 argument nodes which they then modified 4 times. The result reveals that shared visual focus in the discussion was helpful in eliciting the ideas of each individual.

[1] C: (gazing on the shared display) the difficulty/problem of teacher is that the quality of teaching skills which literally affected the learning effectiveness of students. Therefore, the competence of teachers should be raised up in order to promote 12-year compulsory education.
[2] A: (gazing on the shared display) I believe that the teaching skill is not only focus on their education level but should include the professional proficiency as well.
[3] B: (gazing on the shared display) the level of teaching skills.
[4] B: (gazing on the shared display)(hand pointing at the shared display) Yes, exactly, taking education background for instance, the qualification for being a teaching is just passing the examination to acquire the teaching certificate, thus, some of campuses have staff teaching subjects they are not qualified to teach. For example, Math was the subject most commonly taught by teachers not fully qualified in the area, followed by information technology, computer science, psychology and languages. That is because of a shortage of secondary teachers, schools often had little choice but to assign staff to teach areas they had not studied; therefore, I think, teachers should generally qualify for the role by having strong professional credentials and formal training rather than a teaching certificates.
[5] A: (gazing on the shared display) because one of important point is .....
[6] B: (gazing on the shared display) accordingly, teaching skill is the most imperative essence in the teaching education.
[7]A: (gazing on the shared display): the teaching skills are including professional proficiency as well as their education background.

Figure 2. The students' conversation is elaborative knowledge

To get better understanding of how Non-SD and the SD environments affected the eye contact of group members, this study analyzed the activity video and counted the number of eye contacts within a group. The result is shown in Figure 3. In Figure 3, each circle represents a group member and the number on the solid arrow represents eye contact frequency between one member and another. The number on the dotted arrow represents the frequency with which one member watched another member's laptop computer. For example, in Figure 3a, member A engaged in eye contact with member B 68 times and looked at member C's laptop computer 71 times.

It was found that the shared display promoted eye contact between group members. For instance, the total eye contact frequency count in the SD environment (500 times in Figure 2d and 663 times in Figure 3e) was significantly higher than that of the Non-SD environment (301 times in Figure 3a and 418 times in Figure 3b). Previous studies pointed out that an instance of eye contact is commonly used as an expression of intention (Gomez, 1996), especially when eye contact functions as an important confirmation cue in face-to-face collaborative learning. The result showed that the shared display increased the instance of confirmation in face-to-face learning. It was supposed that when group members discuss group work on the shared display, they often confirmed the intention of others through eye contact. It was also found that the shared display promoted exchange of information by enabling members to watch each other's computers. The number of instances of watching the computers of others and the shared display under the SD environment (318, 149 and 217 times, respectively) was higher than that of the Non-SD environment (290, 49 and 172 times, respectively). Notably, instead of watching computers of other members, the three groups watched the shared display more frequently (229, 88 and 208 times, respectively). The result shows that the shared display can help to establish shared visual focus and further promote confirmation between group members in achieving exchange of information. Such exchange of information can explain why shared visual focus could help to elicit ideas from each individual and inspire new search directions.

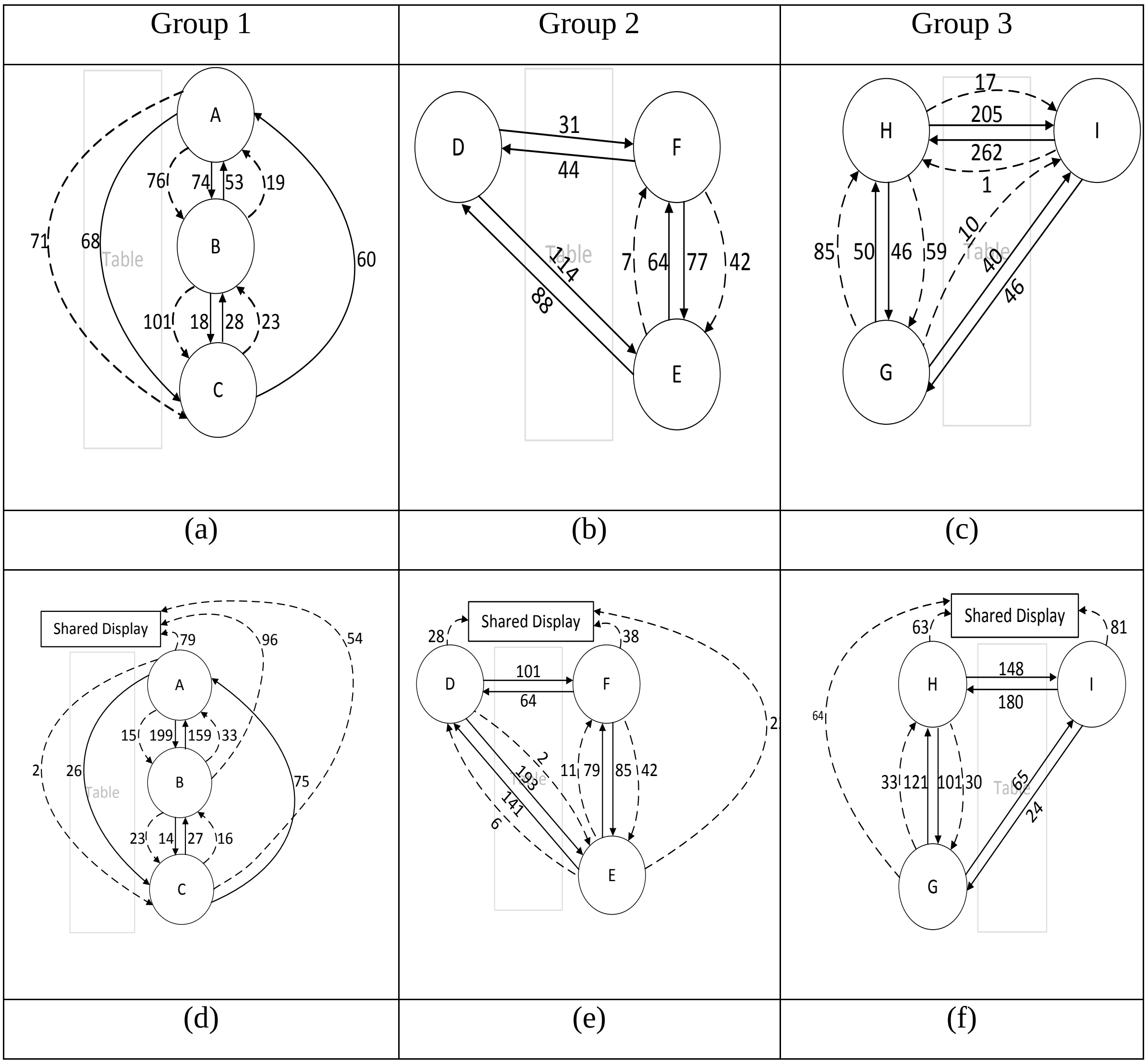

Figure 3. Students' eye contact in Non-SD (a-c) and SD (d-f) environments

Watch group member

Watch shared display or device

This study also analyzed the activity video and counted the number of hand-pointing occurrences within each group in order to understand how the Non-SD and the SD environments affected hand-pointing behavior. The result is shown in Figure 4. The number on the solid arrow represents the frequency of hand-pointing between one member and another. The number on the dotted arrow represented the frequency with which one member pointed at another member's laptop computer. For example, in Figure 4a, member A pointed at member B 2 times and pointed at member C's laptop computer 5 times.

The hand-pointing frequency of individual devices under the Non-SD environment was 32, 0 and 70 respectively (Figure 4a-c) and that of the SD environment was 45, 15 and 48, respectively (Figure 4d-f). It did not show a significant difference between the two environments. Interestingly, it was found that the hand-pointing behavior shifted from pointing at one another or pointing at another's laptop computer to pointing at the shared display. The result showed that group members tended to use the shared display to discuss and organize group work instead of working on their personal devices. It also revealed a change of attention during collaborative activities. Hand-pointing represents the direction of attention during human communication [7]. Within the SD environment, students often focused on the shared display rather than interacting with each other via their personal devices. Our study showed that the SD environment can shift attention to group work, which is helpful in improving group performance.

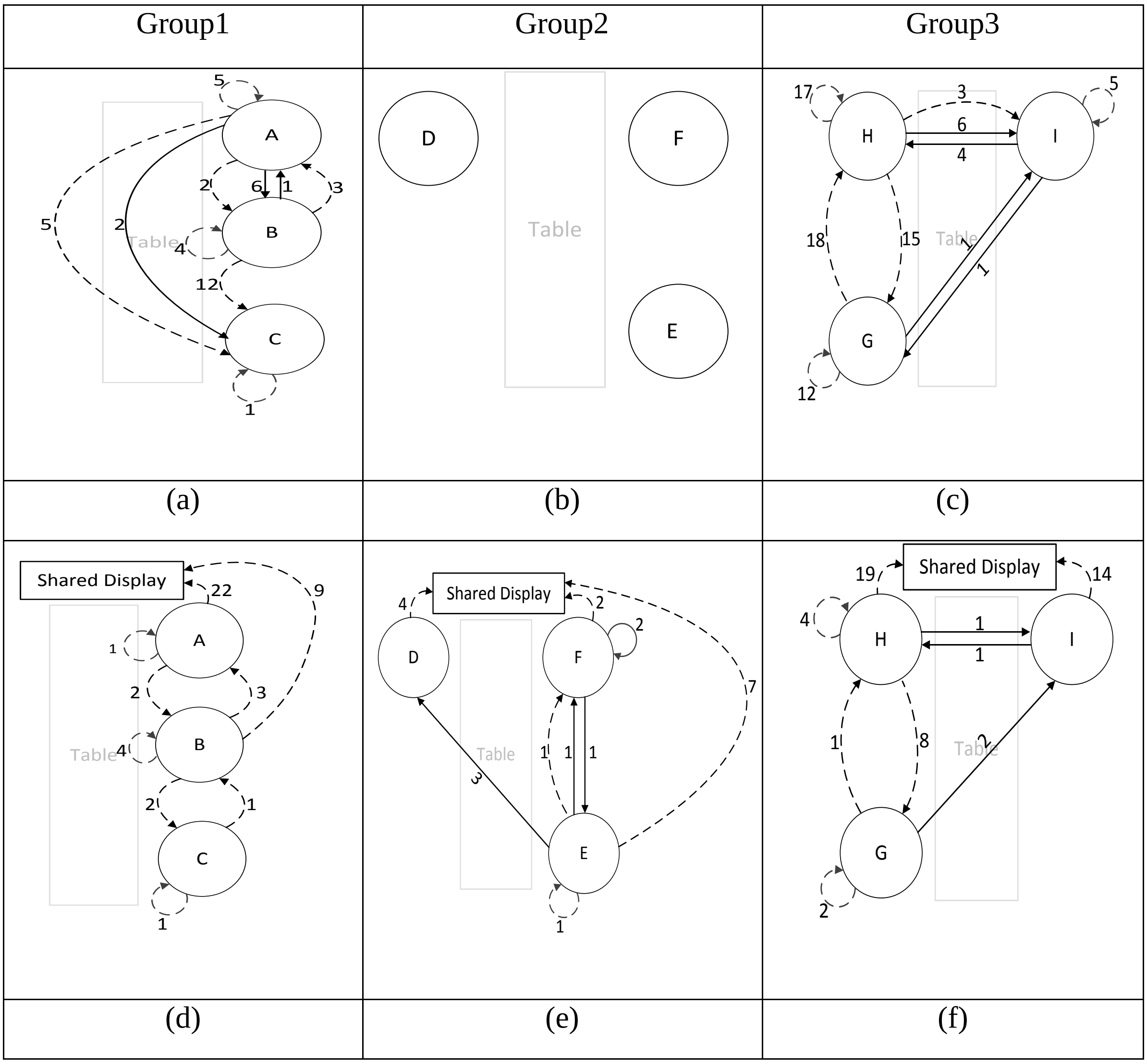

Figure 4. Students' hand-pointing behaviors in the Non-SD (a-c) and SD environments (d-f)

Point at group member

Point at screen

Table 1. The counts of students' conversation utterances under the Non-SD and SD environments

	Procedure discussion	Searching	Document explanation	Group argument	Group decision-making	Total
Non-SD	307(24%)	97(8%)	169(16%)	510(40%)	153(12%)	1236
SDG	159(12%)	28(2%)	158(12%)	803(59%)	210(15%)	1358

Besides investigating the effect of a shared display upon computer-mediated communication and non-verbal interactions, we also tried to analyze students' conversational utterances to reveal how group members developed collaborative strategies. In the activity video, we found five main types of conversational utterances during collaboration. Table 1 shows the counts these. There was no significant difference between totals of conversational utterances within the Non-SD and SD environments (1236 and 1358, respectively). However, there were clear differences in the character of conversational utterances between these two environments. Group members produced more instances of procedural discussion and searching within the Non-SD environment (307 and 97, respectively) than those in the SD environment (159 and 28, respectively). However, they produced fewer instances of group argument in the Non-SD environment (510) than in the SD environment (803). The result shows that group members often questioned procedure and search results during activities rather than focusing on group arguments within the Non-SD environment. This suggests that the shared display can enhance activity awareness and thus reduce the number of conversational utterances dealing with procedure discussion and searching. This finding is consistent with the eye contact and hand-pointing analysis. The shared display shifted more attention to group work during the discussion, so members spent less time describing their work status and search results and more pursuing group argument and elaborating knowledge interactively.

4. Conclusion and Implications

Many researchers contend that mind tools can improve high order thinking in students and improve the acquisition of new understanding of knowledge. Therefore, this study adopts the shared display mind tool, combining a shared display with a one-to-one learning environment to help students engage in collaborative mind activities. By analyzing the activity log and video, it was found that the shared display mind tool can facilitate information exchange and sharing. The shared display mind tool can also help students to establish shared visual focus and to attract the attention of group members. It further elicits ideas from each individual and draws out new search directions to enhance the elaboration of knowledge for new understanding.

The results of this study show that the shared display mind tool can help students conduct collaborative mind activities, but due to the limited number of available devices, only nine subjects were enrolled in the experiment. A future study will involve a large number of subjects to confirm the effect of shared display upon collaborative mind activities. The current subjects were graduate students. Future studies should use students with different knowledge levels to reveal how the shared display mind tool can provide assistance to a wider range of collaborative mind activities. In addition, the shared display may also be applied to other fields of knowledge. These new findings can also be provided to the designers of learning systems to aid them in improving their current design of collaborative mind tools and curriculum design in the classroom.

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