Are One-to-One Computers Necessary? An Analysis of Collaborative Web Exploration Activities Supported by Shared Displays

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ABSTRACT

Collaborative web exploration, in which learners work together to explore the World Wide Web, has become a key learning activity in education contexts. Learners can use a shared computer with a shared display to explore the web together. However, such a shared-computer approach may limit active participation among learners. To address this issue, this study proposed to use one-to-one (1:1) computers, connected to the shared displays through a groupware, to facilitate the collaborative tasks. This study analyzed the exploratory activities and discussion dialogues obtained when students were exploring the web with the shared computer and the 1:1 shared-displays. The results show that with only shared computers student discussions did not coherently facilitate the group to judge information or make group decision. On the contrary, when using the 1:1 computers with the shared displays, students collected and surveyed richer information on the web. The approach could support students to take part in individual exploration and join the group activity based on their individual exploration. Compared to the shared-computer approach, students demonstrated a more elaborative discussion patterns in which students clarify and self-reflect upon the information they found to judge the value of the information and make group decision.

Keywords

One-to-one, Shared display, Interaction pattern, Collaborative web exploration activities

Introduction

Collaborative learning has gained significant attention to improve student learning in educational approaches (Dillenbourg & Traum, 2006; Liu & Lee, 2005; Zurita & Nussbaum, 2004). Among various scenarios of collaborative learning, collaborative web exploration, where learners work together to explore the Web, has become a key learning activity in educational contexts because it facilitates learners with greater access to various information and greater opportunities to learn collaboratively with peers (Lee, 2005; Morris & Horvitz, 2007). Such collaborative learning activities often takes place in various situations, such as problem solving (Kuiper, et al., 2009), learning in the library (Twidale, Nichols, & Paice, 1997), proposal planning (Morris, 2008) and school coursework (Amershi & Morris, 2008; Morris, Lombardo, & Wigdor, 2010). Learners could thus experience knowledge restructuration by exploring, sharing and discussing information and thoughts (Paul & Morris, 2009).

Due to the educational benefit of the collaborative web exploration, various designs of face-to-face web exploration groupware that support learners to search the web information together was proposed. With the facilitation of groupware, learners can share their search results and work together on the results to collaboratively solve problems (Amershi & Morris, 2008; Aneiros & Estivill-Castro, 2005). Such a groupware is based on shared-display design, which means users could simultaneously use of easy input devices such as computer mice to collaborate in a shared computer with a single shared display (Stewart et al., 1999; Morris, Paepcke, & Winograd, 2006; Ryall et al., 2004; Scott et al., 2003). For instance, in the study by Ryall et al. (2004), Morris et al. (2006), they utilized a shared computer with an interactive table with multi-touch function to support face-to-face collaborative web exploration. Such a shared-display approach could promote the shared understanding of the task among learners (Liu & Kao, 2007, Liu et al., 2009) and increase the awareness of members' work status (Dietz & Leigh, 2001; Morris, et al., 2010).

However, previous study by Issroff and del Soldato (1996) indicated that the shared-computer approach may limit active participation among group members due to the lack of control on the shared computer. Moreover, the web exploration activity is a complicated cognitive process involving various exploratory activities, such as information of searching, clarification, judgment, and reading (Hill, 1999; Tu, Shih, & Tsai, 2008). In other words, the collaborative web exploration activities are a complicated activity dynamics including individual and group activities. Hence, the limited accessibility of the shared computer impedes learners to integrate their search results

with the group exploration activity (Amershi & Morris, 2008). As a result, the learners may not be able to extend to broader scopes of perspectives through the collaborative web exploration activities. Moreover, such a lack of accessibility can make members frustrated toward interaction because some learners will dominate the searching activity and ignore other member's ideas (Amershi & Morris, 2008). Hence, there is a strong need to provide an effective mechanism which supports all learners to cohesively explore on the web together. In other word, the mechanism can not only accommodate individual needs, but also facilitate the whole group to explore the web.

One-to-one (1:1) computers such as personal laptop computers, smart phones and tablet PCs may be used to address the above issue. Such mobile computers interconnected by a wireless network can be applied to improve coordination, communication, organization of materials, negotiation and interactivity in classrooms (Zurita & Nussbaum, 2004). Several studies had proposed innovative systems to support collaborative web exploration with the 1:1 computers. For instance, WebSplitter (Han et al., 2000), CoSearch (Amershi & Morris, 2008), and CoSense (Paul & Morris, 2009) enable group members to use such 1:1 computers to conduct search activities on one shared computer. However, in such a 1:1 approach, it was difficult for learners to share information and be aware of other members' work status because learners may be overly pre-occupied with their computers (Liu et al., 2009). This may interfere with social interaction that is necessary for building mutual understanding (Amershi & Morris, 2009; Liu & Kao, 2007).

Due to the aforementioned limitations of the shared-computer and 1:1 approaches, this study thus proposed a 1:1 shared-display approach to resolve the limitations. With the 1:1 shared-display approach, each member can utilize 1:1 computers to search and read web resources, while collaborating with others members on the shared display to explore the web collaboratively. It is hoped that learner's individual exploration and group interaction during the web. However, the group dynamics is complex when both shared-displays and 1:1 computers were applied. Therefore, it is necessary to analyze the influence of the 1:1 shared-display approach on individual and group activities. Previous study by Lee (2010) has investigated the influence of the shared display on the collaborative web exploration. However, whether the 1:1 computers are necessary to implement an effective collaborative web exploration activity and how the 1:1 computers may influence such an exploratory activity is still not clear. To this end, this study conducted an empirical study to examine how the learners collaboratively explore the web in the 1:1 shared-display approach by answering the following research questions:

- Do students take different exploratory activities when they explore the web with 1:1 computers?
- How the 1:1 computers may influence students' discussion process?
- What are the benefits of using 1:1 computers with shared displays to support collaborative web exploration?

Method

Participants and the exploration activity

This study conducted an experiment to investigate how shared-computer and 1:1 shared-display approaches influence the collaborative web exploration activity. The participants were nine graduate students from a course entitled 'The theory and practice of mobile learning' at a university in Taiwan. Two of the participants were female while the others were male. The students were divided into three groups of three. Each group took part in two collaborative web exploration activities to answer specific questions given by the teacher. The questions involved in the two activities were "how mobile technologies can be applied to support learning?" and "how groupware can be applied in classroom learning contexts". The teacher firstly introduced the background of the two questions. To obtain an answer to the questions, the students then had to 1) search for related studies, 2) analyze pros and cons of collected information, and 3) propose suggestions of future development. By the end of activity, each group had to present their conclusion to the class. Each activity lasted three hours. The students used different approaches to explore the answers of the questions on the web.

Instruments

The shared-computer and one-to-one shared-display approaches

The shared-computer and 1:1 shared-display approaches were used to facilitate the above activities (shown as Figure 1 and 2). The two approaches were both equipped with a shared display groupware which involves a shared

computer and a shared display. The groupware was developed by Liu et al. (2010). The shared display groupware provides a mind map as the interface for each group to share exchange and link information they found on the web because mind maps are helpful to promote the integration and evaluation of information (Liu et al., 2005). The mind map support exploration with several components detailed below:

- Concept node: learners can add a concept as a node to indicate the keywords they used to search the web.
- File node: System supports learners to store information they found in different file types, such as PDF, Word, Notepad, Image and Webpage.
- Comment node: Learners can summarize, reflect upon the information they found by adding a comment node in the mind map.
- Links: Learners can link any two nodes of any type that they consider to be related.

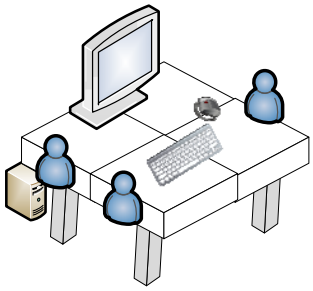

Figure 1. The shared-computer approach

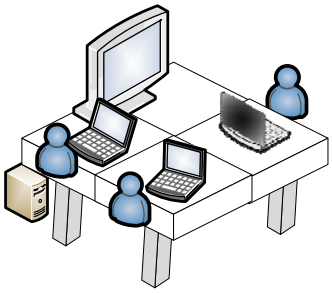

Figure 2. The 1:1 shared-display approach

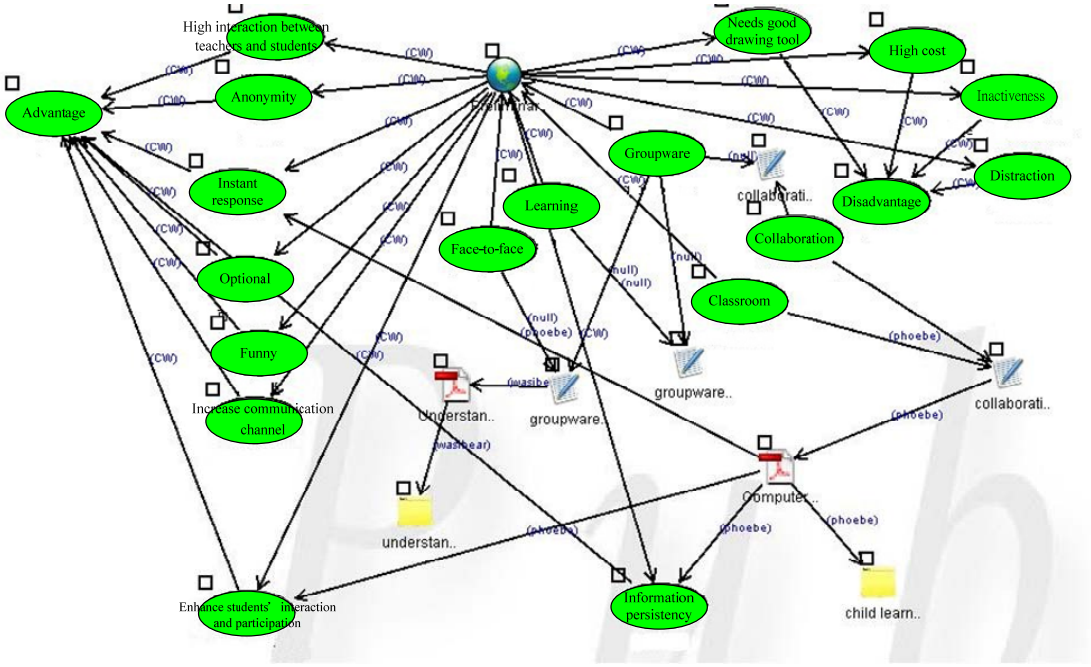

Figure 3. A mind map developed by a student group while exploring the web

Figure 3 shows an example of such a mind map generated through the groupware. The group firstly searched for information on the web and found an important web page (the earth icon). From the page, they extracted important concepts indicated by this page and inserted these concepts onto the map (green ovals). By search with these concepts, the students group further found two papers (PDF icon). After reading the two papers, they wrote down comments on the two papers (post-it icon). Because the map displays all the steps that the students took to explore the web, it could help us to understand group exploratory process in the two approaches. In both of the two approaches, the students could use the groupware. The only difference between the two approaches is that the students could use their own laptop computers to operate the groupware in the 1:1 shared-display approach while they could only use the groupware through the shared computer in the shared-computer approach.

Data collection

This study collected three types of activity records to answer the research questions. These activity records include groupware activity logs, onscreen videos, and activity video as detailed below:

- *Onscreen videos*: The students could conduct several types of exploratory activities in the two approaches. More specifically, they could search on the web, read files they found, and use groupware individually or with peers. In order to capture the students' exploratory activities on computers, each shared-computer and 1:1 computer were installed with an onscreen recorder. The onscreen videos recorded can show how each student conduct these exploratory activities.
- *Groupware activity logs*: During the collaborative web exploration activity, the groupware recorded automatically participants' activities on the mind map. These activities include adding, deleting, and linking concept nodes, as well as browsing and uploading file nodes. These activity logs may reflect how the students organize information during the activity.
- *Activity videos*: Three video cameras were mounted on the ceiling of the classroom and connected to a monitoring system. Each camera was set to point to a group workspace to videotape group discussion activities. The students did not feel the cameras intrusively interrupt their discussion activities as the cameras were hidden on the ceiling of the classroom.

Data analysis

To understand how the two different approaches support group to organize knowledge, the groupware activity logs were analyzed to obtain more comprehensive activities. Nine types of activities were identified from activity logs, including adding/deleting a concept, adding/deleting a comment, adding/deleting a link between nodes and uploading/deleting/browsing a file. On the other hands, to obtain a better understanding of group activity, the study observed the time that the students spent on different tasks from the onscreen videos. The observation was made to understand how the students performed group and individual activities on the shared computers and 1:1 computers. More specifically, the time that the students spent on browsing web, reading files, using groupware were extracted from the videos. By doing so, we can obtain a better understanding of how individual students work together to explore the web in the two approaches.

In addition, the study also analyzed the dialogues in the activity videos to understand the group interactions in the two approaches. The dialogues were segmented into threads which was a basic unit of analysis of this study. A sequence of utterances in the dialogues was considered as a thread when these utterances were related to a specific topic. All the dialogue threads were classified into categories based on their functions during exploration. The classification of dialogue threads was conducted by two researchers. Disagreements were resolve upon discussion. The inter-coder reliability (agreement) for the classification was 93.3%, indicating that the analysis was adequately reliable.

The study further analyzed the sequential pattern of the above dialogue threads to reveal the group interaction pattern, because the sequential pattern analysis was an effective method to discover the transition relationship between different activities (Yamauchi, Yokozawa, Shinohara, & Ishida, 2000; Ezeife & Lu, 2005; Wasson & Mørch, 2000). The patterns were represented as a transition diagram depicting the transition probability between any two thread types. More specifically, the transition probability from thread A to thread B is the ratio of "the frequency of A to B" to "the frequency of B". Such pattern could illustrate the transition between different threads to reveal the progress of the group discussion.

Result and Discussion

Exploratory activities

Table 1 shows the results of time used for different exploratory activities among groups in the two approaches. Regarding the searching activity, the students could only search on the web together in the shared computer approach as they did not have 1:1 computers. They spent a considerable portion of time on searching on the web together.

Conversely, the students often searched for information on the web individually when they used the 1:1 shared-display approach. They rarely joined together to search. The results reflect that the collaborative web exploration activity may involve both group and individual activities. However, with the shared computer approach, the student could not conduct individual activities as they did not 1:1 computers to support their individual activities.

Table 1. The time distribution of exploratory activities in the two approaches

Approach	Shared-computer			1:1 shared-display		
Group	G1	G2	G3	G1	G2	G3
Searching the web together	15%	3%	10%	1%	1%	0%
Searching the web individually	N/A	N/A	N/A	16%	24%	7%
Reading files together	28%	57%	48%	7%	11%	5%
Reading files individually	N/A	N/A	N/A	39%	25%	34%
Using groupware together	54%	38%	41%	7%	7%	4%
Using groupware individually	N/A	N/A	N/A	28%	29%	47%
Others	3%	2%	1%	2%	3%	3%
Total	100%	100%	100%	100%	100%	100%

Regarding the reading activity, the students in the shared-computer approach spent much time on reading files together as they could not read files individually. On the contrary, in the 1:1 shared-display approach, the students demonstrated frequently individual reading activities. More specifically, they spent more time on reading individually than they did together. Such results may be because the reading paces of the students are different. In the shared-computer approach, the students were restricted by the device and have to compromise with others while reading information. On the contrary, in the 1:1 shared-display approach, they could read information according to their own reading pace. Such results support that in the collaborative web exploration activity, the 1:1 computers may be necessary to accommodate the needs of different students.

Regarding the groupware activity, the students in the shared-computer approach spent considerable time on using groupware together. However, in the 1:1 shared-display approach, their groupware activities were conducted in two manners. The analysis of the activity videos found that the students firstly used the groupware to manage information they found and wrote down their comments on the information. The students spend about 28% ~ 47% time on such activities. They then joined together to use the groupware to integrate and link different information and the perspectives from all group members. However, the students only spent very limited time on such a use of groupware (4%~7%). On the contrary, without the 1:1 computers, the students in the shared-computer approach used the groupware by taking turns, which led to long waiting time. Such results suggest that 1:1 computers may have transformed the dynamic of the collaborative activity into a two-phases learning activity. More specifically, the students firstly took part in individual exploration and then joined the group activity based on their individual exploration.

Groupware activity

Table 2 shows the groupware activities of three groups in the shared-computer and 1:1 shared-display approaches. The results reveal that overall the student groups used groupware more frequently in the 1:1 shared-display approach than they did in the shared-computer approach. More specifically, group 2 and group 3 added and deleted more concept nodes and browsed more files in the 1:1 shared-display approach. However, group 1 did not demonstrate profoundly different groupware activities in the two approaches.

Such results may be attributed to the autonomy promoted by the 1:1 computers. Because the students did not have individual learning device in the shared-computer approach, it is difficult for them to join the mind mapping activity. Hence, they performed few knowledge organization activities in the shared-computer approach. On the contrary, each student had opportunities to participate in the group mind mapping activity in the 1:1 shared-display approach. Moreover, these 1:1 computers enabled them to browse files according to their own reading pace. Such results indicate that collaborative web exploration activities require not only a shared computer but also 1:1 computers by which students can take part in the group activity.

Table 2. The mind mapping activities in two approaches

Approach	Shared-computer			1:1 shared-display		
Group	G1	G2	G3	G1	G2	G3
Numbers of added concept nodes	12	14	19	7	15	27
Numbers of deleted concept nodes	5	1	4	4	8	7
Numbers of added comment nodes	6	14	0	5	13	4
Numbers of deleted comment nodes	1	0	0	2	1	2
Frequency of created linking	16	23	15	9	20	41
Frequency of deleted linking	3	0	15	4	1	34
Numbers of uploaded papers	4	2	3	3	2	6
Numbers of deleted papers	0	0	0	1	0	3
Numbers of browsing paper	8	5	6	12	16	23
Total	55	59	62	47	76	147

Interaction pattern

All the dialogue threads were classified into categories based on the content of the dialogues. This study found a total 11 categories of dialogue threads. Table 3 shows that the categories and some examples of the dialogue threads.

Table 3. Threads categorization

Threads	Purpose	Examples
Procedure discussion	Members discuss the process of their exploration activity.	A: I think we should search for related information first.
Direction	Members negotiate what and how to find information.	A: I think we should search for information about groupware for collaboration.
Information judgment	Members judge the value of the information searching process.	A: I think your idea is out-of-date.
Information organization	Members discuss how to organize information with groupware.	A: Can we use the term “network groupware” instead of simple “groupware”? B: Groupware is not necessarily networked!
Self-explanation	Members take a self-explanation strategy to clarify information they found.	A: What is synchronous and asynchronous?
Clarification	Members clarify the content of information they found to their peers.	A: What is the main idea of this paper? B: It focused on the experiment comparison.
Group decision	Members negotiate to make decision.	A: Should we add this issue?
Status probe	Members report their working status to others.	A: Did you read this paper? B: Yes, I did.
Technological problem	The problem related to the technological environment.	A: What’s wrong with the computer?
Action request	Members ask others to perform work.	A: Please scroll down the screen. There should be a figure.
Informal conversation	The dialogues were irrelevant to the learning task.	A: Your wireless mouse is fancy.

Table 4 shows frequency and percentages of the 11 categories of the dialogue threads in the two approaches. The total number of dialogue threads of the three groups in the shared-computer approach is 992 which is much higher than 746 that they demonstrated in the 1:1 shared-display approach. This may be because the students spent more time on individual exploration activities. Table 4 also demonstrated that the students often requested their peers to take certain actions on the shared computers in the shared-computer approach. This may be because they lacked individual learning device. Such action requests were less frequent in the 1:1 shared-display approach. Conversely, they demonstrated higher percentage of procedure discussion because they had to integrate their individual exploration results into the group activity. Such result is consisted with the onscreen video indicating that the students first took part in individual exploration and then joined the group activity based on their individual

exploration. However, in the 1:1 shared-display approach, they encountered a more complex technological setting. Hence, they often discussed with other members to resolve the technological problems.

Table 4. Frequency and percentage of dialogue threads in the two approaches

Approach	Shared-computer			1:1 shared-display		
Group	G1	G2	G3	G1	G2	G3
Procedure discussion	33(9%)	13(3%)	10(4%)	21(7%)	17(5%)	12(14%)
Direction	21(6%)	23(6%)	26(11%)	17(6%)	19(5%)	8(9%)
Information judgment	33(9%)	71(17%)	26(11%)	26(9%)	65(18%)	11(13%)
Information organization	32(9%)	42(10%)	17(7%)	15(5%)	29(8%)	12(14%)
Self-explanation	53(15%)	94(23%)	38(17%)	83(29%)	59(16%)	7(8%)
Clarification	28(8%)	73(18%)	40(17%)	26(9%)	59(16%)	12(14%)
Group decision	8(2%)	4(1%)	10(4%)	5(2%)	3(1%)	1(1%)
Status probe	32(9%)	13(3%)	22(10%)	25(9%)	31(8%)	4(5%)
Technological problem	12(3%)	10(2%)	5(2%)	19(7%)	23(6%)	13(15%)
Action request	60(17%)	47(11%)	20(9%)	17(6%)	47(13%)	3(3%)
Informal conversation	36(10%)	25(6%)	15(7%)	36(12%)	17(5%)	4(5%)
Total	348(100%)	415(100%)	229(100%)	290(100%)	369(100%)	87(100%)

The interaction patterns in the two approaches were schematized in Figure 4 and Figure 5. It should be noted that the technological problem, action request, and informal conversation threads were excluded in the interaction pattern analysis because these threads are not the core activities during collaborative web exploration activities. Moreover, this study only displays the major transitions among the dialogue threads by ignoring the transition with small probability. More specifically, the transition probabilities were compared with the random transition probability under uniform distribution (1/8) by Chi-square because there were eight major dialogue threads. Only the transitions which demonstrated significantly higher probability than the random transition did under the uniform distribution were displayed in the transition diagram.

Figure 4 and Figure 5 illustrate that the students exhibited different interaction patterns in the two approaches. The interaction patterns show that the students often took a self-explanation and clarification strategies together during their discussion (Clarification -> Self-explanation and Self-explanation -> Clarification) in the shared computer approach. Based on such discussions, they further discussed how to organize the information they founded (Clarification -> Information organization). However, the results of these discussions were not used in the discussion of information judgment and group decision because there is not a major transition between these dialogue threads. In other words, the discussion becomes fragmented because the dialogue threads did not coherently facilitate the group to judge information and make group decision.

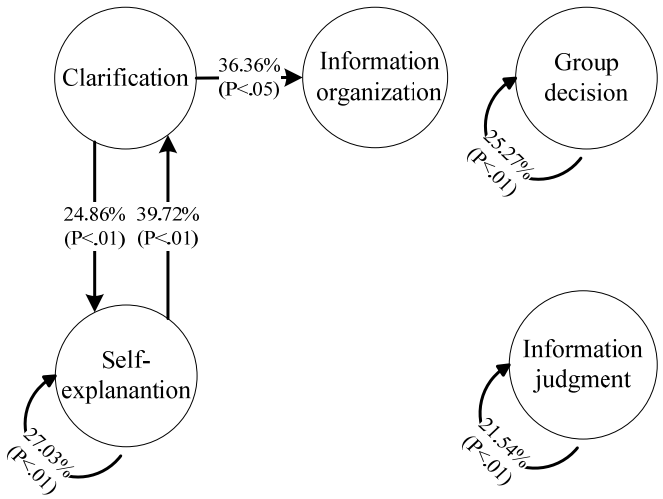

Figure 4. The interaction pattern in the shared-computer approach

On the contrary, the students in the 1:1 shared-display approach demonstrated a different interaction pattern. In such a pattern, the students' self-explanation did not only connect to the clarification of information (self-explanation -> clarification), but also to the judgment of information (self-explanation -> information judgment). Meanwhile, the discussion of information judgment also connected to the clarification of information (information judgment -> clarification) and helped the group to make decision (information judgment -> group decision). However, when they were judging the value of information, they often needed to probe the status of their peers because each student was using their own 1:1 computers (information judgment -> status probe). Compared to the shared-computer approach, the students demonstrated a more elaborative discussion patterns in which the students clarified and self-reflected upon the information to judge the value of information and make group decision.

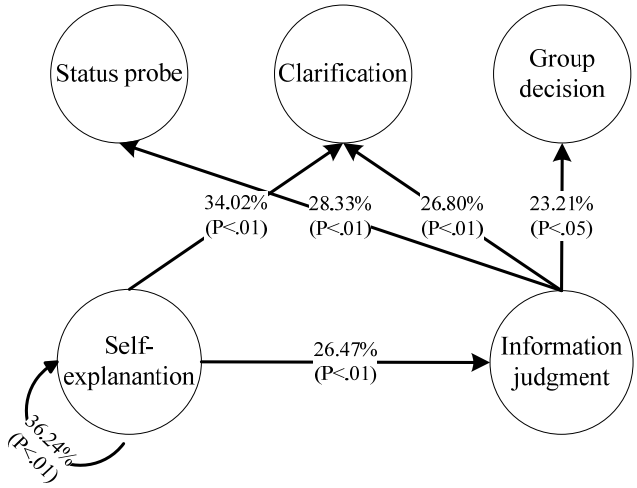

Figure 5. The interaction pattern in the 1:1 shared-display approach

Conclusion and Implication

Educators and researchers have emphasized the important of collaborative web exploration activities in educational context. The shared-computer approach was widely applied to facilitate students to explore on the web in a collaborative manner. However, such an approach may limit students' active participation and impede group interaction. This study therefore proposed the 1:1 shared-display approach to facilitate such a collaborative learning activity. The results of this study show that 1:1 computers are necessary to support collaborative web exploration activity with shared displays as they could support the students to take part in individual exploration and join the group activity based on their individual exploration. When using the 1:1 computers with the shared display, the students discussed with each other in a more elaborative way than they did without such computers.

The analysis of this study found that the collaborative web exploration activities involved both group and individual activities. More specifically, the students firstly needed to conduct individual exploration and then joined group activity to discuss with other members. However, the students in the shared-computer approach rarely conduct individual activity due to the lack of 1:1 computers. The 1:1 shared-display approach could support both of individual and group activities as well as the rapid transition between the two activities. Researchers such as Jeong and Chi (1997) asserted that both the self-construction and co-construction are crucial to collaborative learning. Previous studies by Elwart-Keys et al. (1990) and Mandviwalla and Offman (1994) also asserted that students during collaborative learning need to transit between the self-construction and co-construction activities. The findings of this study supports that lack of individual devices may limit the self-exploration activities during the collaborative learning. Educators may find both shared displays and 1:1 individual devices are necessary to implement an effective collaborative learning activity.

The study by Liu and Kao (2007), Amershi and Morris (2008) and Lee (2010) found that the shared displays are necessary to increase the activity awareness as they can become the shared focus among different students. One further research question following these studies is what benefits the 1:1 computers can afford in the shared-display

setting. The analysis of this study found that the students in the 1:1 shared-display approach demonstrated more frequently exploratory activities on the mind map than they did in the shared-computer. In other words, the students with the 1:1 computers demonstrated more active participation in both individual and group learning activities in a way that can accommodate each individual's reading pace. Such results echo the assentation of Soloway and Norris (2001) indicating devices "at hands" are a critical condition to facilitate active technology-enhance learning activities as students do not need to spend extra efforts on accessing the learning devices and sharing the learning devices with others. Recently, more and more shared displays are now available in public areas such as libraries. There is a need to provide some facilities to help students to orchestrate the 1:1 computers with the shared displays. By doing so, the shared displays can better support collaborative learning by engaging all students to participate in the collaborative activity.

Previous studies by Liu and Tsai (2008) has identified several interaction patterns, such as distributed and centralized interaction patterns, during collaborative discussion in terms of the question-response relationships between students. The study by Lee (2010) further analyzed the interaction patterns based on the availability of shared displays. The results of his study confirmed that the shared displays may influence the interaction patterns in terms of verbal and non-verbal interactions. These literatures indicated that both the question-response relationship and non-verbal interaction records are helpful to uncover the interaction patterns during collaborative learning. However, this study analyzed the interaction patterns based on the functional objectives of dialogues. In other words, student dialogues were categorized based on their functions and dialogues were analyzed based on the sequence relationships between these functional dialogues. The results of this study found that the students demonstrated a more elaborative discussion patterns when they explored with 1:1 computers than they did without the computers. Such a finding supports that such a method is helpful to understand how discussion progressed to achieve the group goal and the quality of discussion. Researchers may find it helpful to investigate interaction patterns during collaborative learning in other collaborative contexts.

The result of the study exhibited the benefits of the 1:1 computers in the collaborative web activities. However, the participants of this study were graduate students and most of the participants were male. In addition, they were from the course 'The theory and practice of mobile learning'. They might hold more positive perceptions toward the use of one-to-one computers in learning. Therefore, the findings of this study may not be over-generalized to students of different levels or different student groups. In addition, this study investigated the exploratory activities and interaction pattern as students are using laptop computers with shared-displays. It would be interesting to investigate how students learn collaboratively with different 1:1 computers, such as iPads or smart phones together with the shared-displays. Moreover, the findings of this study were obtained from system logs, onscreen and activity videos. It will be worthwhile to investigate how the two technological environments may influence students' perceptions of collaborative learning. For instance, questionnaires may be used to obtain students' perception of the collaborative activity. Gathering answers of these issues may be helpful to gain a better understanding of the role of 1:1 computers and shared displays in supporting collaborative learning.

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