Effectiveness of collaborative learning using the digital pen and the mind-map

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Abstract: During a "Period for Integrated Study" at a school in Japan, a teacher engaged in research encouraged children to engage in collaborative learning using a digital pen and "mind-maps." The children wrote persuasive "idea sentences" and compared them with the ideas of the other children. The authors felt that this process of collaborative learning and logical thinking by the children could be improved by having an "expert teacher" provide input from a remote location. Teachers at universities were asked to play the roles of the experts, because of their capacity to think logically. The authors found that this form of collaborative learning improved children's post-logical thinking abilities. When the children replied to a survey of attitudes, they reported that they felt that their logical thinking abilities had improved. When the authors analyzed the "idea sentences," the influence of the "expert teachers" could clearly be seen.

1.Introduction

Having analyzed the results of the nationwide academic ability survey, we concluded that children were not generally capable of relating specific events and ideas, and they often found it difficult to edit sentences or link ideas together (National Institute for Educational Policy Research 2009). Therefore, we considered that today's elementary school children had problems in logical thinking. We decided to develop lessons in collaborative learning utilizing a digital pen and a mind-map. Our rationale for doing so was based on the following related studies. Takahashi et al. (2009) advances the theory that "reciprocal observation of thought with others" could be effective in developing children's logical literacy in the context of lessons. Fukasawa and Katahira (2007) argue that using mind-maps improved thought more than bullet form writing. Yamamoto et al. (2009) report that children's planning and idea arrangement abilities can be improved through learning by mind-maps.

We decided to include an expert teacher with experience in logical thinking in lessons conducted by video conferencing. This was instituted in response to Nakayama et al.'s (2009) observation that "distributed collaborative learning" could make a significant difference to levels of effective learning in a computer based group exercise, when compared to "collaborative learning in one classroom." Also, Naruse and Miyaji (2003) show that technical college students can be provided with greater incentives to learn when they study together with university students through video conferencing.

We shared mind-maps and digital pens by using the remote desktop system, because it is usually difficult to see mind-maps from a remote location.

2.Objectives

Logical thinking can be explained as the ability to write effective reasons for one's assertions (Takahashi et al. 2009). During the "Period for Integrated study", the children utilized a digital pen for drawing a mind-map as part of collaborative learning (Figure 1). Also, they were helped with logical thinking by an expert teacher at a remote location. This study is intended as an investigation into the improvement of children's logical thinking abilities in this learning environment.

Figure 1: The child draws a mind-map with a digital pen.

Figure 2: The child receives support from an expert teacher in the remote location.

3. Method

3.1 Instructional planning

The research subjects were a class of 36 fifth graders from a Tokyo public elementary school. The "Period for Integrated study" consisted of 15 stages (see Table 1).

Lesson number	Flow of the unit	Notes
1	Children study how to draw the mind-map.	
2	Children study how to write the "idea sentences."	
3,4	Each child draws a mind-map. Children in each group draw a mind-map using the digital pens, and share ideas. Children share their ideas in the classroom through their group's mind-maps. Children write "idea sentences" based on the shared mind-map.	Introducing the digital pen, the mind-map and collaborative learning into lessons
5,6	The same as lesson 3 and 4	
7,8 Theme [1]	Each child draws a mind-map. Each child writes an "idea sentence"(pre "idea sentence") Children draw a mind-map in their each their using the digital pens, and share ideas. Children share their ideas in the classroom through their group's mind-maps. The first expert teacher demonstrates how to "think the theme" using the video conferencing system and the screen. Then he shows the shared mind-map. Children write "idea sentences" based on the shared mind-map (post	Verification class Expert teacher participation

	"idea sentence")	
9,10 Theme [2]	The same as lessons 7 and 8 (The second expert teacher demonstrates how to "think the theme" using the video conferencing system and the screen. Then he shows the shared mind-map.)	The same as lessons 7 and 8
11,12Theme [3]	Each child draws a mind-map. Each child writes an "idea sentence"(pre "idea sentence") The children draw a mind-map for each group using the digital pens, and share ideas. Children share their ideas in the classroom about presenting the group's mind-maps. Children write "idea sentences" based on the shared mind-map (post "idea sentence")	Evaluate lessons Any expert teacher does not participate.
13,14Theme [4]	The same as lessons 11 and 12	The same as lessons 11 and 12
15	Children reflect on their learning in the unit.	

Table 1: Instructional planning

3.2 Regarding the "Idea sentences"

The children wrote "idea sentences" of approximately 200 characters before and after the lessons. Themes were quoted from "Training by idea sentences of 200 characters using the Fujiwara style" by Kazuhiro Fujiwara, although to some extent we revised this approach (Table 2).

Theme [1] "Do you agree or not that we will go back to the past using a time machine?"
Theme [2] "Do you agree or not that we will get money by helping?"
Theme [3] "Do you agree or not that newspapers are better than television for providing news?"
Theme [4] "Do you agree or not that priority seats are not necessary in trains and buses?"

Table 2: Themes of lessons (Problems of lessons)

3.3 Scaffolding by the mind-map

The general method of writing "idea sentences" is bullet form writing. However, this method makes it difficult to write whole ideas on one sheet of paper. Also, it may be difficult for children to freely add content. It may also be hard for them to understand whether they have gathered enough appropriate content. We therefore decided that the children should complete the mind-map before writing the "idea sentences," which would then better reflect their learning and understanding (Figure 3). We considered that the children were capable of thinking logically and editing their ideas. We also considered that children could compare their "idea sentences" with those of others, and revise their ideas if necessary. In order to transfer learning in this way, it is important to improve children's meta-cognition by reflecting on the learning, so as to improve their abilities in logical thinking.

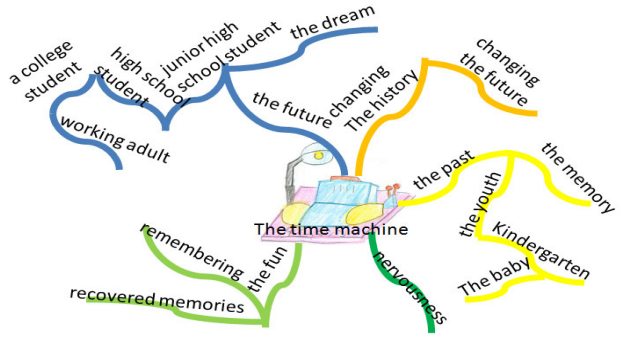


Figure 3: An example of children's mind-map

3.4 Note about selecting the expert teachers

We set up the university teachers who have had educational experiences in elementary schools as the expert teachers for the following reasons. Redish (1996) and Shulman propose the theory that we should distinguish between knowledge of the lesson content and knowledge of the teaching method, in order to decide on the most effective teaching methods. Also, Yamauchi (2003) argues that when children only meet the expert teachers in school, they will encounter much misunderstanding and conflict rather than beginning to learn.

3.5 Design of the learning environment

We used the video conference system named "Scopia," produced by the RADVISION Japan Company, when we connected the expert teachers to the classroom. We also used the digital pen system from the Anote Maxell Company. The digital pen is a system by which the children's handwriting can be shared. It uses special paper on which patterns of dots are printed and infrared rays are used to project the writing in enlarged form on a screen. The digital pen system can share the information using Open NOTE software. It is very helpful for children to make their thinking process visible and to be able to receive feedback. Also, children generally benefit from feedback when they are revising their own thinking and engaging with a learning problem. Barron et al. (1998), Black and William (1998), and Vye et al. (1998b) argue that increasing the likelihood of the development of formative evaluation can promote learning and the transfer of learning. As a result, children can then come to appreciate such values when revising their ideas. Therefore, we enabled the children to reflect on the lessons in the two following ways.

First, we provided opportunities for children to reflect on their ideas by creating a mind-map for each group based on the mind-map drawn by each child. Second, children and the expert teacher can share the information immediately by drawing the mind-map using the digital pen system. In this way, the sharing enables the presentation of different ideas and the evaluation of one group's mind-map by the children from another group, so that the children can reflect on this immediately when they revise their thinking. These two methods can enable the children to increase their opportunities for formative evaluation. It is possible to carry out the first method in an ordinary classroom environment. However, the second one is more difficult because of temporal and physical restrictions. However, if we provide the kind of learning environment mentioned above, we can improve the current educational situation. In such lessons, children record their ideas on the learning problems in the mind-map by using the digital pens. Mind-maps are sent to a personal computer by Bluetooth and are shared among children by a projector. We also used software called Team Viewer, which can use the desktops of separate computers to share a mind-map with children and an expert teacher (Figure 4).

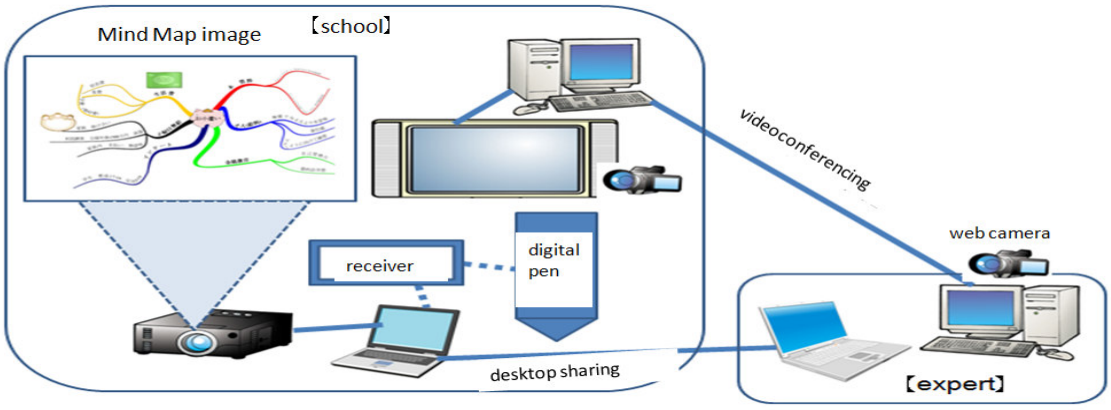


Figure4: An image of the learning environment

4. Methodology of evaluation

We evaluated the lessons using the following four methods:

(1) A children's attitude survey:

We questioned the children after lessons via a four-point scale questionnaire.

(2) Reciprocal evaluation of the “idea sentences” by the children:

The children decided which “idea sentence” is most persuasive by reciprocal evaluation before or after a lesson. We attempted to remove their preconceptions by the use of the following methods:

(i) Children evaluated the typed “idea sentences” which prevented the preconceptions attached to hand writing.

(ii) Children evaluated “idea sentences” that replaced a “pre” sentence with a “post” sentence in random ways to avoid the preconception of thinking that a “post” one was necessarily better.

(iii) We replaced school register numbers to avoid the children identifying who had written particular ideas down, in order to avoid further preconceptions.

(3) Evaluation of the “idea sentences” by the teacher:

Five public elementary school teachers evaluated the “idea sentences” (as mentioned in (2)) by following the three criteria of “clearness of insistence,” “validity of insistence” (Tomita et al. 2004) and “concreteness of insistence.” The authors used “concreteness of insistence” as a criteria because it was necessary for children who were in the developmental grade as elementary school students to learn to think logically.

(4) A qualitative analysis of post “idea sentences” when an expert teacher participated:

We analyzed post “idea sentences” in order to evaluate the influence of the expert teachers with regard to the first and second lessons in which they used whole ”idea sentences.” Two public elementary school teachers (not the same as (3)) evaluated them using the following two methods:

The mind-map of the expert teachers	Key phrases	Children's “idea sentences”	Count
I will meet the ancestors.	I will meet the ancestors.	Because I will talk to the ancestors if I go back to the distant past and meet them.	1
		Because I want to see my mother and father in their youth.	1
I would disappear if the history were changed.	I disappear.	Because I or an important person might disappear.	1
		Because the friend would go or I would disappear.	1

Table 3: Examples of the count

(i) Teachers counted the expressions as in Table 3 when they found them concerning the keyword or key phrase in the mind-map written by the expert teachers (we call the expression the key phrase in the latter part of this paper).

(ii) Teachers counted key phrases in the lessons’ video that were appreciated by the expert teachers.

Teachers counted the key phrases that were affected by the expert teachers’ talk to the children without the mind-map. For example, the expert teacher of the first lesson wrote the key phrase, “I know the mystery of history” on the mind-map. However, he used the more concrete key phrase, “Ryoma Sakamoto,” the name of a famous historical figure, as one of his oral key phrases. Because some children wrote this key phrase in the “idea sentences” which were extracted from the expert teachers’ oral key phrases, teachers counted them as if they were affected by the expert teachers (Table 4).

A key phrase described in the mind-map by the expert teachers “Understand the mystery of the history”	“Ryoma Sakamoto” which is as an expert teachers’ key phrase when he explains the mind-map orally.
16	11

Table 4: Usage conditions of key phrases (36 children)

We considered that the key phrases were not affected by the expert teachers when children saw them in the following way:

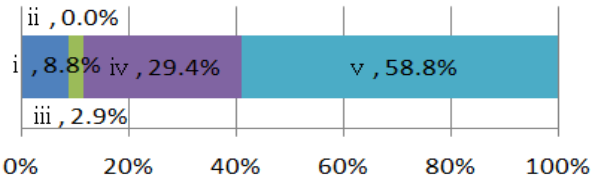
(1) Children wrote, “If I go back to the past, I can improve a bad aspect of my character.”

(2) The children used key phrases such as Anne Frank and except Ryoma Sakamoto and often sometimes included an irrelevant historical figure in their “idea sentences.”

5. Results and discussion

5.1 An attitude survey for children

We found that children appreciated the lessons when the expert teachers participated in the video conference system. For example, approximately 60 percent of the children answered that the expert teacher's teaching was influential on the "idea sentences" (Figure 5). When we asked the children what was strongest cause affected by post "idea sentences," it appeared that the children did not perceive a difference between the effectiveness of teaching from an expert teacher at their school and using the video conferencing (Figure 6). Moreover, they wanted to be continuously taught by the expert teachers (Figure 7), and they thought that it became easy to polish the "idea sentences" because of the teaching of an expert (Figure 8).



(i) Drawing a mind-map myself.
(ii) Drawing a mind-map based on results of collaborative learning by the group.
(iii) Looking the mind-maps which were drawn by the each group while learning
(iv) Listening to explanations of mind-maps which were drawn by the each group at the presentation
(v) Listening to the teaching of an expert

Figure 5: Factors that affect the "idea sentences"

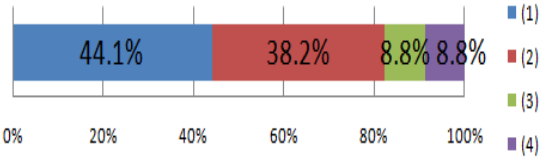


Figure 6: Did you feel the differences between the distance and classroom participation of the expert teachers?

*Figures 6–8 and Figure 10: (1) I strongly agree. (2) I agree. (3) I disagree. (4) I strong disagree.

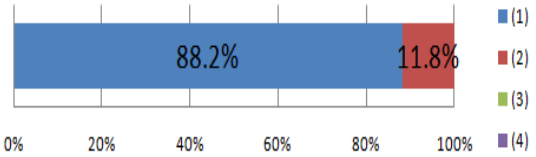


Figure 7: Do you want the expert teacher's teaching once again?

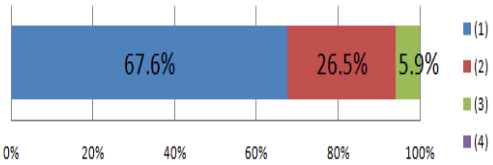


Figure 8: Is it easy to polish the "idea sentences" through participating with the expert teacher?

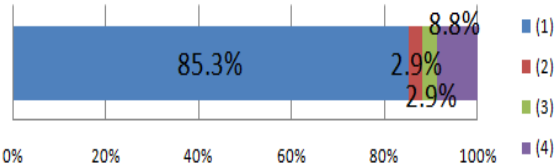


Figure 9: Which of expert teachers did you refer when you wrote the mind-map?

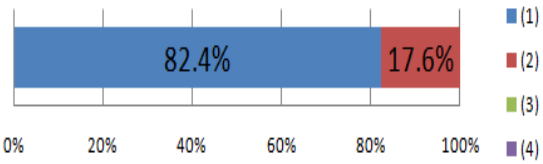


Figure 10: Was it easy to write the "idea sentences" through using the mind-map ?

Furthermore, we asked children about the following two statements concerning the two expert teachers in regard to understanding whether there a difference resulted from relying on the two expert teachers or not:

" Expert teachers participated in our lessons twice."

" Choose one item from the following answers."

(1) I referred to both expert teachers' teaching.

(2) I referred to the first expert teacher's teaching more than the second expert teacher's.
(3) I referred the second expert teacher's teaching more than the first expert teacher's.
(4) I didn't refer to both expert teachers' teaching.

The results revealed that 85 percent of the children referred to both expert teachers' teaching (Figure 9). We asked children whether it became easy to write the "idea sentences" by drawing a mind-map first. All replied affirmatively (Figure 10).

Therefore, we concluded that it that the expert teachers who had educational experiences at elementary schools participated in and helped the learning, using video conference system, had made an effective contribution. We also decided that drawing the mind-map before writing the "idea sentences" was necessary in order to make them easier for the children to write.

5.2 Reciprocal evaluation by children

According to the reciprocal evaluation, there were many children who appreciated the post "idea sentences," regardless of the participation of the expert teachers (Figure 11). ("E" indicates that an expert teacher was participating. "NE" indicates that an expert teacher had not participated.) Also, there were also many children who appreciated the post "idea sentences," regardless of the participation of the expert teacher in self-evaluation and reciprocal evaluation by the children. There was no significant difference between the self-evaluation and the reciprocal evaluation.

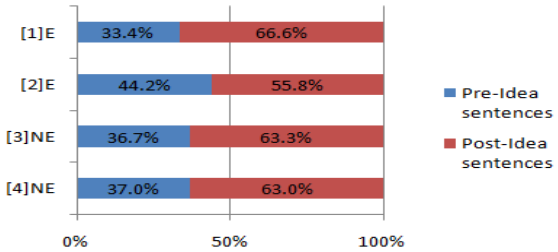


Figure 11: Reciprocal evaluation by children

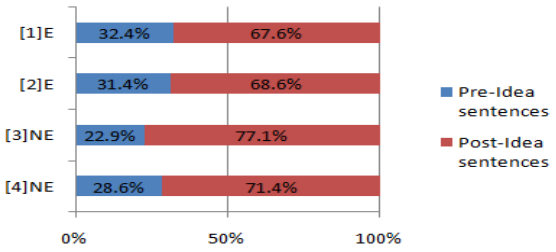


Figure 12: Self-evaluation by children

5.3 Evaluation of children's "idea sentences" by the teachers

Teachers appreciated post "idea sentences," significantly comparing them with pre "idea sentences" from two viewpoints: "clearness of insistence" and "concreteness of insistence," regarding the evaluation of children's "idea sentences" by them as the third evaluation ($p < .01$) (Figures 13 and 15). It seems that logical thinking improved through collaborative learning by using the mind-map (by following the children's "idea sentences"). However, there were no significant difference in the ratio by which teachers appreciated the post "idea sentences," when we focused on whether the expert teachers participated or not. Furthermore, there was no significant difference regarding the participation of the expert teachers in forming pre and post "idea sentences" when we focused on the issue of validity (Figure 14).

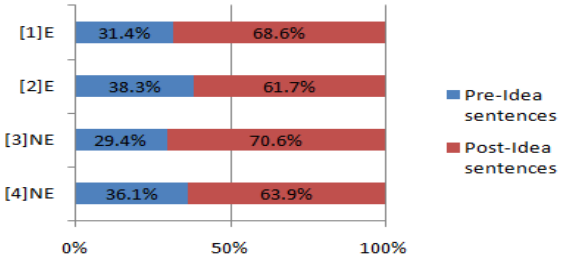


Figure 13: Clearness of insistence

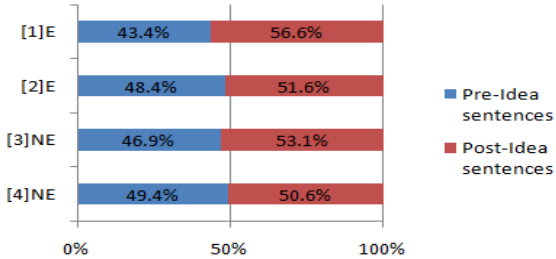


Figure 14: The number of validities

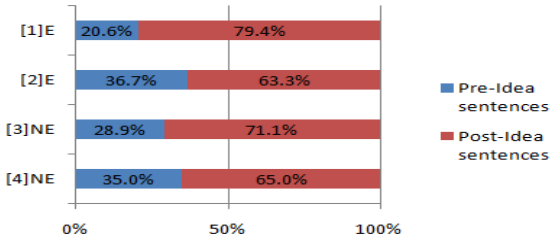


Figure 15: Concreteness of insistence

We defined the number of validities as by a process of standardization by dividing the number of characters of the children's "idea sentences" and averaging the total number of key phrases which the five teachers saw as being "valid" in all the children's " idea sentences" (and called this the "the number of validities").

" Example of children's "idea sentences":

Theme [1]"Do you agree or not that we will go back to the past using a time machine?"

Child "A" (pre "idea sentence"). I believe in time machines, because time machines appeare in "Doraemon." I thought that I wanted to make one, but I didn't make one. I have changed my dream. My dream is to look for a four-dimensional world. And then, I want to become an entertainer and to earn a lot of money.
Child "A" (post "idea sentence") I agree to going back to the past using a time machine. I have two reasons. The first reason is that I would be able to meet famous people in the past. The historical persons who I would like to meet are "Ryoma Sakamoto" and "Souseki Natsume." The second reason is that I would recover "lost articles." I like that idea.

5.4 Qualitative analysis of post "idea sentences" in case of an expert teacher participated

We analyzed the "idea sentences" in the first ([1]) and second ([2]) lesson in which the expert teachers participated in detail, because there were differences between the evaluation of the "idea sentences" (children's self and reciprocal evaluation and the evaluation by teachers) and the children's attitudes survey regarding the participation of the expert teachers.

Two teachers analyzed the "idea sentences" of children in the light of the following three items:

(a) The group having the influence of the expert teachers:

(There are key phrases in the "idea sentences" which were affected by the mind-maps of the expert teachers.)

(b) The group having the influence of the expert teachers:

(There are key phrases in the "Idea sentences" which were affected by the expert teachers' oral teaching regarding their mind-maps.)

(c) The group having no expert teachers' influence:

(There are no key phrases in the "idea sentences" which have been affected by the expert teachers.)

Firstly, we analyzed the relationships between the following two points.

(1) The number of validities (Figure 14)

(2) The total number of the key phrases in the "idea sentences" of groups that have the influence of the expert teachers (a) and (b) mentioned above (Tables 3 and 4)

We conducted a correlation analysis between the number of validities and the number of key phrases in the groups with the influence of the expert teachers. We found the following correlations as a result: [1] E($r = .41$, $p < .05$) [2] E($r = .51$, $p < .01$)

Also, we conducted a correlation analysis between the number of validities and the number of key phrases in each of the three categories (Table 5). We could not find correlations between the number of validities and the number of key phrases in the group (c) which had no expert teachers' influence. We could find correlations between the number of validities and the number of key phrases in the groups having the influence of the expert

teachers. Therefore, we concluded that the expert teachers probably improved the ability for logical thinking in the children. This is proven by the children understanding the expert teachers as the number one factor affecting their "idea sentences" in Figure 5 (factors which affect the "idea sentences" when children polish them) and by the affirmative reply from the children's attitude survey (Figure 8). However, we concluded that the expert teachers' oral teaching (b) did not necessarily affect the improvement of the children's logical thinking as in the expert's mind-map (a) in Table 5.

	([1]E) The number of validities	([2]E) The number of validities
(a)	($r = .37$, $p < .05$)	($r = .34$, $p < .05$)
(b)	n.s.	($r = .35$, $p < .05$)
(c)	n.s.	n.s.

Table 5: Correlations between the number of validities and the number of key phrases in each category (a), (b) and (c)

6. Conclusions

With regard to the educational process we have described, we can conclude that collaborative learning using mind-maps is an effective way of improving children's logical thinking. We found that the post "idea sentences" were more logical than the pre "idea sentences."

We could not find significant differences between pre and post "idea sentences" when we focused on the participation of the expert teachers. However, we could discover the influence of the expert teachers through our survey of children's attitudes. Furthermore, there were correlations between the number of key phrases that were influenced by the expert teachers and the number of validities in the "idea sentences." Therefore, it seems that there was some influence of the expert teachers when children wrote their "idea sentences."

In our future work, we intend to look more closely at how the participation and involvement of expert teachers can help children improve their logical thinking.

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