1. INTRODUCTION

Having analyzed the results of the nationwide academic ability survey, we concluded that elementary school children were not generally capable of relating specific events and ideas, and often had difficulty editing sentences or linking ideas together (National Institute for Educational Policy Research 2009). Therefore, we considered that today’s elementary school children have problems with logical thinking.

To address this, we decided to develop lessons in collaborative learning utilizing a digital pen and "mind-maps." The children wrote "idea sentences," which they compared with the ideas of other children. This process of collaborative learning and logical thinking was then improved by having an "expert teacher" provide input from a remote location. University teachers were asked to play this expert role, because of their capacity to think logically. The findings showed that this form of collaborative learning improved the logicality of children’s expression. In response to an attitude survey, the children reported that the expert had had the greatest influence on their idea sentences when they were refining them. Moreover, when the authors analyzed the idea sentences, the positive influence of the expert teachers was evident in terms of the “concreteness,” “validity,” and “cleanness” of their claims. This indicates improvement in the logicality of their expression and suggests the effectiveness of the learning support provided by expert teachers. Furthermore, we revealed the effectiveness of using mind-maps, which according to the survey of children’s attitudes and teachers’ qualitative evaluation, helped students improve the logicality of expression in their idea sentences.

Key words: Digital Pen, Mind-Map, Expert teacher, Distance education, Collaborative Learning, Period for Integrated Study
be divided into three stages, from infants to junior high school students and upward, and that long-term instruction is required. Moreover, Kawano (2011) worked on developing a curriculum for logical thinking based on the trend of growth in logical thinking ability. He clarified the aspects that led to this growth, and planned to provide continuous instruction in logical thinking. Based on these studies, we concluded that it would be difficult to promote the logical thinking ability of elementary school children in the short term.

Furthermore, the “Conference of the Central Council of Education—Elementary and Secondary Education Subcommittee” (2004) reported “logicality of expression” to be the evaluation standard of logical thinking ability. They also noted that sentences that include logicality of expression externalize children’s ideas based on their logical thinking ability (Sawyer 2009). Furthermore, there is some possibility of temporarily improving logicality of expression using the imitation method, which indicates that training to enhance logicality of expression may improve logical thinking ability. Therefore, we decided to evaluate the improvement of the logicality of expression in short-term educational practice.

Tomida and Maruno (2004) highlighted “validity of claim” and “clearness of claim” as the evaluation standards of logical thinking ability. As described earlier, referring to the relationship between logical thinking ability and logicality of expression, we also considered these two aspects as the standards for logicality of expression. Thus, in this paper, we use the terms “validity of claim” and “clearness of claim” when evaluating logicality of expression. We also included “concreteness of claim” as an original perspective on the standards, because we contend that concreteness is required to enhance logical thinking ability at the developmental stage of elementary school children.

With reference to the above, in this paper, we define “logicality of expression” as “the tendency for the expression of a claim to be clear using valid and concrete grounds.” This is discussed below.

2. OBJECTIVES

We set lessons called “Periods for Integrated study,” which consisted of collaborative learning using MMs drawn with a digital pen to write idea sentences on learning problems (Figure 1). These lessons were taught remotely by experts using video conferencing technology (Figure 2).

This study aimed to reveal the effectiveness of learning support using MMs and experts by investigating the improvement in children’s logicality of expression in the learning environment.

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).

3.2. Idea sentences

The children wrote “idea sentences” of approximately 200 characters each before and after the lessons. Themes were quoted from “Training using idea sentences of 200 characters using the Fujiwara style” developed by Kazuhiro Fujiwara (2010), although we revised this approach to some extent (Table 2).

3.3. Engagement of the expert teacher

In this study, we used university teachers with educational experience in elementary schools as the expert teachers for the following reasons. Redish (1996) and Shulman (1986, 1987) proposed
Effectiveness of Learning Support by Expert Teachers in Lessons Using a Digital Pen

Yamauchi (2003) also argued that when children only meet expert teachers in school, they might experience misunderstanding and conflict rather than learning.

Furthermore, according to Shimamura (2004), 79.1% of elementary and junior high school teachers consider composition instruction important; however, he emphasizes the low level of teachers’ satisfaction (48.2%). In this research, he revealed that idea sentences, which teachers set for children as a form of composition, were at a low level of approximately 19.5%, while “sentences about children’s lives” were outstanding at 80.0%. That is, based on the results of the abovementioned survey, university faculty were considered more suitable than elementary school teachers in providing instruction to improve children’s logicality of expression.

Thus, we engaged experts from university faculties who taught literacy education in first-year seminars and graduate research in specialized university courses, and who had previously been elementary school teachers. As such, they were regarded as having excellent abilities to instruct children on how to improve logicality of expression.
The experts taught the children following the procedure below.
(a) The expert teachers examined and evaluated the children’s MMs.
(b) The experts chose the most appropriate MM in each group and explained why it was good.
(c) The experts taught thinking methods through a learning problem using their own MMs.

With the aim of improving the children’s logicality of expression, the following five concrete instructions were given in relation to the evaluation standards mentioned above, namely “concreteness of claim,” “validity of claim,” and “clearness of claim.”

- We conducted a lesson to improve concreteness of claim by allowing children to use more grounds, indicating the key phrases used, and asking children to change their viewpoint on whether or not other views and ideas existed. “Concreteness” (Example idea sentence 1)
- We conducted a lesson to improve validity of claim by using adequate grounds and explaining and indicating the support grounds. “Validity” (Example idea sentence 2)
- We conducted a lesson to make the idea sentences clearer by not only indicating the grounds for claims, but also limiting these and the sphere of the claims. “Clearness of claim” (Example idea sentence 3)
- We taught the pleasure of thinking by setting familiar and enjoyable topics that the children could understand.
- We showed key phrases as a superordinate concept by ascertaining the relationship and understanding the children’s MMs.

3.4. Scaffolding using mind-maps

Generally, idea sentences are written in bullet form. However, this method makes it difficult to write all ideas on one sheet of paper. It may also be difficult for children to freely add content or understand whether they have gathered sufficient appropriate content.

Therefore, we decided that the children should complete the MMs before writing their idea sentences, in the hope that doing so would help them better reflect on their learning and understanding (Figure 3). We considered that children could refine their ideas through enhancing the logicality of expression in their idea sentences. We also considered that they could compare their idea sentences with those of others, and revise them if necessary.

To transfer learning in this way, it is important to improve children’s meta-cognition by reflecting on their learning, which will improve their logical thinking abilities.

In terms of the effectiveness of MMs, according to the National Institute for Educational Policy Research (2005, 2009), approximately 40% of students like to write sentences, while approximately half or less have the ability to decide what to write. In contrast, more than 70% of students like to draw pictures and color. By adding the use of MMs to lessons, children are more eager to learn compared to when only simple collaborative learning is employed. In addition, Buzan and Buzan (2010) note, “In view of its radiant nature, every key word or image added to a mind-map itself adds the possibility of a new and greater range of associations, which themselves add the possibility of new and greater ranges, and so on, ad infinitum.”

Thus, we can expect improvements in the ability to create an idea as an effect of using MMs. It seems that idea sentences become more concrete and their validity improves by associating the ideas with concrete grounds using MMs. Furthermore, we considered that when using MMs, children could immediately choose necessary grounds to clarify their sentences, because the MMs allow them to easily recognize all key phrases at once. Thus, we decided to use MMs in tandem with collaborative learning, as this could potentially improve the validity, clearness, and concreteness of the children’s ideas, which were the evaluation standards used for logicality of expression in our research.

We also planned the lessons so that students would be familiar with how to create an MM before the verification classes were conducted (Table 1).
This was achieved by providing instruction on drawing MMs (lesson No. 1) and five further lessons (lesson Nos. 2–6). We judged that students could use MMs effectively, as 86.3% were able to draw MMs as homework based on “The seven rules of mind-maps” (Tootake 2008) before the verification classes. Furthermore, after the lessons, 88.9% of students answered in the affirmative regarding the seventh rule, namely “enjoying.” Therefore, we judged that the students had sufficient skills to utilize MMs when participating in future lessons.

3.5. Design of the learning environment

We used the videoconference system “Scopia,” produced by the RADVISION Japan Company, to connect the expert teachers to the classroom. We also used the digital pen system from Anote Maxell Company. The digital pen is a system that enables sharing children’s handwriting using special paper on which patterns of dots are printed. Infrared rays are then used to project the writing in enlarged form on a screen. The digital pen system can be used to share information using Open NOTE software. It is helpful in making the children’s thinking process visible and enables them to receive feedback. Children also generally benefit from feedback when revising their own thinking and engaging with a learning problem. Barron et al. (1998), Black and William (1998), and Vye et al. (1998) maintained that increasing the likelihood of the development of formative evaluation could promote learning and the transfer of learning. As a result, children come to appreciate such values when revising their ideas. Therefore, we enabled the children to reflect on the lessons in two ways.

First, we provided them with opportunities to reflect on their ideas by creating a mind-map in groups based on the MMs drawn by each individual child.

Second, the children and expert teacher were able to share the information immediately by drawing MMs using the digital pen system. In this way, sharing enabled the presentation of different ideas and evaluation of the MM of one group by children from another group. This enabled them to reflect on and revise their ideas immediately.

These two methods enabled 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 is more difficult, because of temporal and physical restrictions. However, if we provide the type of learning environment mentioned above, we can improve the current education situation.

In these lessons, children recorded their ideas on the learning problems on the MM using digital pens. The MMs were then sent to a personal computer using Bluetooth and shared among children via a projector. We also used software called Team Viewer, which uses separate computer desktops to share a MM with the children and an expert teacher (Figure 4).

4. EVALUATION METHODOLOGY

We evaluated the lessons using the following four methods.
(1) Children’s attitude survey:

We questioned the children after the lessons using a four-point scale questionnaire and description. The questionnaire items were as follows.

Regarding the video conferencing: (i) What was the quality of the videoconferences and reasons for your answer? (ii) Did you notice any difference between the face-to-face lessons and videoconference lessons, and why? (iii) When do you want to ask expert teachers for advice? (Description) (iv) Was the expert teachers’ instruction easy to understand? (v) Was there any difference between the two expert teachers’ instruction in terms of being easy-to-understand, and why? (vi) Is it important to provide opportunities to ask the expert teachers questions, and why? (vii) Would you like to ask the expert teachers for advice next time, and why? (viii) Did the instruction by expert teachers influence your idea sentences?

Regarding the idea sentences: (ix) Do you understand that you need to provide reasons when you describe an idea? (x) Is it easy to write your idea by drawing an MM before writing idea sentences? (xi) Was it easy to polish the idea sentences after being taught by the expert teachers? (xii) Was it easy to refine the idea sentences after asking your group for ideas? (xiii) Was it easy to refine the idea sentences after asking your class for ideas?

Regarding MMs: (xiv) Do you write ideas on the MM when drawing it in a group? (Description) (xv) Choose the items from the choices based on the order in which they influenced your idea.

Regarding the lessons: (xvi) What contents did you learn from the lessons? (Description) (xvii) Propose better lessons. (Description) (xviii) What is the standard when you conduct a reciprocal evaluation with other students? (Description)

# “Reasons” and “description” of an item were expressed through free description.

# Among items (i)–(xiii), the choices for item (i) were as follows: “Very good,” “Good,” “Slightly bad,” and “Very bad.” For (ii), (iv), and (vi)–(xiii), the choices on a four-point Likert scale were as follows: “Agree very much,” “Slightly agree,” “Do not agree very much,” and “Do not agree at all.” Regarding the choices for items (v) and (xv), please refer to Figures 5 and 6. We also aimed to promote the logicality of expression and evaluate the validity, clearness, and concreteness of claims as evaluation standards. Therefore, we omitted items not directly related to these standards, apart from (v), (xv), and (xvi), which are underlined, because we verified the effectiveness of learning support by the experts and MMs in our total learning environment.

(2) Teacher’s evaluation of idea sentences:

Five public elementary school teachers evaluated the idea sentences (as mentioned in (2)) according to the three criteria of validity of claim, clearness of claim (Tomida et al. 2004), and concreteness of claim. The authors used concreteness of claim as a criterion, because it was necessary for children at the developmental level of elementary school to learn to think logically.

The five teachers evaluated the pre-idea sentences and posted one sentence they deemed high in concreteness and clearness.

We also set the “number of validities” as the average number of such expressions in a student’s idea sentences, for which the five teachers judged that the reasons were appropriate and the ideas

<table>
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<th>Table 3: Examples of the count</th>
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<td>Mind-map of expert teachers</td>
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<td>I will meet the ancestors.</td>
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<td>I would disappear if history was changed.</td>
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<th>Table 4: Usage conditions of key phrases (36 children)</th>
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<td>A key phrase described in the mind-map by the expert teachers “Understand an historic mystery.”</td>
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valid. To standardize the average, it was divided by the number of characters used in students’ idea sentences. (As mentioned below, we termed this the number of validities.)

We also attempted to remove the children’s preconceptions using the following methods:
(i) Children evaluated the typed idea sentences, which prevented any preconceptions they may have attached to handwriting.
(ii) Children evaluated the idea sentences by randomly replacing “pre” sentences with “post” sentences to avoid the preconception of thinking that a “post” sentence would necessarily be better.
(iii) We replaced the children’s school register numbers at random to avoid them identifying who had written particular ideas to avoid further preconceptions.

(3) We conducted a qualitative analysis of the post–idea sentences to evaluate the influence of the expert teachers in terms of the first (Lesson nos. 7 and 8) and second (Lesson nos. 9 and 10) lessons in which they used whole idea sentences. Two public elementary school teachers (not the same as those mentioned in 4 (2)) evaluated the sentences using the following two methods:
(i) As shown in Table 3, they counted expressions that contained a keyword or key phrase from the expert teachers’ MM. (We call such expressions “key phrases” in the latter part of this paper.)
(ii) The teachers also counted the key phrases in the lesson videos that were increased by the expert teachers. In the same way as for 3(i), the teachers counted the key phrases that were influenced by what the expert teachers said to the children without the expert teachers’ MMs. For example, the first expert teacher (Lessons 7 and 8) wrote the key phrase, “I know about an historic mystery” on the MM. 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 extracted from the expert teacher’s oral key phrases, they were counted as having been influenced by the expert teacher (Table 4).

We also counted the following cases that did not correspond with (i) or (ii) as cases not affected by the expert. For example, “You could go to the past and improve your bad character,” and cases for which children wrote “Anne Frank” or other personages apart from “Ryoma Sakamoto.”

(4) Analysis by comparing the pre– and post–idea sentences

We evaluated the effectiveness of the MMs and experts respectively based on differences in the logicality of expression by comparing the children’s pre– and post–idea sentences.

5. RESULTS AND DISCUSSION

5.1. Evaluation of the effectiveness of expert participation

We first evaluated the efficacy of participation of the two experts who teach First–Year Experience or Specialized courses at university, who also had educational experience in elementary schools.

5.1.1. Effectiveness of expert teachers’ participation based on children’s attitude survey

We discovered that the expert teachers’ instruction was the factor most influencing the children’s post–idea sentences based on the survey responses of approximately 60% of the children. The children chose from the following items to prioritize whether or not they had influenced their idea sentences (Figure 5).

We also asked the children about the following two statements concerning the two expert teachers in terms of understanding whether or not a difference resulted from relying on them: “Expert teachers participated in our lessons twice. Choose one item from the following answers.” The results revealed that 85% of the children referred to the teaching of both expert teachers (Figure 6).

Therefore, we concluded that it was an effective contribution when the expert teachers, who had educational experience at elementary school, participated in and helped the children’s learning using the videoconference system.

5.1.2. Effectiveness of expert teachers’ participation based on example idea sentences

We also considered the effectiveness of the expert teachers’ participation by qualitatively analyzing the idea sentences.

Initially, according to example idea sentence 1, a child wrote the following reasons: “I would die too” and “I would be eaten,” focusing only on his/her death.

Afterwards, children rethought their ideas based on the expert teachers’ key phrases and instruction, “If I changed history, people would disappear,” as given in his MM and “People used to die of diseases in the old days from which they would easily recover today. Thus, if we went carelessly into the past, we would die. Then, you
may think that you should bring medicines, but doing so would change history, would it not?"
(Video record: 55 minutes 45 seconds, lesson nos. 7 and 8.) Through the instruction mentioned
above, children began to consider the risks such as, "History might change" and "I would miss my
friends," from a broader and more concrete viewpoint by understanding the influence of going
into the past as a problem that might affect everyone, not just oneself.

Example idea sentence 1: [Concreteness of claim]
(Pre-idea sentences): I am opposed to going to the past using the time machine.
I have two reasons.
First, if I went back 150 years and spoke with Ryoma Sakamoto for a long time, he would not be
able to go to the places he wanted to go. Then, I would change history.
Second, if I went back to the present but had changed the past, I would miss my friends and I
would disappear. Therefore, I am opposed to it.

Example idea sentence 2: [Validity of claim]
(Pre-idea sentences): I agree to go to the past using a time machine.

Figure 5: Factors that affect idea sentences

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

Figure 6: Which expert teachers did you refer to when you wrote the mind-map?

(1) I referred to the teaching of both expert teachers.
(2) I referred to the first expert teacher’s teaching more than that of the second expert teacher.
(3) I referred to the second expert teacher’s teaching more than that of the first expert teacher.
(4) I did not refer to either expert teachers’ teaching.

Therefore, I am opposed to it.
Post-idea sentences: I am opposed to going to the past using the time machine.
I have two reasons.
First, if I went back 150 years and spoke with Ryoma Sakamoto for a long time, he would not be
able to go to the places he wanted to go. Then, I would change history.
Second, if I went back to the present but had changed the past, I would miss my friends and I
would disappear. Therefore, I am opposed to it.

Moreover, in example pre-idea sentence 2, the children recalled and considered only the past that
was familiar to them. However, the expert stated, “You supposed that you would return to the past
when you were an infant, but I supposed a very long time ago: An ancient time when I would meet
Ryoma Sakamoto” (video record: 53 minutes 00 seconds, lesson nos. 7 and 8). Furthermore, the
experts instructed the students to explain their concrete grounds for agreeing with returning to
the past using the time machine: “You may publish a book” (video record: 53 minutes 37
seconds, lesson nos. 7 and 8), and “You could find out the prize-winning number in a public
lottery and become a very rich person” (video record: 54 minutes 07 seconds, lesson nos. 7 and 8)

In this way, children wrote only about the past that was familiar to them: A past (two or three
days ago) that they wanted to revise but also ancient times—“I will go to the Edo era and solve
an historic mystery” and “I will investigate the daily life of a famous historic person”—using
the key phrases posited by the experts. The children then improved the validity of their claims by using
various grounds as mentioned.
Thus, the findings showed that the children could develop their logicality of expression by
increasing the grounds to reconsider their problems based on the expert’s instruction.

Example idea sentence 3: [Toulmin Model]
(Pre-idea sentences): I agree to go to the past using a time machine.

Figure 6: Which expert teachers did you refer to when you wrote the mind-map?
Because I can retry what I failed at and I will not become disgusted with the present. I thought that I wanted to go back to the past, because I broke the DS touch pen at the end of the 4th grade, which was a big problem for me. In the end, my father repaired it. Therefore, I agree with going back to the past using the time machine. (Post-idea sentences): I agree to go back to the past by time machine. I have three reasons.

First, I can start what I want to restart again because where I lost it has become clear.

Second, for example, long long ago, this is because I thought that if I went to the Edo era, I could solve an historic mystery. Moreover, it is interesting.

Third, I would meet a prominent person in history and wanted to examine that day in the life of that person.

I regret that it is only possible to come and go to the past once. However, I agree to go to the past using the time machine.

Finally, in the lower example idea sentence 3, the child clarified his/her own idea. We then wanted to evaluate the pre- and post-idea sentences of the child while quoting the Toulmin Model (Inoue 2007). Initially, the child made the claim, “I was against going by time machine to the past” in a pre-idea sentence, citing as reason the risk of confusion. The expert teacher instructed the children using simple language such as in the following key phrase: “You are going to the past, and you and your friend may get out,” and “What should you do or think while preventing it to enjoy the time in the past?” (Lesson nos. 7 and 8, Video record 57 minutes 50 seconds). This was used to suggest that the children limit the range of the claim to improve the logicality of expression of their idea sentences.

As a result, in the post-idea sentence, we confirmed that their expressions limited the range of the claim, but the pre-idea sentences did not. One child claimed, “I agree to go to the past by time machine.” The reason given included not only “We want to know the truth about the death of Mozart,” but also “If we make a plan to go to the past for several months, I think this is a good composition. I want to know the truth.” Therefore, if we plan for several months to go to the past, I think the suggestion is good. (Limitation).

Therefore, I agree to go to the past.

5.1.3. Effectiveness of expert teacher participation based on the number of valid expressions.

Because a difference was seen between the attitude survey (5.1.1) and Figures 7-9 regarding the effect of the expert teacher, we analyzed the post-idea sentences written by the children at the time of the expert participation class, and examined [1]E and [2]E in greater detail. ([1], [2], and later [3] and [4] refer to the theme number. “E” indicates that an expert teacher participated.)

Unlike in section 5.2.3, two different teachers judged the valid grounds for the children’s claims in the idea sentences by analyzing them from the viewpoint of (a) and (b) following the procedure: expressions we thought were influenced by the expert teachers and expressions we thought were devised by the children without the expert teachers’ influence.

Because the expert had not necessarily had an influence in the case of expressions (for children’s individual MMIs and expressions in pre-idea sentences) already used by the children before
receiving the expert instruction, even if the expert nominated these expressions as grounds for the problems, we excluded these from the count of (a).

After analyzing the number of expressions between (a) and (b) (Table 5), a significant difference was found (p<.01). Therefore, we understand that the children’s post-idea sentences were greatly influenced by the expert teachers.

In this regard, Figure 5 shows “a factor that affected the children at the time of polishing the idea sentences,” recognizing that the expert teachers affected the idea sentences.

In addition, regarding validity, there was almost no change with or without an expert teacher between the pre- and post-idea sentences. As mentioned in section 5.1.1, we considered the number of valid grounds that the children could write as limited, because the children’s idea sentences were limited to approximately 200 characters. We estimated that because of this factor, there would be no significant difference in the valid number by expert teacher participation.

The fixation of logicality of expression from expert instruction in [3]NE and [4]NE is not clear (“N” indicates NO). However, in this study, the influence from expert teachers was observed after classes [1]E and [2]E, as discussed in section 5.1.1 and Table 5. In addition, validity, clearness, and concreteness of claim improved through expert instruction, as mentioned in section 5.1.2. We judged that the logicality of expression improved following the instruction by the expert teacher in accordance with the above.

5.1.4. Difference between expert teacher and elementary school teacher

In addition, we set a mock instruction scene for four teachers, not those in sections 5.1.3 and 5.2.3, after class practice (February 26 and 27, 2012), and verified whether there was a difference between the instruction of the experts on whom we depended for this practice and that of an elementary school teacher. In the process of verification, five elementary school teachers mastered the ability to follow the abovementioned “Seven rules of mind-maps” (Tootake 2008) in relation to describing the MMs. Afterwards, we showed them the video recording of the child announcement scene at the time of the verification class. After they watched the video recording, we confirmed whether the children had been instructed through mock instruction. As a result, a common point of the four teachers was to use most of the instruction time to evaluate the children’s MMs and teach them how to write MMs. Thus, we were unable to confirm whether or not the teachers had instructed the children to clarify their ideas by limiting the range of the claim or to propose various grounds for their claims by showing key phrases with which to switch their viewpoint to improve the concreteness of their claim and present sufficient grounds and documents, as the expert teachers had done in their instruction. Therefore, we hypothesized that the influence of elementary school teachers would not be more significant than that of expert teachers in improving the logicality of expressions.

5.2. Verification of effectiveness of collaborative learning using MMs

We next verified how MMs were effectively used in this practice.

5.2.1. Effectiveness of MMs in the attitude survey

The effect of collaborative learning using MMs was confirmed by descriptions in the children’s attitude survey.

One child replied as follows regarding what he/she had learned in class and recognized that his/her learning had been associated with the MM.

“1. When I write a mind-map, the number of associated words increases.”

“2. I understand that I did not understand that we would show the mind-map to each other with our group friends.”

“3. I noticed that we showed the mind-map to each other with group friends in a different way.”

We also asked them why they had drawn MMs:

“When you drew a mind-map in a group, you might not have written the ideas from your own mind-map on the group’s mind-map. When you
did write your own idea, why did you write it? In addition, when you did not write an idea, why did you not write it?” In response, one child replied that he had written his idea because it represented sufficient grounds for the theme, but then in the group, what he deemed to be better grounds were given. He gave this as a reason for not writing his idea in the group.

We found that the children were able to improve the logicality of expression by the following means. They could easily associate their knowledge or experience to a theme using MMs, they improved the concreteness of their ideas while adopting various viewpoints, and they improved the validity of their claims by sufficiently evaluating the grounds by drawing MMs in a group.

5.2.2. Effectiveness of MMs in idea sentences

When we evaluated the effectiveness of MMs in terms of the post–idea sentences, we described how we extracted idea sentences 1–3 (cited above). The Course of Study sleeve notes (national language) for elementary and junior high school contained an explanation of concreteness, validity, and clarity, but divided them into the low-ranking end-point (eight items in total) of two or three each, as shown in Table 6. We also referred to other evaluation standards such as teachers’ textbooks, which had a more concrete perspective, and referred to various preceding studies (Inoue 2007, Ueda 2009, Tanaka 2011).

Based on these eight items, we evaluated all sentences in each idea sentence in the lead writers with one Tokyo public school teacher as an object (1 unit). As such, we counted end-point 1 when the associations of the keywords were at the point that corresponded to that end-point (eight maximum), which was influenced by the expert teacher in one idea sentence and was related to and affected by the MMs. Table 6 provides the results of this evaluation. The totals for concreteness, validity, and clarity are not included in Table 6 because one idea sentence may correspond to a plural end-point.

Regarding example idea sentences 1–3, we analyzed which of the children’s expressions were clear based on one of each of the three perspectives of concreteness, validity, and clearness.

In addition, other than example idea sentences 1–3, we found the following based on the evaluation (Table 6). The key phrases used in the experts’ MMs brought “ii concreteness” [knowledge, experience] and “iii concreteness” [various viewpoints] to the post–idea sentences. Thus, in section 5.2.1, we expressed the association between the influence of MMs, how each child’s knowledge and experience was recalled, and how their vision was widened by evaluating their idea sentences from a different viewpoint. In addition, “v validity” [enough evidence] was relatively frequent; however, the key phrases used by the experts in the MMs for

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<th>Table 6: Results of the evaluation of post–idea sentences regarding the effectiveness of MMs using the eight lower end-points</th>
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<tr>
<td>Applicable number of post–idea sentences in “[1]E” and “[2]E”</td>
</tr>
<tr>
<td>i Concreteness of claim [Intelligence gathering] 0</td>
</tr>
<tr>
<td>ii Concreteness of claim [Knowledge, Experience] 20</td>
</tr>
<tr>
<td>iii Concreteness of claim [Various viewpoints] 14</td>
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<tr>
<td>(Example idea sentence 1)</td>
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<tr>
<td>Subtotal (Concreteness of claim) 34</td>
</tr>
<tr>
<td>iv Validity of claim [Generalization] 3</td>
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<tr>
<td>v Validity of claim [Enough evidence] 15</td>
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<tr>
<td>(Example idea sentence 2)</td>
</tr>
<tr>
<td>Subtotal (Validity of claim) 18</td>
</tr>
<tr>
<td>vi Clearness of claim [Use of plural information measures] 0</td>
</tr>
<tr>
<td>vii Clearness of claim [Distinction between a fact and an idea] 4</td>
</tr>
<tr>
<td>viii Clearness of claim [Limitation of the claim] 2</td>
</tr>
<tr>
<td>(Example idea sentence 3)</td>
</tr>
<tr>
<td>Subtotal (Clearness of claim) 6</td>
</tr>
<tr>
<td>Number of post–idea sentences that corresponded to one of the eight items mentioned above 30</td>
</tr>
<tr>
<td>Total number of post–idea sentences evaluated 71</td>
</tr>
<tr>
<td>Number of participating children ([1] E+ [2] E)</td>
</tr>
</tbody>
</table>
the cause were replaced with grounds. It is thought that they were caused through this supplementation.

In addition, 30 post-idea sentences corresponded to one of the 8 evaluation items, representing 42.3% of the total number (71) of post-idea sentences evaluated. Therefore, when we include the results of the attitude surveys (section 5.2.1) for concreteness and validity, MMs had a constant effect in terms of improving the logicality of the children’s expression.

Using the example idea sentence cited above, we next show the effectiveness of MM qualitatively.

In example pre-idea sentence 1, a child proposed the idea using grounds such as “I would die too” in relation to his extinction. Children used “History would be replaced” and “A friend would disappear” as grounds when influenced by the MM key phrases of the expert teacher. Furthermore, regarding the ground “History would be replaced” in the MM, in the post-idea sentence, “Ryoma would not be able to go to the places that he must go, and history would take place as a result of our meeting Ryoma Sakamoto and talking,” the child associated the grounds for his claim and could then describe them. A new key phrase emerged from the associations, which is one of the characteristics of MM, as discussed. We thus contend that the children made a concrete post-idea sentence using the key phrase and improved the logicality of their expression. In addition, Usami (1992) described how in a class on logical thought, children were able to think in concrete situations. Thus, providing children with sufficient concrete grounds is an effective way to improve their logicality of expression.

Thus, we can confirm that idea sentences were made more valid (as in example idea sentence 2) through collaborative learning using MMs. In the pre-idea sentence, the child proposed “I would fail again” as a key phrase. However, influenced by the MM key phrase that the expert teacher later showed, the child amended his grounds to “We would understand the truth of history” and “We could write a book.” In the post-idea sentences, children wrote the following grounds: “We could go to the Edo era and solve an historic mystery” and “We could meet a person who won in history to write a book and examine that day in the life of that person.” In other words, the children improved the validity of their claims in the post-idea sentences by proposing sufficient grounds.

Furthermore, in example idea sentence 3, the child wrote, “If we plan for several months to go into the past, I think that the suggestion is good,” while in the post-idea sentence, the child wrote, “You may die if you go to the past.” A child also wrote the phrase, “We want to know the truth about the death of Mozart,” and this phrase was proposed by the child as a ground in a post-idea sentence: “We could understand the truth of history.” Thus, new key phrases emerged from the associations, which are one characteristic of MMs.
as described above. Thus, logicality of expression might be evident in post-idea sentences as a result of the children using MMs. As mentioned, one characteristic of MMs is that a new key phrase emerges from the associations, and the logicality of expression might then bring concreteness and validity to the post-idea sentence as a result of its use.

5.2.3. Effectiveness of MMs in the teacher evaluation

In addition, regarding the judgment of the idea sentence by the teacher in verification method (2), two viewpoints, concreteness and clearness, significantly increased in the post-idea sentences (p<.01) (Figure 7, Figure 9). (In Figures 7–9, “E” indicates that an expert teacher participated; “NE” indicates that an expert teacher did not participate.)

This result indicates that logicality of expression improved through collaborative learning using MM.

In section 5.2, we discussed the effectiveness of MM in this practice. We found that the children used a characteristic of MM called association in collaborative learning using MM and created consecutive key phrases. Using MM also allowed them to recall their knowledge and experience, and the children could then improve their concreteness by considering whether or not alternative viewpoints existed. They improved the validity of their ideas by expanding the grounds for their claims, and thus, the logicality of their expressions was improved.

6. CONCLUSION

Based on the foregoing, this study found that in a class using a digital pen system, MMs, and collaborative learning, and facilitated by remote expert participation, the following occurred:

• A comparison of the pre- and post-idea sentences of the class showed that the logicality of expression improved in the post-idea sentences. Furthermore, when using MMs, the children recognized the effectiveness of their use in collaborative learning.

• Regarding the presence of the expert, as discussed in section 5.2.3, no difference was evident in the evaluation for the pre- and post-idea sentences. However, the children’s attitude survey showed the experts’ influence when the children were polishing their expressions. As discussed in section 5.1.2, expert teachers influenced the qualitative analysis of the post-idea sentences.

Concreteness, validity, and clearness improved as a result of the expert teachers’ instruction, as did the logicality of expression.

Future studies should examine methods to retain the effect under the influence of an expert teacher to improve children’s logicality of expression and logical thinking ability. We would also like to investigate how a digital pen affects the logicality of expression.

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