Factors determining students' satisfaction in a learning environment including the digital pen at an elementary school in Japan

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Abstract: The authors implemented lessons to improve the logical thinking of students at the elementary school level. In the lessons, students engaged in collaborative learning with expert teachers utilizing a mind map (MM) drawn with a digital pen. In previously published findings, it was found that the learning environment including the digital pen system was relatively effective. However, the authors could not determine what kind of scaffolding was most effective. Therefore, a causal relationship model was used to assess lesson satisfaction among students based on an attitude survey and verified using covariance structure analysis. The results showed that "MM" and "collaborative learning with the expert teacher" influenced "understanding of and satisfaction with the lessons," while use of the digital pen did not affect the summative evaluation of the lessons. Therefore, it seems that students perceived the digital pen in a similar way to an ordinary writing implement, and thus that it blended well into the learning environment.

1. Introduction

At present, Japanese elementary school students have problems with logical thinking, according to the results of a nationwide academic ability survey (National Institute for Educational Policy Research, 2009). Therefore, the present authors built a learning environment using a digital pen system and developed lessons to improve the use of logic by students, with an evaluation scale as seen in (Figure 1). The authors evaluated how the learning environment was affected by the use of the digital pens. In the lessons, first, a primary school teacher assigned learning problems to students, who then drew a mind map (MM) and wrote "pre idea sentences" with an ordinary pen. Next, the students drew MMs using a digital pen shared among group members. University faculty who had previously been teachers at the elementary level were engaged as "expert teachers." By sharing MMs and receiving feedback from their peers, students could revise their ideas and create new ones. The expert teachers evaluated students' MMs by video-conference. Finally, in the last 30 minutes of the class, students rewrote their idea sentence (called "post one") in to reflect the results of the feedback from sharing and the expert teachers' feedback (Table 1). In previously published findings, it was found that collaborative learning using MM improved the logicalness of students' output by the experts' instruction, according to the results of analysis of an attitude survey and changes in idea sentences between pre- and post-tests (Authors, 2012a; Authors, 2012b). However, it was unclear what kind of scaffolding was most effective in this learning environment. Therefore, the authors decided to conduct the same lessons again in three new classes to reveal the more effective form of scaffolding by holding an attitude survey for all students after the lessons were complete.

2. Objectives

The objective of the present study is to reveal what kind of scaffolding is most effective for achieving student impressions of and satisfaction with the lessons; in other words, to verify the model using covariance structure analysis to posit causal relationships related to student satisfaction after extracting explanatory variables by factor analysis.

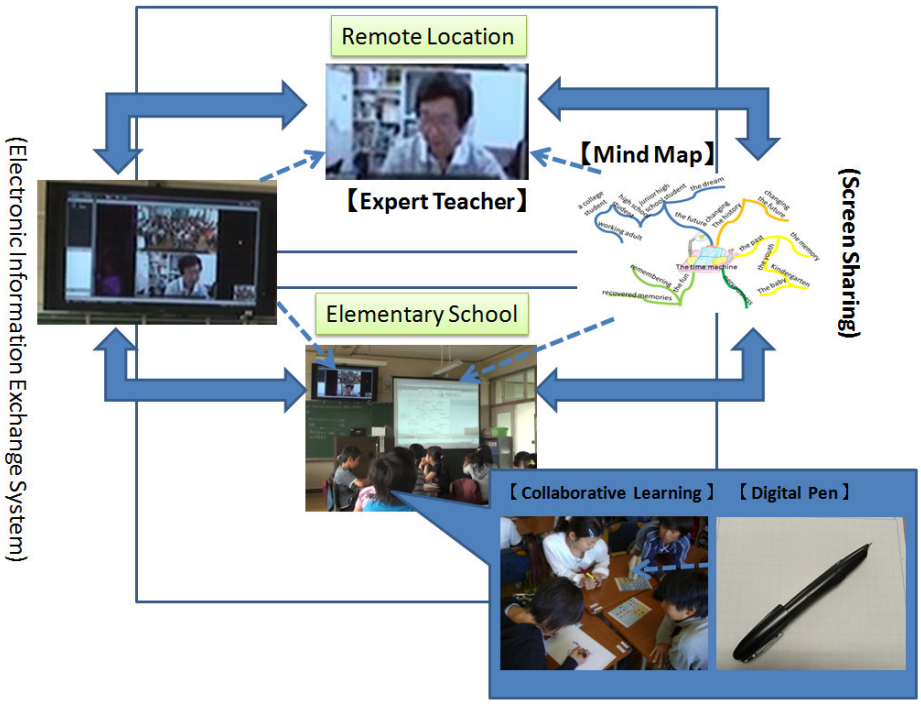

Figure1: The learning environment

3. Method

3.1 Instructional planning

The research took place from June 1 to July 13, 2011. The subjects were 94 fifth graders in three classes at a Tokyo public elementary school. Fifteen lessons were taught. Table 1 is the instruction plan.

Lesson number	Unit flow (class topics)	Notes
1	Students learn how to draw with a MM.	
2	Students learn how to write “idea sentences.”	
3, 4	Each child draws a MM. Students in each group draw a MM using a digital pen and share ideas. Groups share their ideas with the class through their MM. Students write “idea sentences” based on the shared MM.	Introducing the digital pen, the MM, and collaborative learning into lessons
5, 6	The same as lessons 3 and 4	
7, 8 Theme 1	Each child draws a MM. Each child writes a “pre idea sentence.” Groups share ideas with the class through their MM. The first expert teacher demonstrates how to “think the theme” using the video conferencing system and the screen. Then he	Verification Participation of expert teachers

	shows the shared mind-map. Children write "post idea sentences" based on the shared mind-map.	
9, 10 Theme 2	The same as lessons 7 and 8, but with the second teacher	The same as lessons 7 and 8
11, 12 Theme 3	The same as lessons 3 and 4 (that is, without the participation of the expert teacher)	No participation of expert teachers
13, 14 Theme 4	The same as lessons 11 and 12	The same as lessons 11 and 12
15	Students reflect on their learning.	

Table 1: Instructional planning

3.2 Regarding the Idea Sentences

The students wrote "idea sentences" of approximately 400 characters before and after the lessons. Themes were taken from Fujiwara (2010) and revised to some extent. It was decided that the students should complete the MM before writing the idea sentences (Figure 2). In addition, the number of characters in idea sentences was changed from 200 characters in Fujiwara to 400 characters because it had been previously found that the shorter sentences limited the students' ability to express themselves logically (Authors, 2012b).

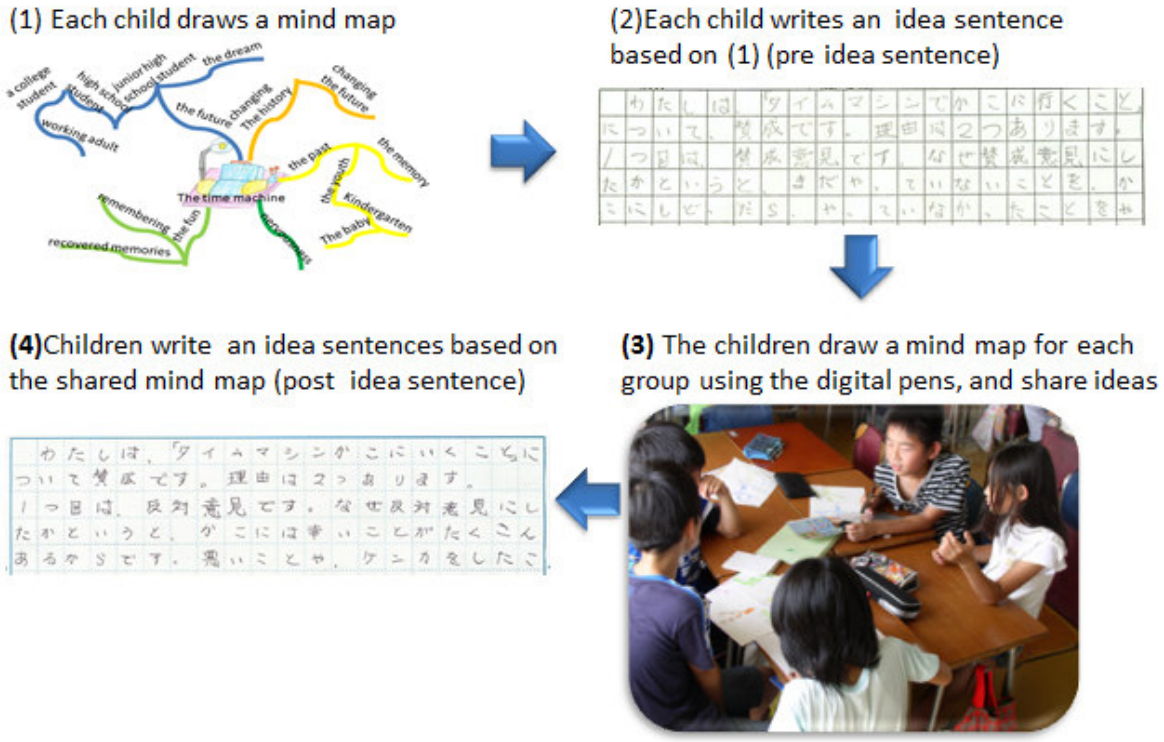

Figure2: The flow of a lesson

4. Evaluation Methodology

4.1. Attitude Survey

Students answered questions on a four-point Likert-type (from I agree to I disagree) scaled under topics such as “MM,” “expert teachers,” “digital pen,” “collaborative learning,” “lessons,” and so on. Students were asked about “the pleasure of learning activity with scaffolding,” “incentive in the near future,” “ease of writing the idea sentences using the MM,” “the expert teachers and the digital pen,” “deepening of the idea sentences through collaborative learning,” “ease of improving the idea sentences by collaborative learning and the help of the expert teachers,” and so on. Table 2 gives all questionnaire items; there were 34 in total.

■Questions about the MM
· Do you think that it was easy to write the idea sentences when drawing the MM? (MM1)
· Do you think that it was easy to understand how to draw the MM? (MM2)
· Do you want to draw a MM before writing an idea sentence in the future? (MM3)
· Do you think that it is pleasant to learn using the MM? (MM4)
· Do you want to introduce the MM learning method to students in other grades? (MM5)
■Questions about the expert teachers
· Do you think that the instruction from the expert teachers deepened your thought? (expt1)
· Do you think that the instructions of the expert teachers were easy to understand? (expt2)
· Do you want to receive more lessons from the expert teachers in the future? (expt3)
· Do you think that the instruction of the expert teachers influenced your idea sentences? (expt4)
· Do you think that it was easy to improve your idea sentences with the instruction of the expert teachers? (expt5)
· Do you think that it was pleasant to have the expert teachers’ instruction? (expt6)
· Do you want to introduce a learning method using the instruction of expert teachers to students in other grades? (expt7)
■Questions about the digital pen
· Do you think that your friends’ ways of using the digital pen deepened your thought? (DP1)
· Do you think that it was different drawing with the ordinary pen and the digital pen? (DP2)
· Do you want to study using the digital pen in the future? (DP3)
· Do you think that it was pleasant to use the digital pen? (DP4)
· Do you want to introduce learning using the digital pen to students in other grades? (DP5)
■Questions about collaborative learning
· Do you think that discussion with friends deepened your thought? (CL1)
· Do you think that the discussion with friends was easy to understand? (CL 2)
· Do you want to continue learning through discussion with friends in the future? (CL 3)
· Do you think that the discussion with friends influenced your thought? (CL 4)
· Do you think that it was easy to improve your idea sentences by discussion with friends in your group? (CL 5)
· Do you think that it was easy to improve your idea sentences by discussion with friends in your class? (CL 6)
· Do you think that it was pleasant to discuss with friends in your group or class?(CL 7)
· Do you want to introduce the method of discussion with your group or class to students in other grades? (CL 8)
■Questions about the lessons
· Do you think that it was pleasant to participate in the lessons? (Lesson1)

Table2: Attitude questionnaire items

Internal reliability was verified by Cronbach’s alpha, with results as follows: questions about the MM (Cronbach’s alpha=.745), questions about the expert teachers (.739), questions about the digital pen (.693), questions about collaborative learning (.855), question about the lessons (.826), and other questions (.693). Since scores of around .70 or higher are considered reliable, in the present case reliability was confirmed.

4.2. Analysis Procedure

Factor analysis was conducted to develop a causal relationship model based on factors extracted, and goodness of fit was verified by covariance structure analysis.

5. Results and Discussion

5.1. Extraction of Latent Variables

Exploratory factor analysis was conducted for the 34 grouped items. First, the unweighted least squares method or more. Next, factor analysis was conducted again after deleting questionnaire items with factor loadings of 0.4 or less in all factors or 0.4 or more in several factors. Seven factors were extracted, five of which are shown in the scree plot below (Oshio, 2011), as Figure 3.

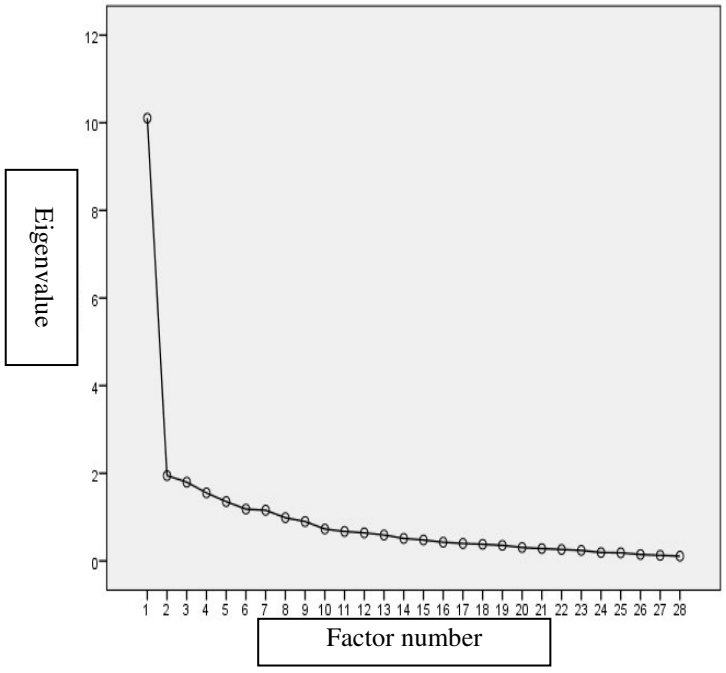

Figure 3: Scree plot on factors

No factor was used for the proposal of introducing these lessons to other students, as represented by question items such as MM5, because this does not bear on the identification of an effective scaffolding method (Matsuo & Nakamura, 2010).

Four factors were ultimately adopted. Factor patterns after the Promax rotation in the second factor analysis are shown in Table 3. Correlations between the factors are shown in Table 4. These four factors were named as follows: “Favorable impression and understanding of collaborative learning with the expert teacher,” as factor 1; “Understanding of and satisfaction with the lessons,” as factor 2; “Favorable impression of the digital pen,” as factor 3; and “Favorable impression of the MM,” as factor 4. These are shown in Table 3. Thus, these 4 factors were adopted as latent variables affecting the 15 items.

Correlations between the factors are shown in Table 4. Although there is almost no correlation between factors 3 and 4, there are moderately high correlations between any other two factors. This suggests that there are some causal relationships present (Toyoda, Maeda, & Yanai, 1992). These causal relationships here can be hypothesized as follows: 3. Favorable impression of the digital pen→4. Favorable impression of the MM→1. Favorable impression and understanding of collaborative learning with the expert teacher→2. Understanding of and satisfaction with the lessons.” This was called the “initial model.”

	Factor 1	Factor 2	Factor 3	Factor 4
MM3	.192	.031	-.002	.500
MM4	.007	.254	.129	.531
expert 2	.464	.178	.252	-.085
expt3	.732	-.011	-.050	-.011
expt6	.768	-.144	-.033	.021
DP3	-.176	.213	.919	.088
DP4	-.070	-.038	.845	.281
DP5	.107	-.282	.595	-.028
CL2	.410	.393	-.001	.059
CL3	.582	.389	.000	-.013
CL7	.936	-.066	-.031	.191
Lesson2	.034	.556	-.001	.122
Lesson 4	-.013	.720	.030	.088
Lesson 6	-.094	.636	-.019	-.018
Lesson 7	.637	-.046	-.218	.148
Contribution ratio	12.972	8.251	8.762	4.938

Factor extracting method: unweighted least squares method
Rotation method: Promax with Kaiser Normalization

Table 3: Four factors extraction and factor patterns

Table 4: Correlations between the four factors

Factor	1	2	3	4
1	1.000	.586	.502	.333
2	.586	1.000	.447	.343
3	.502	.447	1.000	.105
4	.333	.343	.105	1.000

Factor 1: "Favorable impressions and understandings on collaborative learning with the expert teacher"
Factor 2: "Understandings and satisfactions on the lessons"
Factor 3: "Favorable impressions of the digital pen"
Factor 4: "Favorable impressions of the MM"

In other words, it was presumed first that students' impressions of the MM would be more favorable if they also had favorable impressions of the digital pen and could draw the MM well; second, that students create ideas and key phrases in sequence by discussing the learning problem using the MM in their groups, and then share them with the expert teacher and with their classmates; and third, that favorable impressions and understanding of collaborative learning will improve when an expert teacher instructs students. Finally, students' understanding of and satisfaction with the lessons are improved by collaborative learning with the expert teacher.

5.2. Verification of the Model Regarding Student Satisfaction

The authors set 15 questionnaire items as observed variables and four factors extracted by factor analysis as latent variables in the initial model mentioned above which shows the causal relationships between factors. Covariance structure analysis was conducted using the maximum likelihood estimation for the model, and GFI, AGFI, AIC, and RMSEA were used to evaluate the model, with reference to Toyoda's discussion regarding the use of goodness of fit (Toyoda, Maeda & Yanai, 1992) (Toyoda 1998).

On this basis, the model shown in figure 4 (the "final model") was reached by repeating the analyses and interviewing teachers to account for differences between the initial model and the observed data. Figure 4 shows the

results: GFI is 0.917 and AGFI is 0.874. It can be suggested that the model in Figure 4 fits the phenomenon of educational practice at the elementary school, because GFI is higher than 0.9 and AGFI is not much lower.

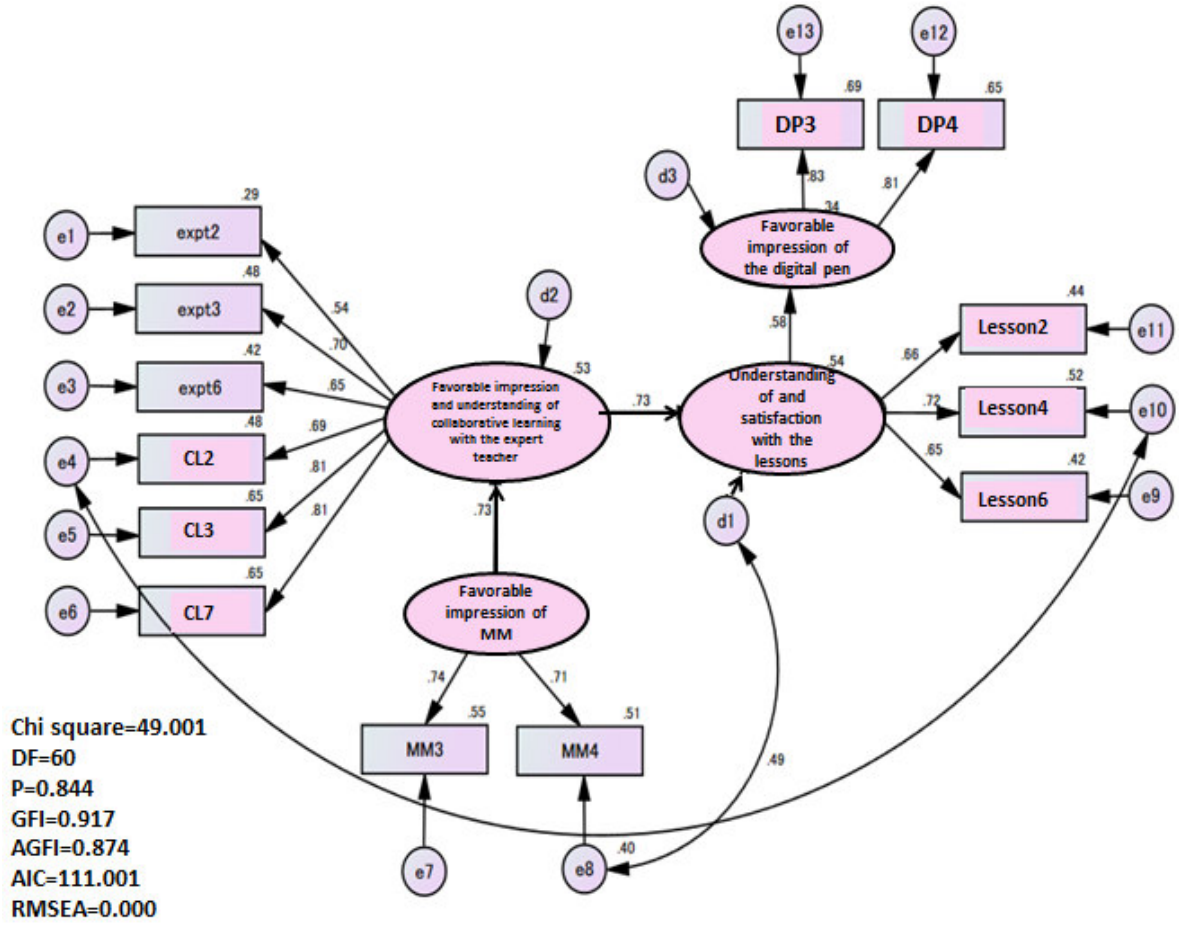

Figure 4: Covariance structure analysis between the four factors (final model)

In addition, a model with a smaller AIC value can fit the observed data well, and therefore it is the smallest one selected in Figure 4. Furthermore, it is indicated that the model is valid, because the RMSEA value is smaller than 0.05. The influence indices on all paths were significant at the 5% level. Therefore, figure 4 was adopted as the final model on the basis of the goodness-of-fit indices as mentioned above.

The final model shows causal relationships as follows: 4. Favorable impressions of the MM→1. Favorable impression and understanding of collaborative learning with the expert teacher→2. Understanding of and satisfaction with the lessons→3. Favorable impression of the digital pen. That is, first, students create ideas and key phrases in sequence using the MM by discussing the learning problem in groups. Then, at the point where students have favorable impressions of the MM, they share their ideas with an expert teacher and classmates, and the instruction of the expert teacher leads to favorable impressions and understanding of collaborative learning. Finally, collaborative learning with the expert teacher leads students to greater understanding of and satisfaction with the lessons.

It seems clear that students will recognize the benefits of the digital pen when they reflect on the lessons, because understanding of and satisfaction with the lessons affect impressions of the digital pen. Therefore, the students did not recognize the direct effect of the digital pen as they did with the other forms of scaffolding: the MM, the expert teacher, and collaborative learning. It seems that similar recognition of the digital pen depends on reduction of non-essential cognitive load (Oshima, 2008) by the digital pen. However, the digital pen made it possible for students to be taught by experts who were not physically present in the school and to share the ideas

with classmates easily. Therefore, the digital pen system seems to be a tool of clear utility as compared to ordinary writing implements.

6. Future Work

It is interesting that the digital pen does not affect learning outcomes directly. This suggests that this ICT tool that can be inconspicuously adopted in the classroom, which is valuable since it allows the preservation of the ordinary educational environment and context. It is important for teachers to understand and discuss the features, effectiveness, and utilization of various ICT tools based on data from real classroom settings, the advent of which can be expected in the classrooms of the not-too-distant future, and to move educational practice in corresponding directions. This study has shown that the digital pen is an advantageous but inconspicuous tool of this sort.

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