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A DESIGN EXPERIMENT IN ELEMENTARY SCIENCE LESSON USING CONCEPT MAPPING SOFTWARE FOR RECONSTRUCTING LEARNING PROCESSES: CONCEPTUAL UNDERSTANDING OF "THREE STATES OF MATTER"

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Abstract. In this study, we improved a science curriculum that was developed in 2004 using Concept Mapping Software for Reconstructing Learning processes, and introduced into a new lesson in 2006. The result of comparative analysis between two lessons showed that students in the lesson in 2006 had more deep understanding than the students in the lesson in 2004. Furthermore, teachers' evaluation revealed that this curriculum improvement was effective to support students deepen their scientific understanding.

1 Introduction

Concept maps (Novak & Gowin, 1984) are widely used in educational researches and practices to support externalizing the knowledge and thought of the learner. Recently, various software to create concept map on the computer have been developed (e.g. Cañas *et al*., 2004).

Inagaki *et al.* (2001) developed a concept mapping software to support externalizing learners' thinking process. Exploiting the digital computer technology, this software saves all operations, such as erasing or rearranging labels and links, and is able to play back the concept mapping process whenever necessary, even in the middle of the concept mapping. This function has been evaluated as a strong tool to support learners' reflection and dialogue.

This software has been introduced into many experimental lessons. For example, Daikoku *et al.* (in press) introduced this software into a junior high science lesson, and evaluated the effectiveness of using the software in collaborative learning environment. Deguchi *et al.* (2006) and Deguchi *et al.* (2007) showed that the bookmarking function of the software, a function to mark the specific points of all the concept mapping process, could support students reflection and dialogue.

In these experimental lessons, the effectiveness of the software to support learning has been revealed, but consecutive evaluation and improvement of the curriculum using this software have not conducted. Once a curriculum developed, it has to be refined and repeatedly introduced into actual lessons. Through such a research, it will be able to clarify the important points, that means design principle, in introducing concept mapping software into school lessons. From the viewpoint of design experiment, it could be noted that, such a curriculum introducing information technologies have to be consecutively improved to create a better learning environment (Brown, 1992).

In this study, we improved the curriculum using the software that was held in an elementary science lesson in 2004, and conducted a new lesson in 2006. Additionally, we had a comparative analysis and questionnaire based survey in order to evaluate the improvement of the curriculum.

2 Concept Mapping Software for Reconstructing Learning Process

Figure 1 shows the user interface of the concept mapping software for reconstructing learning processes. Text labels can be placed anywhere by dragging and dropping from the text label template to the desired position in the layout area. Images such as photos can be also placed in the concept map, as shown in Figure 1. To create a link, click consecutively on the two labels you wish to connect. To playback the concept mapping process, the playback button or the playback scrollbar is used. With the playback function, user can mark specific points in the concept mapping process. To mark the points, use the bookmarking function, then the bookmark (triangular mark) will appear above the playback scrollbar.

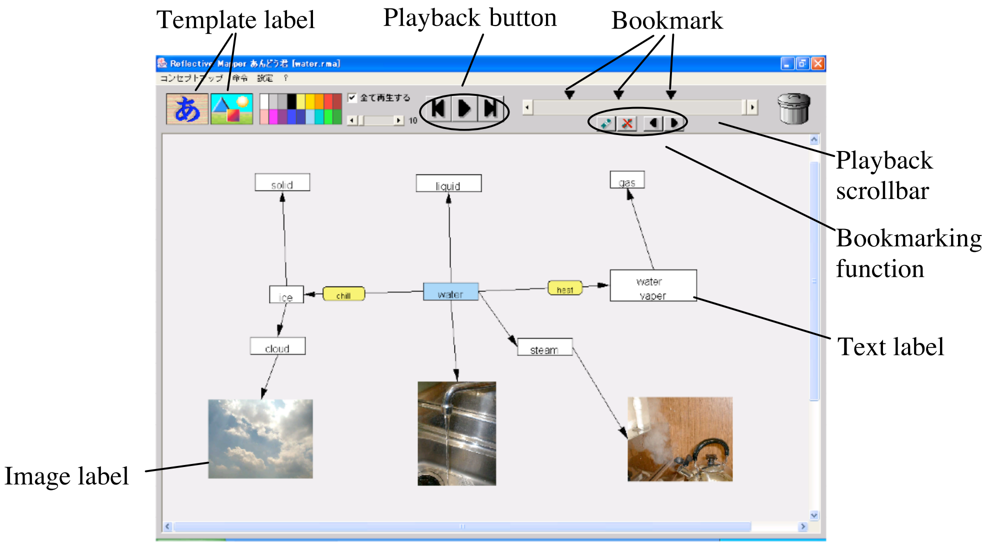

Figure 1. User interface of Concept Mapping Software for Reconstructing Learning Processes

3 Outline of the curriculum

The two lessons were conducted in a fourth-grade (ten years old) in a Japanese elementary school (lesson1: 34 students in 2004, lesson2: 35 students in 2006). The same unit “Three states of matter” (15 hours in total) were held in two lessons, and the purpose of the lesson was to understand that all kinds of matter have three different states, which are temperature-dependent. Throughout these lessons, each student created a concept map using the software. Table 1 shows the unit flow.

Figure 2 shows an example of the final scene of concept mapping by a student in lesson 1. The three states labels (solid, and liquid and gaseous) and ten substance labels(lead, wax, aluminum, naphthalene, salt, water, alcohol, carbon dioxide, oxygen, butane) were given to students. Students made links between state label to substance label if they think each substance change to each state.

Table 1. Unit flow

(1)	The teacher presents 10 materials (water, alcohol, aluminum, wax, lead, salt, naphthalene, butane, carbon dioxide and oxygen), and the students each predict whether these materials change their state (liquid, solid or gas) following temperature changes or not, and express their predictions by creating concept map using the software.
(2)	The class conducts experiments in which room-temperature liquid materials are cooled or heated, and the students correct their concept maps based on the results of the experiment.
(3)	Students reflect their concept-mapping process by using the software’s playback function and correct their predictions of the state changes of room-temperature solid and gaseous materials.
(4)	Students reflect on thinking processes by using the software’s playback function to look back on their concept mapping process and to explain their thinking processes others.
(5)	The class conducts experiments in which room-temperature solid materials are cooled or heated, and students correct their concept maps based on the results of the experiment.
(6)	Students reflect their concept-mapping processes by using the software’s playback function and correct their predictions of the state changes of room-temperature gaseous materials.
(7)	The class conducts an experiment in which room-temperature gaseous materials are cooled or heated, and students correct their concept maps based on the results of the experiment.
(8)	Students reflect their thinking processes by using the software’s playback function to look back on their concept mapping process and explain their thinking processes to others.

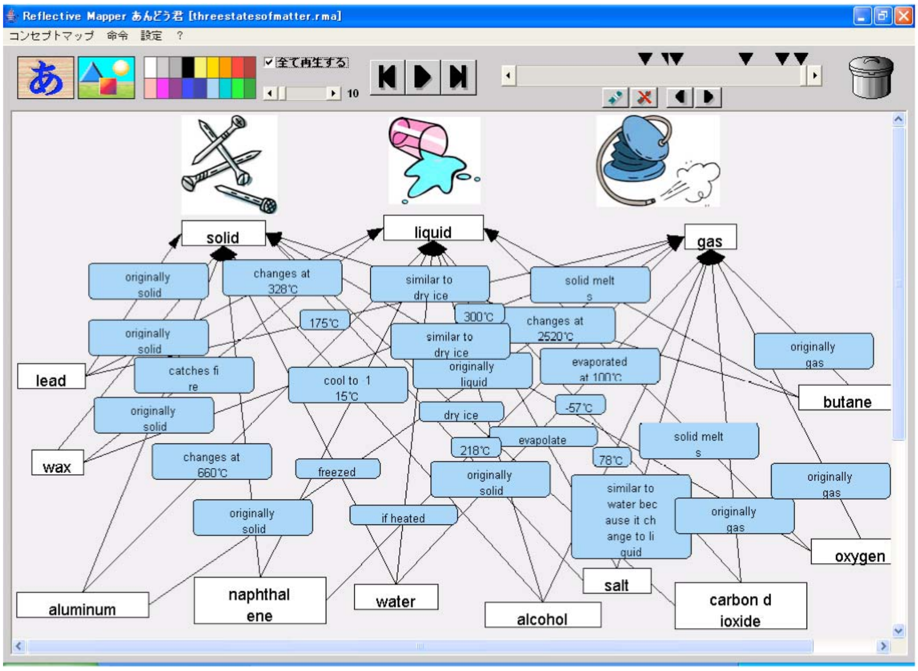

Figure 2. Example of a concept map created in the lesson 1

4 Improvement of the curriculum

Table 2 shows the curriculum improvement from the lesson in 2004 (lesson 1) to 2006 (lesson 2). The improved points were following three; form of concept map, manner of discussion, and focus on key factor.

4.1 Form of the concept map

In lesson 1, the form of concept map includes linking phrases between labels that represent detailed results of hands-on experiments that explained state changing of the substances (fig. 2). On the other hand, in lesson 2, we changed this form of concept map, not to make linking phrases and represent only links. One of the purposes of this lesson was to understand “every substances changes their states,” so we change the form of the concept map just to represent each substances “change” or “not change” their states by creating only links. Through this improvement of focusing students' simple idea of state changing on the concept map, we aimed to deepen students' scientific understanding of three states of matters.

4.2 Manner of discussion

When students have discussion (phase 4 and 8 in Table 1), in lesson 1, they explained their thinking process to others with no attention of common features or the different points between their concept maps. In lesson 2, we changed the manner of discussion to explain their thinking process with a focus on common features or the different points between their concept maps and to make intensive discussion about those features or points. We aimed to deepen students' scientific understanding of three states of matters through clarifying the viewpoints in explaining the thinking process, and focusing the discussion.

4.3 Focus on key factor

One of the key factors in this curriculum was the temperature, that substances change their states. In lesson 1, we didn't paid much attention on each temperature of state changing, but just showed the table of boiling and melting point at the end of the lesson. On the other hand, in lesson 2, we set the activity that students check boiling and melting point of the substances they treated after each three hands-on experiments (phase 2, 5 and 7 in Table 1). Setting this activity to confirm the boiling and melting point, we aimed that students reflect their own concept maps reconfirming the results of experiments which they changed the temperature of the substances. And furthermore, we aimed that students try to think “will other substances change their states if the temperature be changed?," that means, apply the concept of states changing of the substances represented on their concept maps to other substances they never treated in the lesson. Through such an experience, students' scientific understanding of three states of matter will be deepen.

Table 2. Improvement of the curriculum

	Lesson 1 (in 2004)	Lesson2 (in 2006)
Form of the concept map	With linking phrase	Without linking phrase
Manner of discussion	Without focus on common features or the different points	With focus on common features or the different points and make intensive discussion
Focus on key factor	Without focus on temperature that substances change their states	With focus on temperature that substances change their states

5 Comparative analysis of conceptual understanding

5.1 Method

5.1.1 Subjects

The subjects were the students joined the two lessons (lesson 1: 34 students, lesson 2: 35 students).

5.1.2 Tasks

Before and after the lesson regarding the three states of matter, each student had to take a pre-test and a post-test. Each test consisted of questions regarding 16 substances. Each question asked whether or not the substance existed in solid, liquid, and gaseous forms. In each question, students were given options: "exists," "does not exist," and "I have no idea." Before and after the lesson, students all together took a same test (pre-test and post-test). It took them approximately 15 minutes to answer the questions.

5.1.3 Analysis

Pre-test and post-test scores were obtained. One point was given to students who answered that every states of solid, liquid, and gas of a substance "exists." For nine substances learned in the unit, the perfect score was nine. For seven substances not learned in the unit, the perfect score was seven. For 16 substances in total, the perfect score was 16.

5.2 Results

Table 3 shows the results of the pre-test and post-test in lesson 1 and 2.

It shows the average score and standard deviation in the aspects of "all substances" "substances learned in the unit" and "substances not learned in the unit." In the aspect of "all substances," for example, students in lesson 1 had average pre-test and post-test score of 1.47 and 11.18, whereas in lesson 2 had 1.54 and 14.00. The average scores among the two lessons were compared using the one-factor analysis of variance between the subjects.

The result of the analysis of variance for the pre-test showed that in the aspects of "all substances" "substances learned in the unit" and "substances not learned in the unit," no significant differences in average scores were observed between the lessons ($F(1, 67)=0.20$ *n.s.* $F(1, 67)=0.60$ *n.s.* $F(1, 67)=0.02$ *n.s.*).

In the results of post-test, there was no significant difference in the aspect of "substances learned in the unit" between the lessons ($F(1, 67)=1.66$ *n.s.*). On the other hand, in the aspects of "all substances" and "substances not learned in the unit," there were significant differences in average scores between two lessons ($F(1, 67)=27.84$ $p<0.1$ $F(1, 67)=12.59$ $p<0.1$). It revealed that in the aspect of "all substances" and "substances not learned in the unit" in post-test, the average score of students in lesson 2 was significantly higher than that in lesson 1.

These results mean that in lesson 2 we improved the curriculum, the students were able to apply the knowledge about three states of matters to the substances that were not learned in the lesson, which could mean students' scientific understanding was deepen than in lesson 1.

Table 3. Results of the pre-test and post-test: average score (standard deviation)

Lesson	pre-test			post-test		
	all	learned	not learned	all	learned	not learned
Lesson 1	1.47	0.97	0.50	11.18	6.94	4.24
	(1.75)	(1.04)	(0.92)	(4.63)	(2.62)	(2.21)
Lesson 2	1.54	0.86	0.69	14.00	7.57	6.83
	(1.83)	(0.99)	(1.04)	(2.53)	(1.10)	(1.80)

N=34(lesson 1), 35(lesson 2).

6 Teacher's evaluation of improvement of the curriculum

6.1 Method

6.1.1 Subjects

The subject was an elementary school teacher who conducted lesson 2.

6.1.2 Tasks

A questionnaire based survey was conducted. The teacher answered the questions via e-mail. The teacher was told to freely answer the questions that ask whether three improvement points of the curriculum; form of concept map, manner of discussion, and focus on key factor were effective to deepen students' scientific understanding.

6.2 Results

The teacher evaluated that all of the three points to improve the curriculum were effective. Table 4 shows the results of the teachers' evaluation.

Regarding "form of concept map," he pointed that students could simply focus on the existence or nonexistence of the links by not representing linking phrase, when explaining their thinking and discussing the difference of their thinking. Furthermore, he also said that students could reflect their thinking process appropriately. From these results, this improvement was evaluated to be able to support students' discussion and reflection.

Regarding "manner of discussion," he evaluated that the activity of explaining their thinking process with a focus on common features or the different points and making intensive discussion about those features or points clarify the difference of their thinking, and focus the viewpoints of discussion. Furthermore, through recognizing the difference of their thinking, students could find the next issue. These results show that this improvement was evaluated to be able to support students' sharing of their thinking, and articulating the next issues to solve.

Regarding "focus on key factor," he evaluated that focusing on the boiling and melting point of the substances and confirming that state changing is related to the temperature could enhance the students' understanding of three states of matter. Furthermore, it was also evaluated that many students could apply the knowledge about three states of matters to the substances that were not learned in the lesson. From this result, this improvement was evaluated to be able to support students deepen their scientific understanding.

Table 4. Results of the teachers' evaluation

Aspects of improvements	Answer
Form of concept map	It was obvious when and how the links were added through playing back the concept mapping process. So students could reflect their thinking process appropriately. Without linking phrase, they could simply focus on with or without links, that means whether the substances change their states or not.
Manner of discussion	Students focus on the difference of their thinking each other. By focusing the point argument, they could intensively discuss why do they have different thinking, and deepen their understanding. For example, there was a student think that room-temperature gaseous substance change its state to liquid and solid, but another students think that change its states only to liquid. These situation made students recognize the next issue to solve.
Focus on key factor	After each three hands on experiments, I showed the table of boiling and melting point. I think, by confirming the temperature, students understand that substances change their states if they change the temperature. I think there are many students who could correctly apply the knowledge about three states of matters to the substances that were not learned in the lesson.

7 Conclusion

In this study, to make improvement of the elementary science curriculum using concept mapping software for reconstructing learning processes, we improved the lesson about three states of matter that was held in 2004 (lesson 1), and conducted a new lesson in 2006 (lesson 2).

We improved the curriculum based on three aspects, and conducted the comparative analysis of conceptual understanding, it was revealed that in lesson 2, students were able to apply the knowledge about three states of matters to the substances that were not learned in the lesson, which could mean students' scientific understanding was more deepen than in lesson 1. Furthermore, it was showed that the teacher who conducted lesson 2 evaluated that all of the three aspect of improvement were effective to support students deepen their understanding of three states of matter.

Following two points will be mentioned as future tasks. Firstly, more detailed comparison between two lessons has to be conducted. And secondly, design principle of the lesson in introducing concept mapping software into school lesson have to be more examined through accumulating consecutive research.

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References

Brown, A. L. (1992). Design Experiments: Theoretical and Methodological Challenges in Evaluating Complex Interventions in Classroom Settings. *The Journal of the Learning Sciences*, 2(2), pp.141-178.

Cañas, A. J., Hill, G., Carff, R., Suri, N., Lott, J., Eskridge, T., Gómez, G., Arroyo, M., Carvajal, R. (2004). CmapTools: A Knowledge Modeling and Sharing Environment, In: Concept Maps: Theory, Methodology, Technology, *Proceedings of the First International Conference on Concept Mapping*, A.J. Cañas, J.D. Novak, and F.M. González, Editors , Universidad Pública de Navarra: Pamplona, Spain. p. 125-133.

Daikoku, T., Funaoi, H., Deguchi, A., Inagaki, S., Yamaguchi, E. (in press). Teaching Method for Collaborative Note-taking Strategy to Improve Skill of Arranging Concepts, *Proceedings of World Conference on Educational Multimedia, Hypermedia & Telecommunications 2008.*

Deguchi, A., Inagaki, S., Yamaguchi, E., & Funaoi, H. (2006). Situated Evaluation of Concept Mapping Software with Bookmarking Function for Supporting Reflection and Dialogue: Interaction Analysis of Collaborative Learning Processes. *Proceedings of World Conference on Educational Multimedia, Hypermedia & Telecommunications 2005*, pp.2111-2118.

Deguchi, A., Inagaki, S., Yamaguchi, E., & Funaoi, H. (2007). Thinking process based reflection promotes conceptual change: In the lesson of “Three States of Matter” using concept mapping software for reconstructing learning processes. *Paper present at the meeting of* the *National Association for Research in Science Teaching*, New Orleans, LA, [CD-ROM].

Inagaki, S., Funaoi, H., & Yamaguchi, E. (2001). Development and evaluation of a concept mapping software to reconstruct learning processes. (in Japanese), *Journal of Science Education in Japan*, 25(5), 304-315.

Novak, J. D., & Gowin, D. B. (1984). *Learning How to Learn*. New York: Cambridge University Press.