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The Effects of Motivational Teaching Strategies on Learning Behavior among Peers during Collaborative Learning

TAKAGAKI, Mayumi
International and Cultural Studies,Tsuda College

NAKANISHI, Yoshifumi
Faculty of Education, MIE UNIVERSITY

TAZUME, Hirotsugu
Faculty of Education, Kyoto University of Education

SHIMIZU, Makoto
Faculty of Education, Saitama University

Abstract

A strategy of collaborative learning for teaching the Volume and Temperature to 4th graders was developed for each sub-category of motivation-enhancing structures (i.e., Task, Authority, Grouping, Evaluation) proposed by Maehr & Midgley (1991). The purpose of this study was to investigate how our teaching strategies affect the scientific understanding and learning behaviors among peers in the lessons. The analyses of the data included a quantitative analysis based on pre and post unit questionnaires, a descriptive analysis based on the concept of “thermal motions of the atoms,” and an interpretive analysis based on students’ dialogue and behaviors during each class process. These analyses indicated the following : 1) our teaching strategies promoted the acquisition of scientific concepts (volume increases but mass does not change with increased temperature), 2) metacognitive social elaboration was induced by introducing function of teaching strategy’s element related personal preconceptions and experiences to task, and made optimum choices to examine the predictions, and 3) expectancy from others in social relationships was promoted by introducing function of teaching strategy’s element supported for participation and discussion, and evaluated reciprocally among peers based on individually. In addition, these results suggested a need for another indirect constraint condition besides these direct consideration.

Key Words : teaching strategy, conceptual change, social elaboration, expectancy from others, learning strategy, collaborative science learning

1. Issues and Purposes

“Cooperative learning,” such as through discussions with classmates and experiment/observation activities, as well as individual learning is often integrated in actual educational situations such as schools. In order to enhance “motivation” and promote understanding not only for individuals but also for groups, teachers are required to take a multifaceted instructional approach in these cooperative learning situations.

Maehr and Midgley (1991) integrated cognitive, emotional, and social factors of motivation, based on Epstein's (1989) theory, so as to enhance learner motivation and understanding of the curriculum contents in cooperative learning. They then structured relevant factors into six dimensions: (1) Task (All learners attempt and appreciate the fun of learning. Associate the task so as to make use of pre-existing knowledge and daily experience); (2) Authority (Make the best choice, or decision in learning situations by oneself. Develop responsibility, independence, and learning skills. Acquire self-regulating skills for learning); (3) Grouping (Solve problems/make decisions in group settings, interact with peers in a significant manner. Acknowledge one another's unique ideas, and recognize one's ability to make a contribution); (4) Evaluation (Evaluate the progress toward one's goal, and improve one's performance. Realize the improvement in knowledge and skills, and recognize one's sense of competence and self-efficacy); (5) Recognition/Reward (Offer an opportunity for all learners to be recognized and a reward for each effort and progress); and (6) Time (Develop one's time management skills, and pursue learning at the learner's pace as much as possible). These dimensions are called the TARGET structures, an acronym composed of the first letters). The framework of the TARGET structures offers valuable insight in terms of being able to directly take a multifaceted instructional approach to enhancing motivation in situations of teaching cooperative learning.

On the other hand, in a previous practical study in educational psychology, dimensions such as the following have been considered to enhance motivation and promote understanding: "Task" (e.g., Bridging strategy: Bridge existing knowledge and tasks to be acquired through dialogue (Clement, 2008)), "Grouping" (e.g., Participants structure: Give a role to all group members and hold them accountable (Herrenkohl, Palincsar, DeWater, & Kawasaki, 1999)), "Evaluation" (e.g., Mutual teaching: Ask questions from one another, clarify meanings, and pursue learning while getting feedback from one another (Palincsar, Collins, Marano, & Magnusson,2000)). But unlike these previous studies, the theoretical framework proposed by Maehr and Midgley (1991), structures cognitive, emotional, and social factors regarding motivation in an integrated way to enhance learner motivation and understanding of the curriculum contents.

In fact, as an attempt to put the theory proposed by Maehr and Midgley (1991) into class practices, Takagaki, Tazume, Nakanishi, Nami, and Sasaki (2009) formulated teaching strategies to respond to the sub-dimensions of the TARGET structures, and empirically examined their teaching effects. Adjusting to the Japanese educational context, Takagaki et al. (2009) devised teaching strategies where "Task", "Authority", "Evaluation", and "Grouping" dimensions were applied to cooperative group learning situations for the unit "the properties of aqueous solutions" of sixth-grade science at elementary schools. Result of conducting the class revealed that the acquisition of a scientific concept regarding properties of aqueous solutions (" that the properties of a solid dissolved in an aqueous solution can be differentiated from those prior to dissolution") was facilitated. Furthermore, when the effects of teaching strategies on changes in a person's perspective on learning, motivation, and learning strategies were analysed, there was an increase in "the emphasis on scientific procedure" in learning and "planning" metacognitive strategies within an individual.

Takagaki et al. (2009) investigated a situation in which cooperative group learning was taught by putting the TARGET structure theory into class practice. The result is important in that the strategy was confirmed to enhance conceptual understanding of the subject content, as well as learning behavior within an individual. Nevertheless, since the research dealt with the influence of devised teaching strategies on learning behavior "within an individual" in cooperative learning situations, it is not clear how the strategies affects learning behavior "between individuals" in such situations. Thus, the issue still remains to be clarified.

Various studies on learning behavior through cooperation between individuals have shown that "metacognitive activities" are encouraged in relationships with others. For example, promotion of monitoring by division of labor among task performers (e.g., Miyake, 1986) and facilitation of planning by sharing the decision-making process (e.g., Barnes & Todd, 1977; Rogoff, 1993) has been indicated in those activities. In addition, studies have demonstrated that in learning through cooperation between individuals, "social relatedness" such as progress management, conflict resolution, and use of different views in relationships with others make a difference in learning effectiveness (e.g., Cohen, 1994). However, it has not been empirically demonstrated what teaching strategies would promote which kind of "metacognitive activities" or "social relatedness" in cooperative learning situations in school education.

Therefore, the present study was designed to examine the effect of devised teaching strategies on learning behavior "between individuals" in cooperative learning in a class that puts the TARGET structure theory into teaching practices. More specifically, we used a scale that was developed by Kinoshita, Matsuura, and Kadoya (2005) to measure the process of metacognition in relationships with others and the social relatedness scale (Relatedness Scale to the Circumference at Learning Scene: RSCL; Suzuki, 1999).

This study will address the unit "The relationship between volume and temperature" in the science class. A study goal of "studying changes in metal, water, and air by heating or cooling, and thinking about their properties" is presented for fourth-grade science B: Matter and Energy in the revised courses of study (the Ministry of Education, Science, Sports and Culture, 1999). However, the difficulty children face in understanding "the change of air" has become an issue at schools (Yamaoka, 2008). One of the reasons is that because air (gas) cannot be visually captured in a direct manner, or recognized through the five senses, unlike a metal (solid) or water (liquid), it is hard to realize that air changes its "volume".

Thus, attempts have been made to conduct classes in which changes in air are visualized, using schematic models of particles (air particles) with a "microscopic view of particles", instead of merely making observations of an experiment according to the current textbook (Kato & Motozawa, 2006). It is not be sufficient to just use the schematic model of particles. Ideas that a large number of children tend to spontaneously express include "the rising model (the volume expands with increase in temperature because the number of particles produced rises)" and "the expansion model (the volume expands with increase in air temperature because the particles themselves expand)". They attempt to understand the phenomenon of volume expansion by relying on these erroneous concepts (Kato, 2006).

According to Morishita (1983), one of the factors leading to the creation of these erroneous concepts is that only the "volume" of air is addressed in traditional classes. Matter has properties such as “volume” and “weight” by nature, and it is necessary to conduct classes that also focus on “weight” to make children comprehend changes in matter. In fact, the rising model and the expansion model cannot explain the phenomenon in which “the volume expands while the weight remains unchanged”. This is explainable on the basis of “the motion model (particles generate considerable energy with increase in air temperature, which excites thermal motions. Although the motion range of particles (volume) increases, the molecules themselves (the number and form) remain unchanged; thus, they will not change in mass)”.

In light of the problems described above, we planed to conduct classes in which changes are visualized, using a schematic model of particles with a “microscopic view of particles”, focusing on the “changes of air” for the unit “The relationship between volume and temperature” in this study (conducted in Session 1 (Periods 1 and 2)). Furthermore, we planned to make the children focus on 2 properties, volume and weight of air, and contrast their preconception of “both volume and weight increase”. Then, we will conduct classes to transform their concept to a scientific one “volume increases, but weight remains unchanged” (conducted in Session 4 (Periods 7 and 8)), and examine whether or not the conceptual change regarding thermal motions of particles was promoted. These classes would be different from the study by Takagaki et al. (2009) in that they made the children focus on 1 property, “form” of a material dissolved in an aqueous solution (solute) in a sixth graders class for “how a material is dissolved”.

Based on the above findings, the purpose of this research was to investigate how and what factors related to teaching strategies affect learning behavior between individuals in cooperative learning situations, by implementing devised classes to create conceptual changes, which were not clarified in the study conducted by Takagaki et al. (2009). The following methods of analysis were adopted for the above purpose: A qualitative analysis was performed on conceptual changes within an individual in responding to pre- and post-unit tests. We addressed metacognitive activities and social relationships with others in changes to learning behavior between individuals: Questionnaires were administered before and after the classes, and general characteristics were analysed using quantitative comparative analysis. Based on the results, we performed an interpretive analysis of the children’s words/comments and behavior during classes in order to clarify the transformation process of learning behavior between individuals from a microscopic perspective.

2. Method

2. 1 Participants

Fourth graders of an elementary school affiliated with T University (N = 39, 20 boys and 19 girls, from one class) and the teacher (the fourth author), a male science teacher with 27 years of experience. The first author and the teacher together created a unit teaching plan, the teacher’s questions, presentation, and explanations.

2. 2 Classes

The classes totalling 10 hours for the science unit, “The relationship between volume and temperature” was conducted between mid-November and early December. The classes were devised according to the unit teaching plan for the textbook “The relationship between volume and temperature” which is compliant with the current “the new courses of study for elementary schools (the Ministry of Education, Science, Sports and Culture, 1999) that consists of 4 Sessions with 8 Periods, with 1 Period lasting 45 minutes.

The theoretical framework of the TARGET structures (Maehr & Midgley, 1991) was to be applied to empirical class practices in Japan for an interventional study. The 4 sub-dimensions, (1) Task, (2) Authority, (3) Grouping, and (4) Evaluation were adopted from research by Takagaki et al. (2009): See Table 1 (goals of the sub-dimensions are in parentheses). When applying the sub-dimensions (1) to (4) above, to education practice in learning situations in Japan, the interventional strategies used as effective instructions by teachers were called “Teaching Strategies” in the present study (Table 1).

2. 3 Procedure

(1) Tests: The same tests were administered before (pre-) and after (post-) the unit and 4 weeks post-unit (transfer) to directly compare understandings of thermal motions of particles in the class teaching the “The relationship between volume and temperature”. Since the content (“volume increases, but weight remains unchanged”) was validated in an experiment in the summary Session 4 (Periods 7 and 8), an experiment to give an example was not conducted. The following multiple-choice questions were presented in the tests, and the children were asked to describe the reasons freely by drawing (schematic models) or in a sentence: Task 1 - “We have heated air contained in a flask. What will become of the air volume? Chose the correct answer from a. through c. (a. Volume increases, b. Volume decreases, and c. Volume remains unchanged) and circle the answer”. Task 2 – “Then, what will become of the weight of the air? Chose the correct answer from a. through c. (a. Weight increases, b. Weight decreases, and c. Weight remains unchanged) and circle the answer”. The correct answers are a. for Task 1 and c. for Task 2. The tests were printed on a sheet of A4 size paper. The teacher read out the questions and the choices, and asked the children to write their own thoughts, as this was not an achievement test. He also told them that the result would not affect their science grade. The test, which should take about 10 minutes, was administered during a break between classes.

(2) Questionnaires: A survey questionnaire was administered before and after the classes; wording of some items of the scales were modified so that elementary school children could answer them. To measure the process of metacognition in relationships with others, the sub-scale (7 items) of “Metacognition by relationships with others” developed by Kinoshita et al. (2005) was adopted. In addition, “Relatedness Scale to the Circumference at Learning Scene (RSCL)” by Suzuki (1999) was used to measure how people were involved with others in learning situations and how they understand others’ expectations. This scale consisted of sub-scales “Role of teaching” and “Others’ expectations” with 3 items each, a total of 6 items. We asked the children to choose an answer for each item on a 5-point scale (“1. Not at all true” to “5. Absolutely true”) (Tables 3 and 4).

(3) Recording of the classes: During the 10-hour classes, a video camera and a digital voice

Table 1. Teaching strategies for promoting motivation in the science classes on “the volume and temperature of substances” (eight periods)

Process of the classes	Dimensions and goals of motivation	Presented tasks	Learning activities using teaching strategies in science classes	
[Pre-unit test] The first session (the first and second period)	【Common to the four sessions】 ① **Task**: Feeling the pleasure of learning Associating the task with prior knowledge and experience All the learners make an effort ② **Authority**: Developing responsibility,	① Behavior changes in the state of air according to the temperature changes through heating are freely anticipated, through association with prior knowledge and experimental results about properties of air, which were studied in science classes in the third grade and experiences in daily life among others.	② Changes in the volume of air through heating are estimated. The optimum method for examining the prediction is selected. →Changes in the volume of air are examined using balloons, soap films, ping-pong balls, beach balls, among others, based on prior knowledge and life experiences. ③ Through experiment and discussion conducted by groups, each self-generated model of air behavior is visualized and students notice various ideas. ④ Through example setting experiments, it is confirmed that the volume of air increases through a raise in temperature. Through reviewing the experimental results, the reason of an increase in the volume of air is re-examined using the self-generated model diagram.	【Common to the four sessions】 ② Acquiring knowledge and skills that are the base of experiments Collecting experimental data and recording the results accurately, with comparing them with anticipation one by one ③ In advance, the teacher explains the way of listening to other members’ ideas, the way of making persuasive speech, and the way of making questions or arguments in group activities. Furthermore, the teacher explains about cooperation in group activities such as sharing the role of recorders and presenters, and consideration of
The second session (the third and fourth period)	independence, and learning skills In the learning situations, optimum choice is conducted. Acquiring self-control skills for learning ③ **Grouping**: Problem solution and decision making are conducted by groups. Sufficient	① Behavior changes in the state of water through heating are freely predicted, remembering the difference in the feeling in hands between at pushing a water pistol and air pistol, which were made in science classes in the third grade, and based on the experimental results in the first and second periods.	② Changes in the volume of water through heating are estimated. The optimum method for examining the prediction is selected. →Changes in the volume of water are examined using syringes, glass tubes, colored water, mercury thermometers, among others, based on prior knowledge and life experiences. ③ Through experiment and discussion conducted by groups, each self-generated model of water behavior is visualized and students notice various ideas. ④ Through example setting experiments, it is confirmed that the volume of water increases through a raise in temperature, though the change is less than air. Through reviewing the experimental results, the reason of an increase in the volume of water is re-examined using the self-generated model diagram.	
The third session (the fifth and sixth period)	interaction with group members is conducted. One’s ability to make a contribution is recognized. ④ **Evaluation**: Improvement of one’s own performance Progress in understanding, competence and self-efficacy are recognized.	① Behavior changes in the state of metal through heating are freely anticipated, remembering the phenomena in daily life such as railroads bending because of extreme heat, and comparing the experimental results in the first/second periods and third/fourth periods.	② Changes in the volume of metal through heating are estimated. The optimum method for examining the prediction is selected. →Changes in the volume of metal are examined using coins (one-yen, five-yen, ten-yen, and fifty-yen), metal balls, wires, among others, based on prior knowledge and life experiences. ③ Through experiment and discussion conducted by groups, each self-generated model of metal behavior is visualized and students notice various ideas. ④ Through example setting experiments, it is confirmed that the volume of metal increases through a raise in temperature, though the change is further less than air and water. Through reviewing the experimental results, the reason of an increase in the volume of metal is re-examined using the self-generated model diagram.	participation by all the members. ③ Sufficient time is given to examine various ideas, integrate them, and solve problems by group members. ④ The teacher walks around the class, checks the experimental conditions designed by groups, promotes them or gives advice to correct them if they are inappropriate.
The fourth session (the seventh and eighth period) [Post-unit-test]		① Changes in the weight of air, water, and metal through heating are freely anticipated based on the experimental results about volume changes through heating air, water, and metal, obtained from the first to sixth periods, and based on the self-generated model of each student.	② Changes in the weight of air, water, and metal through heating are estimated based on the self-generated model, designed by each student. Then, measurement is conducted using an electronic balance. ③ Through experiment and discussion conducted by groups, the phenomenon of “heating substances increases their volume but does not affect the weight” is re-interpreted through comparing ideas of each self-generated model. ④ Using a grain model indicated by the teacher, it is confirmed that mass does not change through a raise in temperature because of the following reason: when temperature of air, water, and metal rises, thermal motions of grains become active and the range of motion (volume) of grains is expanded. However, molecules themselves (the number and forms) do not change. The reason of an increase in the volume and no change in the weight of air, water, and metal is re-examined using the self-generated model diagrams.	④ During the summarizing time in the class, experimental results are presented. Understanding is deepened through comparing with the results of other groups’ experiments and example setting experiments. ④Teachers comprehend students’ understanding situation through presentation and observation cards, make an evaluation and give suitable feedbacks. When students want to conduct re-experiment, teachers should give them a chance to improve.
[Delay test] (After four weeks)		① Remembering what was learned about the volume and temperature of substances	④ From the microscopic perspective of grains, changes in the volume and weight through heating air, water, and metal are explained using self-generated model diagrams.	

Note) The learning contents were designed based on the guidance plans of “the volume and temperature of substances, the fourth grade of elementary school,” included in the textbook based on “the new guidelines for elementary schools.” The difference from the former scheme is that “teaching strategies in science classes,” which is based on “dimensions and goals of motivation (referring Maehr & Midgley, 1991), is included in the classes in each session. Underlined parts indicate the factors of teaching strategies corresponding to the contents of “dimensions and goals of motivation.”

recorder per group were set up to record images and voices. Information necessary for qualitative analysis that could not be recorded by the video, such as the whole picture of the class, the contextual flow and situation, minute facial expressions and gestures were recorded in writing.

3. Results and Discussion

3. 1 Acquisition of the concept regarding thermal motions of particles

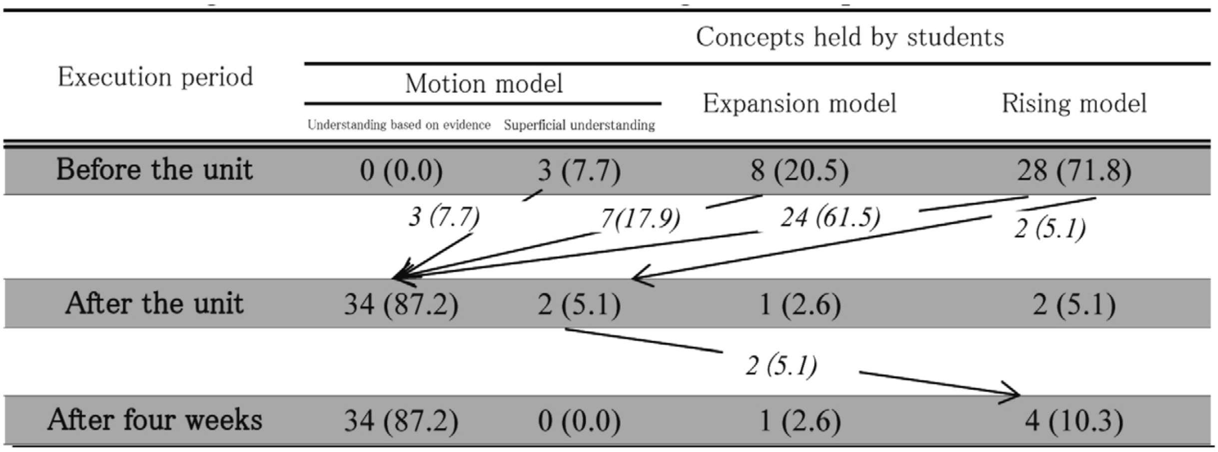
With respect to the analysis of conceptual change process, “an analysis of changes in held concepts” was performed, and a standpoint to find out characteristics of the overall changes was explored. The test answers were analyzed and the held concepts were categorized to clarify the change process. Table 2 shows the criteria. However, it is also possible that the correct answers on the post-unit test could be based on a superficial understanding by just memorizing the knowledge gained in the class. Thus, in order to examine whether a scientific concept was acquired through understanding based on the evidence provided in the experiment/observations or only a superficial understanding was involved in the children who answered correctly, we qualitatively analyzed thefree descriptions regarding the reasons of their choices. As for the evaluation criteria, an answer was considered to be due to a “superficial understanding” when it was given by a simple guess or memorization of terms, whereas an answer was regarded as an “understanding based on the evidence” if it was given based on the evidence the children themselves validated through their experiment. The latter was defined as acquisition of a scientific concept in this study. The first author, the teacher specialized in science, and a graduate student of educational psychology independently evaluated the answers according to the categorization criteria, and the inter-rater agreement was 92.3%. In case judgment by the 3 raters differed, they reassessed it after discussion.

Table 2 shows the held concepts and the number of children by the change pattern. Prior to the unit, children who held “the rising model (71.8%)” was significantly higher than those with “the expansion model (20.5%)”, “the motion model: Understanding based on the evidence (0.0%)”, and “the motion model: Superficial understanding (7.7%)” ($\chi 2$ (3)= 48.90, p<.001: Multiple comparisons were performed using the Ryan’s nominal significance level of 5%. The same procedure was also used for the subsequent $\chi 2$ tests).

$\chi 2$ tests were conducted for the changes in held concepts before the unit and after the unit, with the number of each concept on the former as the expected frequency and that on the latter as the observed frequency. Because the expected frequency included a cell of 0, 0.5 was added to each cell for convenience sake. As the result, the number of children with “the motion model: Understanding based on the evidence (87.2%)” increased, and the number who held “the expansion model (2.6%)” and “the rising model (5.1%)” decreased after the unit, compared with before the unit ($\chi 2$ (3)= 2392.06, p<.001). The number of children who experienced change in held concepts was 36 (92.3%); 34 of them (87.2%) changed to “the motion model: Understanding based on the evidence” and 2 of them (5.1%) changed to “the motion model: Superficial understanding”. The former number was significantly greater than that of the latter (Fisher’s exact tests (two-tailed tests) p=.001). Although conceptual change between the post-unit test and 4weeks post-unit test was studied using the same method, no significant change was found in the number of children for each concept (χ2 (3)= 4.00, n.s.), and only 2 children (5.1%) showed conceptual change, which was from “the motion model: Superficial understanding to the rising model”.

In summarizing the results noted above, children who held “the rising model”, “the expansion model”, or “the motion model: Superficial understanding” (i.e., erroneous concepts) before the unit (pre-unit test) were found to have acquired “the motion model: Understanding based on the evidence” (i.e., a scientific concept) after the unit (post-unit test). The result indicated that they still held the scientific concept on the 4 weeks post-unit test (transfer test).

Table 2. Changes in the number of learners holding each concept



Execution period	Concepts held by students			
	Motion model		Expansion model	Rising model
	Understanding based on evidence	Superficial understanding		
Before the unit	0 (0.0)	3 (7.7)	8 (20.5)	28 (71.8)
After the unit	34 (87.2)	2 (5.1)	1 (2.6)	2 (5.1)
After four weeks	34 (87.2)	0 (0.0)	1 (2.6)	4 (10.3)

Note) The numbers attached to arrows indicate the number of students whose concept has changed (the numbers in quote show the percentage to the whole number of students (%)). The number of students that showed no changes was omitted.

The classification standards of each model based on testing are as follows:

“Motion model: Selecting an increase in volume, no changes in mass (Task 1=ア, 2=ウ). As the reason of the selection, describing “Though motions of grains become active through a rise in temperature, the number and size of the grains do not change. it includes understanding based on evidence, which derives the reason based on the results of experiments and observation, and superficial understanding, which does not. An example of the understanding based on evidence:” “When the temperature is raised, motion of air grains became active, a soap film swelled and the volume increased. However, since the number and size of air grains do not change, the weight was always 35.8g and did not change, through several measurements using an electronic balance.”

Expansion model: Selecting an increase in both volume and mass (Task 1=ア, 2=ア). As the reason of the selection, describing “as the temperature rises, brains swell out large.”

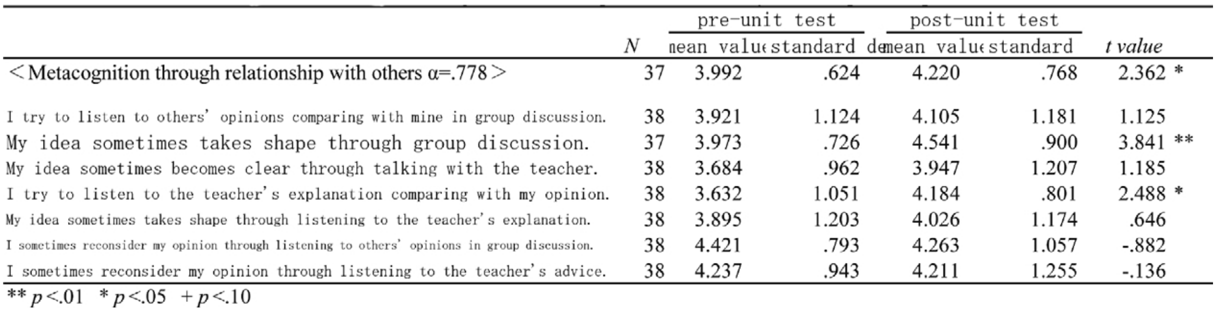
Rising model: Selecting an increase in both volume and mass(Task 1=ア, 2=ア). Explaining the reason that a rise in the temperature rapidly generates rising grains.

3. 2 Changes in learning behavior between individuals

First, Cronbach’s α coefficient was calculated to give consideration to internal consistency of the metacognition measurement scale and RSCL after constructing sub-scales in accordance with previous research. The result indicated that α for “Metacognition by relationships with others” was .778, .826 for “Role of teaching” of RSCL, and a particularly low coefficient (α=.434) was found for “Others’ expectations”. Although adequate levels of α coefficient for usual scale construction were noted for the items other than “Others’ expectations”, extraneous items were also included within the same sub-scale. Therefore, as it seems possible that some items will be more affected than others by the classes, we will conduct examinations of each item in this study, using the sub-scales constructed in the previous research.

Next, paired t-tests were conducted for each sub-scale score to see the change from the pre-class and post-class scores (Tables 3 and 4). Data with a missing value in questionnaire items were excluded from the analysis. The result demonstrated a significant increase in the score of “Metacognition by relationships with others” (t(37)= 2.362, p<.05). As to sub items, there were significant increases in the scores of “Sometimes I can collect my thoughts while talking in a group” (t (37)= 3.841, p<.01) and “I try to listen to my teacher’s explanation while comparing with my opinion” (t (37)= 2.488, p<.05). The 2 items that showed a significant change and the behaviors indicated in the items “I try to listen to my friends’ opinions while comparing with my opinion in group discussions”, “I sometimes get clear about my thoughts while talking to my teacher”, and “Sometimes I can collect my thoughts while listening to my teacher” are considered to be a “behavior in which one examines one’s thoughts by comparing with others’ while clarifying one’s opinion in a social relationship”, which can be regarded as an item related to “Social refinement”. On the other hand, the items other than these are considered to be “Reconstruction of opinion”.

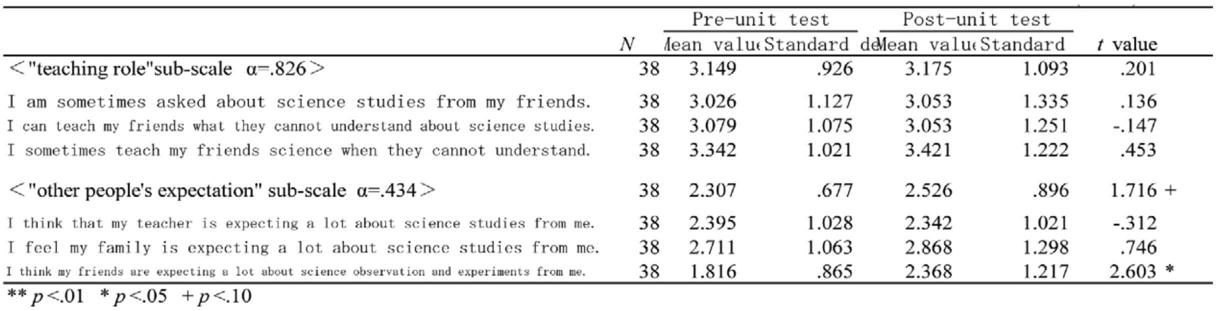
Table 3. Differences in scores of each item of metacognition scale of questionnaire survey between pre- and post-unit test



		pre-unit test		post-unit test		
	N	mean valu	standard de	mean valu	standard	*t value*
＜Metacognition through relationship with others α=.778＞	37	3.992	.624	4.220	.768	2.362 *
I try to listen to others’ opinions comparing with mine in group discussion.	38	3.921	1.124	4.105	1.181	1.125
My idea sometimes takes shape through group discussion.	37	3.973	.726	4.541	.900	3.841 **
My idea sometimes becomes clear through talking with the teacher.	38	3.684	.962	3.947	1.207	1.185
I try to listen to the teacher’s explanation comparing with my opinion.	38	3.632	1.051	4.184	.801	2.488 *
My idea sometimes takes shape through listening to the teacher’s explanation.	38	3.895	1.203	4.026	1.174	.646
I sometimes reconsider my opinion through listening to others’ opinions in group discussion.	38	4.421	.793	4.263	1.057	-.882
I sometimes reconsider my opinion through listening to the teacher’s advice.	38	4.237	.943	4.211	1.255	-.136

** *p*<.01 * *p*<.05 + *p*<.10

Table 4. Differences in the scores of the sub-scale and each item of Relatedness Scale to the Circumference at Learning Scale (RSCL) between pre- and post-unit test



		Pre-unit test		Post-unit test		
	N	Mean valu	Standard de	Mean valu	Standard	*t* value
＜"teaching role"sub-scale α=.826＞	38	3.149	.926	3.175	1.093	.201
I am sometimes asked about science studies from my friends.	38	3.026	1.127	3.053	1.335	.136
I can teach my friends what they cannot understand about science studies.	38	3.079	1.075	3.053	1.251	-.147
I sometimes teach my friends science when they cannot understand.	38	3.342	1.021	3.421	1.222	.453
＜"other people's expectation" sub-scale α=.434＞	38	2.307	.677	2.526	.896	1.716 +
I think that my teacher is expecting a lot about science studies from me.	38	2.395	1.028	2.342	1.021	-.312
I feel my family is expecting a lot about science studies from me.	38	2.711	1.063	2.868	1.298	.746
I think my friends are expecting a lot about science observation and experiments from me.	38	1.816	.865	2.368	1.217	2.603 *

** *p*<.01 * *p*<.05 + *p*<.10

In addition, the item “Others’ expectations” of RSCL showed an increase in score with a significance tendency (t (38)= 1.835, p<.10). Further, regarding the sub items, “I think my friends make expectations on me for an observation or experiment in science class” showed a significant increase (t (38)= 2.603, p<.05). This item seems to measure whether or not children feel “Friends’ expectations", in particular, among other people.

When the correlation coefficient between "Social refinement" and "Friends' expectations" was calculated, the value r=.003 was obtained, which indicated that these 2 scales were independent from each other.

3. 3 Analysis of conversation history in observation/experiment situations

Framework and procedure of analysis What could have happened to the quantitative analysis results of the questionnaire described above? In order to clarify the process, we conducted not only pre- and post-class quantitative examination, but also qualitatively investigated the conversation history in each class. In sampling cases, we gave consideration to clearly and directly showing items to be analyzed and sampling qualitative typicality (Mita, 1965). Specifically, cases that met the following 2 criteria were identified by reference to all conversation data of 12 groups in the 10-hour classes obtained through observation: (1) Group discussion contains types of conceptual change, "the rising model" and "the expansion model", as noted by previous research (Kato, 2006) and typically found in this study. Of the above learners, those who showed change to "the motion model" will be included in the analysis; and (2) From the conversation data, we can directly understand the process (context, situation, etc.) in which communication involved in "Social refinement" as metacognition in relationships with others and "Friends' expectations" as social relatedness occurs. The 3 raters noted above assessed the cases with the inter-rater agreement of 92.8%. When judgment by the 3 raters differed, they reassessed it after discussion. Communication involved in "Social refinement" was found in 11 out of 12 groups, of which 2 cases met the 2 criteria, as shown in Table 5 (Period 1) and Table 6 (Period 2). Furthermore, communication related to "Friends' expectations" was identified in 10 out of 12 groups, of which 2 cases met the 2 criteria, as shown in Table 7 (Period 7) and Table 8 (Period 8).

Subsequently, by taking the following detailed steps, we attempted to understand how "Social refinement" and "Friends' expectations" were promoted in the context of continuous learning behavior between individuals without abstracting inherent meanings of context.

Table 5. An example of conversation in the first period

Turn	Speaker	Contents of utterances
		A task that can be tried based on one's own idea was presented as follows: behavior changes in the state of air caused by temperature changes through heating was freely examined based on one's prior experiences, and students conducted experiments and observation in groups.
1-1	A1:	(Preparing a styrene foam box, pouring hot water. Attaching the spout of a round-bottom flask to a vessel containing soapy water, and a soap film is made. Putting the vessel slowly into the hot water and the state of the soap film is observed.) Wow! The soap film is rapidly swelling upward.
1-2	B1:	(Pouring hot water slowly into a rather big water tank. Blowing a beach ball up to about 80% and the condition of the swelling is checked with hands. Putting the ball into the hot

	water slowly and the surface of the ball is observed. Gradual disappearance of the slack on the ball surface is noticed.) (Standing up) Wow! [The beach ball is] gradually swelling in all the directions!
1-3 A2:	(Looking at B, pointing at the soap film,) look. Air is rapidly rising upward.
1-4 B2:	(Looking back at A, slightly questioningly) What? Air expands not only upward but in all the directions through warming. Look (stroking around the ball, indicating the disappearance on the slack.)
1-5 A3:	(Looking at the surface of the beach ball) Oh? [I could observe only that air was swelling upward through my experiment, but your experiment shows that] air expands in all the directions [not only upward].
1-6 B3:	(Pointing at air grains in the model diagram drawn by B) when we blew soap bubbles [in the second grade], air swelled out in all directions like this, didn't it?
1-7 A4:	Yes (nodding), when I blew soap bubbles, ((surely)) the air inside swelled out in all the directions [not only upward]…
1-8 A5:	(nodding) I remember that … when I put a deflated balloon that I bought at a fair stall in the bath, (opening the arms in a concentric circle) it [swelled out all the directions, not only upward, and] returned to the original state.

Note) A, B, and C indicate students and T indicates a teacher (same as Table 6, 7, and 8). In the ( ) describes characteristic actions and surrounding situations, in the [ ] is supplementary explanation by the rater, in the (( )) is an inaudible utterance, "…" means a short silence, "!" means wonder, "?" means a rising tone. A has an idea of a rising model, B has an idea of an expansion model, and C has an idea of a motion model (identical with Table 6, 7, and 8). The underlined parts indicate the utterances related to social refinement of metacognition through involvement with others.

Table 6. An examples of conversation in the second period

Turn / Speaker	Contents of utterances
	Each student's self-generated model (expressing the behavior of air at heating) was explained and group discussion was conducted with the goal of solving one's task on one's own responsibility, not accepting others' ideas without questions.
2-1 A1:	(Indicating the model (rising model) designed by A) when air is heated, the upper part gets warmed. Based on my experiment, I thought that the number of air grains rising upward rapidly increases ((like this)).
2-2 B1:	(Indicating the model (expansion model) designed by B) my idea is slightly different from A…I think not only the upper part but the whole part expands. (Checking the swelling condition of a beach ball) I have evidence that the beach ball swelled out as a whole in my experiment.
2-3 A2:	The result of B's experiment was like that…but [the task] can be solved through my [designed] experiment…(looking at the experimental device, a round-bottom flask with a balloon at the spout) well…this (the flask) is hard, so I cannot make a hole on the side…
2-4 C1:	(Offering C's experimental device, which is a plastic bottle at the spout of which a soap film is formed, to A) Isn't it easier to make a hole on this (a plastic bottle) than that (a

	round-bottom flask)? May I lend it to you?
2-5 A3:	(delightedly) Oh, really? I can make a hole on the side of this (a plastic bottle). Nice. I can make a comparison between the upper part and middle part ((with this)).
2-6 A4:	(Pouring hot water into a styrene form box with the height in which the lower half of the plastic bottle is soaked. Making a hole on the side of the bottle, soaking the bottle in soapy water, sinking the bottle slowly into the box so that a soap film would not break, observing that the soap film swelling out at the upper and middle of the bottle at the same time) Wow, [the soap film is] swelling both upward and horizontally!
2-7 A5:	(In a clear tone) Without doubt, when air is heated, it expanded both upward and horizontally.
2-8 B2:	Since the soap film swelled out larger than the beach ball, it was easier to observe [that air expands in all directions].
2-9 A6:	Yes (nodding), I understood that air expands in all the directions like this (indicating B's model (expansion model)) through not only [experiment using] a beach ball but also [experiment using] a soap film.

Note) The underlined parts indicate the utterances related to social refinement of metacognition through involvement with others.

Table 7. An Example of conversation in the seventh period

Turn Speaker	Contents of utterances
	Group discussion was conducted about ideas produced by each student regarding the phenomenon of an increase in the volume of air through heating and no change in the weight. In the discussion, various ideas were actively explained one another, such as a rising model (A), expansion model (B), and motion model (C).
3-1 A1:	(Turning on the switch of the electronic balance, confirming that it showed "00.0g" digitally, slowly put the round-bottom flask attached with a blown up balloon on the balance, and the weight was checked. Difference in the weight of the round-bottom flask attached with a pre-blown up balloon was calculated.) 155.8[g] − 155.8[g]=0[g]. Oh! Why [did not the weight change]? [Omission]
3-2 B1:	[Ideas of the models] are different respectively…
3-3 A2:	But is it common that the volume of air increases through heating, right (asking B's and C's approval)?
3-4 B2 C1	Yes (looking at A, nodding), it is true!
3-5 A3:	Yes (looking satisfied with B's and C's approval). Then, shall we think about the method for examining that the weight of air [does not change] (asking B and C)?
3-6 C2:	(Trying to respond to A's proposal and presenting a plastic bottle) How about examining [the change in weight] using this, through not only heating air but cooling it?
3-7 A4:	Yes (pleased with C's suggestion). That's a nice idea!
3-8 C3:	(looking satisfied with A's approval) Then, let's do an experiment again with using this.

3-9 A5:	(Warming the plastic bottle with hot water, cooling it with ice water, and the state of the soap film, swelling and shrinking at the spout, was observed. Again, the weight of the plastic bottle before and after heating was measured accurately.) [Omission] 35.8[g] − 35.8[g]=0[g]. The weight did not change through cooling and heating!
3-10 C6:	(looking at C) If C did not give us advice, we ((must)) not have noticed [the method of re-experiment].
3-11 C4:	Yes (nodding, looking satisfied with A's words). Since the weight did not change through cooling and heating, could we get a rather reliable result [that the weight of air does not change], couldn't we (asking A's approval)?

Note) The underlined parts indicate the utterances related to expectation from friends in social relatedness.

Table 8. An Example of conversation in the eighth period

Turn Speaker	Contents of utterances
	B, who was listening to the discussion between A and C during the seventh period, started to reconsider B's own idea of "expansion model (grains themselves expand)", based on C's "motion model (motions of grains become active)," which agrees with the experimental results.
4-1 B1:	(Tracing B's model diagram with a pencil) the weight of air should have increased in proportion to expansion [of the air]…
B2:	A soap bubble swells out like this (imitating blowing a soap bubble), doesn't it? The weight should have increased in proportion to the expansion. (Looking at C, asking C's approval) what do you think?
4-2 C1:	(Trying to respond to B, looking at the model diagram) well, yes. But…to begin with, grains of air themselves would not expand, would they?
4-3 B3:	Why don't grains of air expand (leaning forward, with asking the basis from C)?
4-4 A1:	(Hitting upon an idea and breaking into the conversation, trying to tell it to B and C) Wait a minute! There is no source that expands air grains.
4-5 B4:	What do you mean by there is no source (asking the evidence, looking at A)?
4-6 A2:	(Trying to answer B's question, pointing at B's model diagram) In this case, air does not enter from outside, does it? Therefore, there is no source [that expands air grains], but in the case of soap bubbles, we blow air from outside into them, don't we?
4-7 C2:	Yes (nodding, looking convinced) I think A's advice is pretty useful.
4-8 A3:	(Looking pleased with C's approval) Therefore, air grains themselves do not expand. What do you think (asking B's opinion)?
4-9 B5:	I see. (Looking at A, satisfied) Thank you. My question has been solved!
4-10 C3:	(Trying to conclude the discussion, showing C's model diagram to A and B) The soap film is pushed out from inside ((like this)), because motion [of air grains] become active, not because air grains expand. Therefore, the weight does not change, whereas the volume increases.

Note) The underlined parts indicate the utterances related to expectation from friends in social relatedness.

1) Cases involved in social refinement

In the class of Period 1, the task to "make children freely explore the changes in the air state due to elevated temperature based on their own experiences" in which all children could work on with their own ideas was provided (Table 5). As the result, they were proactively conducting the experiment based on their own ideas using existing knowledge and experience. For example, Child A put soapy water on the neck of a round-bottom flask, and observed a soap film expanding by heated air, Child B put a deflated beach ball in hot water, and observed it being inflated, and Child C attached a balloon to the neck of a plastic bottle, and observed it being inflated by heated air.

In such task situations where children relied on the experiments based on their own ideas, Child A and Child B's ideas opposed to each other regarding the change in the air state (turn 1-1 to 1-4. "Turn" is omitted below). Then, through the mediums of models with written words as well as spoken words, they drew on already learned knowledge (1-6), linked with their daily experience (1-8), and the contradiction of Child A's idea was highlighted. Child A's experiment was limited, which grasped only the phenomenon of the soap film expanding upward, whereas Child B's experiment demonstrated a phenomenon in which the beach ball inflated wholly. We could see the process in which Child A became convinced by Child B's explanation (1-5) based on the evidence provided in the experiment that "when heated, air expands wholly, not just upward (1-4)", and Child A's idea gradually got refined, in relationship to what had already been learned (1-7) and daily experience (1-8).

Additionally, in the post-experiment discussion situation in Period 2 (Table 6), thoughts among members were visualized by their explaining the schematic models they built as the rationale for their thoughts (Self-generated analogies model: Abell & Roth, 1995; Penner, Lehrer, & Schauble, 1998) to one another. Communication between Child A (the rising model) insisting based on experience and Child B (the expansion model) asserting while supporting his/her experiment data took place over the experiment results on the basis of schematic models. Child A was first expressing doubt on the support of experiment data, instead of directly incorporating Child B's idea (2-3). In the discussion process where "Authority" was given to make one's own best choice or decision, Child A did not blindly accept Child B's opinion. Instead, in order to verify the limitations of the rising model (2-5), Child A repeatedly conducted the experiment (2-6) (Opened a hole on the side of a plastic bottle, put soapy water, heated the bottle in warm water, and observed soap films expanding upward and sideways at the same time), revised his/her opinion, while seeking coordination with Child B's view, using words of "refinement (Explain again by adding a new rationale to one's own or others' argument)" (When heated, air particles certainly expand sideways as well as upward) (2-7 and 2-9).

2) Cases in which friends' expectations were observed

In the class of Period 7, sufficient time and opportunities were provided so that the children would be able to discuss their own ideas concerning "the phenomenon in which the volume expands while the weight remains unchanged when air is heated". In this discussion situation (Table 7), they were proactively giving explanations about various views, such as the rising model (Child A), the expansion model (Child B), and the motion model (Child C) based on their own ideas. As sufficient time given for discussion, differences in knowledge and experience among group members were clearly brought out, causing “a conflict” (3-2). In such situations showing differences, Child A realized (3-5) that his/her opinion (the fact that air volume increases when heated could be confirmed with any model) (3-3) was accepted with nodding and agreement as valuable information by group members (3-4). At the same time, Child A wondered (3-7) at the advice given by members (3-6), and repeatedly conducted the experiment (heated a plastic bottle in warm water, cooled it with ice water, and observed the soap film on the neck expanding and shrinking. Again, accurately measured the mass before and after heating the plastic bottle) (3-9). With these experiences, Child A also realized the value in listening to members’ opinions he/she was not aware of by him/herself (3-10).

Additionally, in the group discussion situation in Period 8 (Table 8), Child B who was listening to the communication between Child A and Child C in Period 7 started rethinking about his/her view “the expansion model (particles themselves expand)” with reference to “the motion model (particle motion gets active)” proposed by Child C, which was consistent with the experiment result. Then, Child A as well as Child C leaned forward to join the evaluation of Child B’s problem solving, specifically suggested an improvement for Child B’s model via Child C’s model (4-4, 4-6, 4-8), thus no one was solving the problem alone. During the course of constructive discussions in which children exchanged opinions and shared thoughts, group members mutually agree on ways to improve tasks (4-7), and praised useful advice (4-9). In that situation, behaviors such as the following intended to meet members’ expectations were confirmed: when asked questions by members, looked into the questioner’s schematic model and reflected on, trying to respond to it (4-2, 4-6), happily explained when agreed by members (4-8), tried to change the direction of the discussion (4-4), and tried to wrap up the discussion (4-10).

4. General Discussion

In the current study, based on the theoretical framework by Maehr & Midgley (1991), we developed and empirically examined specific teaching strategies for each sub-dimension to apply to classes in Japan. It should be noted that we broadened our research scope, compared with Takagaki et al. (2009), in regards to “conceptual change within an individual” (Takagaki et al. studied “how a material is dissolved (focused on 1 property)”, while we examined “the relationship between volume and temperature (focused on 2 properties)”). Our pre- and post-unit test results empirically showed that conceptual change within an individual was facilitated in such a way that preconceptions about air (“when volume increases, the mass also increases (the rising model or the expansion model)”) were changed to a scientific concept (“understanding that even when volume increases, the mass remains unchanged based on evidence provided by the experiment (the motion model: Understanding based on the evidence)”). Next, as for “changes in learning behavior between individuals”, which was not investigated by Takagaki et al. (2009), increases in “Social refinement” as metacognition in relationships with others and “Friends’ expectations” as social relatedness were newly found.

After capturing the overall trend by these quantitative examinations, analyses will be conducted below in the context of specific cases of “3. Analysis of conversation history in observation/experiment situations” in order to clarify what factors of teaching strategies introduced in this study were involved in the occurrence of “Social refinement” and “Friends’ expectations”. In identifying the factors, since each teaching strategy of the TARGET structures contain multiple elements as shown in TABLE 1, a new analysis framework that focused on the functions of all lower-level elements of “teaching strategies (the underlined portions of (1) to (4) in TABLE 1)” was added. With regard to identification of factors, the 3 raters noted above independently evaluated the cases, in keeping with the true pictures of time-oriented/causal relationships in each case, while carefully unravelling the continuous contexts.

4. 1 Factors that affect social refinement

Firstly, in the class of Case 1 (Period 1) in which communication involved in “Social refinement” was observed, the task to “make children explore the changes in the air state due to elevated temperature based on their own experiences” in which all children could work on with their own ideas was provided. Presentation of such task let children conduct experiments using their own contexts, such as soap films, balloons, and beach balls (Table 5): As the result, it is possible that discussions to clarify one another’s views were elicited, based on their pre-existing knowledge about soap bubbles gained in the second grade (1-6, 1-7), their experience of putting a balloon in a bath (1-8), and so forth.

Based on this finding, one of the functions of the teaching strategy elements of the TARGET structures, “Freely predicting the result, while linking the task with their pre-existing knowledge, experiment results, life experience, and daily experience (the underlined portion of Session 1 (1) in Table 1. The inter-rater agreement was 88.9%)” (referred to as “relationship between the pre-existing knowledge or life experience and the task” below), was suggested to promote occurrence of social refinement. However, in light of the analysis of Case 1, a new factor going beyond the consideration of “relationship between the pre-existing knowledge or life experience and the task” was identified. That is, given the actual education practice, “making children face multiple tasks that contain contradictions (Law & Wong, 2003)” was also suggested to be successful in the occurrence of “Social refinement” by relationships with others as a “constraint condition” that could not be explained only by the teaching strategy elements of the TARGET structures.

Secondly, in the group discussion situation in Case 2 where communication regarding “Social refinement” was also observed (Period 2, Table 6), Child A faced an opposing opinion that shook his/her implicitly presented assumption (air particles rise upward when air is heated). Then, Child A first expressed a doubt on the support of others’ experiment data to choose the best way to study his/her own prediction (2-3) and revised his/her opinion (2-7, 2-9: Similar to the experiment of Child B, when heated, air particles certainly expand sideways as well as upward) through the self-regulating process (2-5, 2-6). In this process, “Inter thinking (Grugeon, Hubbard, Smith, & Dawes, 2001)” was found where one absolutely had authority to make a decision, and reached refinement while seeking coordination between his/her view and others’ to obtain support for his/her problem solving.

This result indicated that one of the functions of the teaching strategy elements, “Choosing the best way to verify a prediction (the underlined portion of Session 1 (2) in Table 1. The inter-rater agreement was 86.1%)” (referred to as “selection of methods to verify a prediction” below) promoted occurrence of social refinement. However, in light of the analysis of Case 2, along with the consideration of “selection of methods to verify a prediction”, the following “constraint conditions” not included in the teaching strategy elements of the TARGET structures were also thought to be required: (1) one another’s thoughts are visualized (by means of written words as well as spoken words), and discuss a task based on the supporting data (McNeill & Krajcik, 2008); and (2) make children carefully assert the validity of their chosen views, instead of blindly accepting others’ opinions.

4. 2 Factors that affect friends’ expectations

Firstly, in the class of Case 3 (Period 7) where communication involved in “Friends’ expectations” was observed, opportunities were provided so that all members would discuss their own experiment results concerning “the phenomenon in which the volume expands while the weight remains unchanged when air is heated”. Children expressed their unique ideas (e.g., the rising model, the expansion model, and the motion model), and had a “equivalent tool (model) for explanation and a decision-making power” in the “conflictual situation” (Table 7) that took place. It was found that “a fifty-fifty relationship” group (community) was established only because such teaching strategy element of the TARGET structures where all members could participate in was functioning (“pay attention so that everyone participates. Give sufficient time to solve problems while examining/integrating one another’s ideas” (the underlined portion of (3) common to Sessions 1 to 4 in Table 1. The inter-rater agreement was 90.3%)”) (referred to as “attention to participation and assurance of discussion” below). That is, when they did not know what was right and what was wrong in discussion, the fragments of exchange of opinions were complemented by one another’s facial expressions and gestures in “a fifty-fifty relationship”. Children felt by peers’ expressions and gestures that their views were accepted as valuable information (3-5), and also realized the value in listening to others’ unique ideas (3-10), which presumably lead to their recognition that “others place an expectation on me”.

However, in light of the analysis of Case 3, as a “constraint condition”, an assumption other than the teaching strategy elements of the TARGET structures, the teacher in this study aspired to classes of knowledge creation instead of knowledge transmission; then “a fifty-fifty relationship” group (community) was smoothly established in discussion as shown in Table 7. It is thought to be important to lay such foundation for cooperative learning on a routine basis.

Secondly, in the group discussion situation (Table 8) in Case 4 (Period 8) where communication regarding “Friends’ expectations” was observed, the members were asked to evaluate one another’s views and to correct them as necessary, after making them evaluate their self-imposed ones first. Since this teaching strategy element of the TARGET structures (“make children carefully proceed with the experimental plans formulated by each group, and correct them as necessary” (the underlined portion of (4) common to Sessions 1 to 4 in Table 1. The inter-rater agreement was

91.7%)" (referred to as "correction by mutual evaluations based on checking of self-evaluation" below) was functioning, it was shown that Child A ("the rising model") recognized the necessity of changing his/her view due to Child C's ("the motion model") evaluation after fully reviewing self-evaluation, and was even driven to suggest a revision of Child B's view ("the expansion model"). The very structure in which evaluations from others are involved in revision of self-evaluation, and members' feedbacks are essential (dual-function arguments: Kuhn & Udell, 2007) is demonstrated. Under such structure, it can be assumed that the opportunity to recognize "Friends' expectations" was increased through expressing or obtaining agreement among members (4-7, 4-8), receiving praise (4-9), and getting evaluations by words and gestures. This result is consistent with the research finding that evaluation from others in a group activity lead to motivation to meet others' expectations (Nakanishi, Muramatsu, & Matsuoka, 2006).

In light of the analysis of Case 4, through "the occurrence of conflicts" found in Table 8 as a "constraint condition" that was not included in the teaching strategy elements of the TARGET structures, "constructive interaction (Miyake, 2006)" took place in which a solution was cooperatively created: It was suggested that by letting children experience such change in the interaction, they themselves also came to a realization of "Others' expectations".

Based on the results described above, the significance of the current study can be noted as follows: Firstly, based on the theoretical framework by Maehr & Midgley (1991), we developed specific teaching strategies for each sub-dimension to apply to teaching situations in Japan. Then, we used a broad analysis framework for elements of teaching strategies in class practice, we clarified factors that facilitated changes in "learning behavior between individuals", which was not investigated by Takagaki et al. (2009). Secondly, this study expressly noted that in applying the results gained in this research to the actual education practice, considerations of "constraint conditions" that could not be explained by the teaching strategy elements of the TARGET structures would also be required, and that what these constraint conditions were. However, despite these findings, the present research has a number of limitations as it was based on a single case study. Therefore, it is recommended that further investigations be undertaken including different types of classes where cooperative learning is not sufficiently conducted.

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