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Organizing Active Learning Models in Science Classes (2)

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Abstract: The purpose of this study is to organize active learning models in science classes. Through classroom practice from elementary school to upper secondary school, we observed the followings: 1) the "reciprocal of internalization and externalization," which means collaborative and cooperative learning, is the key to active learning in science lessons; 2) by creating a "subject skeleton," teachers can gain clarity regarding the promotion of deep learning and organize active learning models in science classes.

1. Introduction

The newly revised course of study (notice in March of 2017) aims to realize the goal of "creating a better society through better school education," in addition to focusing on "what you learn," "how to learn," "what can you do," as well as introducing interactive and deep learning (in other words: active learning) as a strategy for qualitative improvement of the learning process in schools. "Learning deeply" means "to work closely with learning objects, work closely with the subjects of learning by working on the viewpoint, and a way of thinking that utilizes the knowledge and ideas learned in each subject, etc., to discover and solve problems, to form own ideas, to conceptually create/create based on one's thought 'process,' subjective viewpoint" (MEXT, 2017).

The Science Working Group of the Curriculum Development Subcommittee of the Central Education Council of Primary and Secondary Education Subcommittee (SWG) has organized a "viewpoint/way of thinking" in science education in summarizing deliberations on the revised course of study, and "in thinking in a multifaceted way by employing skills of scientific inquiry such as analyzing qualitative and quantitative relationships, and temporal and spatial relationships on natural objects and phenomena, comparing, and correlating" (SWG, 2016).

Our science department defines "deep learning" as follows:

(1) Students can associate and combine existing or learnt knowledge and skills to improve their understanding of natural objects and phenomena.

(2) Students can scientifically identify problems and solve them.

(3) Students can understand and improve their meta-cognitive ability through collaborations.

2. Aims, research questions, and method

The research plan for this study is shown in Table 1. Based on the knowledge gained from incorporating a "reciprocal of externalization and internalization," the plan aims to "organize" the strategy for aggressive and learning classes, and create teaching strategies.

Hiramatsu et al. (2017) have already reported on the first year's research results, so we will report on the second and third years' research results.

Table 1 Research plan

Year	Plan
1st year (2016)	Design and put into practice classes that include a "reciprocal of externalization and internalization."
2nd year (2017)	Design and organize lessons that include a "reciprocal of externalization and internalization."
3rd year (2018)	Based on the idea of "deep active learning," develop methods to assess the design of lessons.

In this study, the term "active learning"—as defined by Mizokami (2016)—means: To overcome the habit of learning from unilateral knowledge transfer-type lecture, that is, passive learning. Active learning includes writing, speaking, and presentation as well as involvement in activities facilitating externalization of the internal cognitive processes.

Additionally, "internalization" means understanding and acquiring knowledge; "externalization" means performance—writing, speaking, announcement, etc.—using knowledge (Yasunaga et al., 2016).

During the first two years, we tried to establish the theoretical framework for active learning models in science lessons through analysis of literature on active learning. We also conducted trials for empirical research in science lessons based on the idea of a "reciprocal of externalization and internalization." After analyzing the results and problems of the previous two years' theoretical and empirical researches—and borrowing the idea of Matsushita (2018)—in the third year we created a "subject skeleton" defined by our school to demonstrate ways to realize "deep learning." Moreover, we organized the "genealogy of depth," "opportunities for deep learning," and "steps for deep learning."

3. Outline of practices in the third year

Using the subject skeleton, we experimented with several research practices to develop deep learning from elementary to upper secondary school science classes. In this paper, we discuss the case study of the lower secondary school practice.

In the case study, we conducted a research on the lesson with the unit title "the three states of matter or state changes of matter." Generally, while discussing invisible particles such as atoms and molecules, science teachers tend to use the model of a particle. However, it is unlikely that while dealing with a model most students are also aware of "what the particle model represents" and it is referred to as "particle = atom, molecule, (ion)." Therefore, in this lesson, to understand the changes of state of matter, we adopt a reciprocal of internalization and externalization. We tried to develop a particle model for deeper understanding of the state changes of matter. The scheme of work for the unit is as follow:

1st: Observation and understanding of the primary state change for 1 hour,

2nd: Understanding and explaining of changes of state of matter and its temperature for 4 hours, (5/7 at the time)

3rd: Utilization of tertiary state changes of matter, and the separation of mixture for 2 hours.

The following table is for the research lesson:

Learning phase/contents	Learning activities	Note（◇assessment）
〔Introduction〕 ・Reviewing ・Recognizing the model of three states of matter ・Recognizing the changes of temperature when heating a pure matter	○To confirm that there are three states of matter: gas, solid, and liquid, and consider how each state can be represented using a particle model ○To confirm that melting and boiling points are distinct	○To reflect previous lesson briefly
〔Development〕 ・How do temperature and states of matter change when cooling down?	○Each student predicts whether or not the melting point of a pure matter differs from its freezing point ○Experiment from the perspective of the state of matter at melting and freezing points	○Based on the learning of state changes when heating a matter, students predict state changes when cooling down a matter
【Experiment】 Let's observe the state changes of cetanol and record and explain the states of matter at different temperature readings	○Procedure of experiment is as follows: ・every group collects cetanol prepared at the teacher's desk ・melt cetanol in a water-bath by stirring ・after melting, cooling it down naturally while stirring Students must carefully observe and record the changes in temperature and states of cetanol when heated and cooled	○Pay attention not to touch chemicals ○In the case of observing an overcooled matter, a teacher asks students to observe temperature before and after the point of overcooling ◇To conduct experiment on the freezing of a pure matter safely, observe and record temperature changes correctly and draw a graph (this is to assess knowledge and skills by reviewing a student's worksheet)
・Results of experiment and analysis ・Let's explain the states observed during the experiment using a particle model ・To share the results of experiment and discussion within a class	○Students must draw the graph of changes in temperature and explain the state changes of cetanol using a particle model ○Every group draws the results and their particle model on the white-board, and then shares them with the class	◇To explain the state changes of a pure matter during freezing using a particle model based on previous learning outcome (this is to assess students' scientific thinking, judgment, and presentation after providing instructions walking around and inspecting among the student's experiment desks and on the white board which students described)
〔Conclusion〕 ・Conclusion of today's lesson ・Notice of the next lesson: Let's confirm through an experiment the changes that occur when heating mixed matters	○To confirm that similarity to the case of heating and cooling a matter. For example, there is a mixed state, solid and liquid, of matter at the keeping same temperature in case of cooling a matter, and a melting point and a freezing point are same temperature for a case of a pure matter and so on… ○Remember and understand the behavior of particles in state changes based on the results of worksheet and their learning	○Students of each group must hear other group's results and ideas carefully, and review their own ideas of a particle model. A teacher may ask any group to present their ideas of particle models if it seems to be typical or representational ○To explain briefly the temperature conditions for solidification of matter with the changes of movement of particles

The subject skeleton for this unit is as follows:

Table 2 The subject skeleton for the unit

Practice (hypothesis) to realize "depth of learning" in junior high school	
Learning goal	Students can observe behavior of matter, and consider and explain the three states of matter (solid, liquid, gas) by using a particle model.
Steps to deepen their learning	Learning activities
Conflict	Observe the state changes of matter because of changes in temperature and confirm that there is a point beyond which temperature does not change.
Internalization	Consider a model during the state changes of matter while matching a particle model (solid, liquid, gas) with actual temperature changes.
Externalization	Present the particle models considered by each group and check whether there is any discrepancy, while explaining to each other.
Reflection	Compare the model provided in textbook with the model students created through activity, and then they understand the students' model.

In this lesson, by confirming and organizing the knowledge gained so far about the state changes of matter and particle model of each state of matter, we clarify the purpose of the experiment, which means externalization. By experimenting with the state changes of cetanol while remaining conscious of the purpose of the experiment, we perceive new information (such as the states of matter, harmonizing, and changes in temperature) on the state changes accompanying temperature changes, which means internalization. Focusing on the states of matter under the state changes using a particle model along with newly obtained information, which means externalization, learning activities can be developed. Through associating and combining existing and learnt knowledge and skills related to particles such as atoms and molecules, a reciprocal of externalization and internalization could be initiated.

We think that during the experiment, students can develop their understanding of the state changes and particle model by explaining the states of matter using a particle model based on their observation of states changes of matter, and their measurement of the changes in temperature readings of matter.

In particular, through the explanation activities on the results of the experiment, students can explain that the same matter is made of the same particles even though state change of matter occurs (in the case of this practice, both solids and liquids consist of grains (molecules) of cetanol). It was possible to express as a chemically reliable model, as shown in Fig. 1 and Fig. 2, that the way the particle gathers changes with changes in temperature.

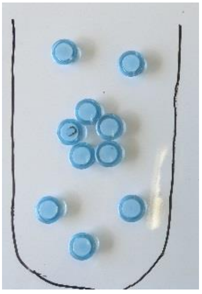

Fig. 1 The model drawn by a student①

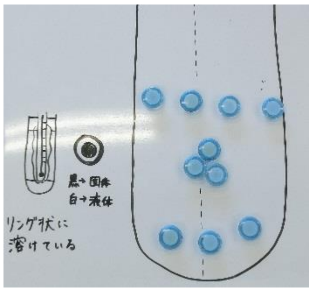

Fig. 2 The model drawn by a student②

Additionally, to develop their understanding of particle model, “deep learning” should be required, which leads to the concept of solid-liquid phase transition and equilibrium between two phases in the “material state (solid, liquid, gas)” taught in upper secondary school chemistry.

4. Findings and conclusion

In the first year of the research, employing a reciprocal of externalization and internalization we learnt the following :1) students can develop their understanding of contents, 2) they can understand advanced contents proactively, 3) through collaborative learning they can develop their learning, 4) success or failure of active learning may depend on the quality of tasks assigned to students in class, and 5) it is necessary to clarify the factors that influence the success of active learning.

After analyzing the first year’s achievements and problems, in the second year we tried to design science lessons based on a reciprocal of externalization and internalization. We learnt the following: 1) the role of science teachers as facilitators is important for improving active learning in science lessons, 2) it is important to compose such questions that students can understand, and 3) a reciprocal of externalization and internalization is required to be flexible and easy to change depending on the actual situation of a class, which can be gauged from pointers such as students’ tweets.

On the basis of analysis of the previous two years’ research results and definition of deep learning in science, we created a subject skeleton in the final year. Consequently, we suggest the following: 1) students transfer their learning to other study areas when appropriate assignments and rubrics are used to control thinking and learning (meta recognition) through a reciprocal of externalization and internalization, 2) a rubric is important and effective for assessing students’ positive learning capacity, 3) it is important that realistic tasks and issues which students have to study should be provided to them, 4) to manage a reciprocal of externalization and internalization and improve deep learning, it is necessary to provide opportunities for practical work such as experiments and observations, as well as for debates on the results and future considerations, and 5) working with others influences active learning, and during a lesson teachers must provide opportunities to students to think individually, as a group, and as a class.

On the basis of these results, it seems that a reciprocal of externalization and internalization is key to effective active learning in science lessons. A reciprocal of externalization and internalization for deep learning should be practiced with both individual students and groups. At the start of a lesson, students perform a mental exercise regarding reciprocal of externalization and internalization and then communicate their thoughts and ideas with the class—this is externalization. Thereafter, they compare their own original ideas with new ideas proposed by others—this is internalization. Finally, they arrive at a conclusion that has daily-life applicability. However, a few steps are required before students engage in group and class communication activities. For example, they have to identify and understand the problem, and teachers have to facilitate students' cognitive conflicts and motivate them to learn.

As Matsushita (2018) pointed out, there are three ways to promote deep learning: 1) "going up and down," which means understanding concepts and principles while going up and down factual knowledge, cases, concepts, and principles, 2) a "transfer" to other units and subjects to understand the problem in a daily-life context, and 3) "collaboration" not only with the teacher but also with students inside and outside the school. Science teachers need to rethink these three points, and examine ways to incorporate them into a lesson. Consequently, a subject skeleton facilitates effective conduct of science lessons and is effective for organizing active learning in science lessons.

The following points require our attention: 1) we need to assess whether this learning activity should be regarded as an example of authentic active learning, 2) we need to examine and develop assessment methods based on the idea of the rubric, and 3) employing the subject skeleton that we developed, we need to propose model science lessons that focus on active learning based on the integration of assessment and practice.

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