Development of Methods of Teaching Science at Elementary Schools in Japan

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Abstract

In science teaching at Japanese elementary schools, a problem-solving approach by way of discovery has been used since 1967. In this approach, the objective is to foster scientific ability by allowing pupils to find laws through experiments and observations. The emphasis is placed on encouraging pupils to induce by themselves based on facts they have found. As a result, “teaching” and “explaining” are underestimated. However, according to the Course of Study revised in March 2008 (and currently in effect), acquisition of fundamental/basic knowledge and skills has been added to the objectives. It was indicated that the verbal activity, such as explanation by means of inductive and deductive ways of thinking is important. Here, the importance of “deductive approach” and “explaining” were noted. Japanese science education was changed significantly.

The purpose of this review is to clarify the process of how this new method of “explaining” has been introduced. To that end, firstly an overview of the transition of science education methods in Japan after the World War II up to present is given. Secondly, the new research trend of meaningful reception learning, which is the background of the revision in 2008 is clarified. Finally, the teaching method applying this approach is explained, using the example of a lesson concerning “flower structure”.

Keywords: Deductive thinking, Discovery learning, Japanese science education, Reception learning
Introduction

The teaching of science at elementary schools in Japan has been implemented based on the theory of problem solving by discovery for almost 50 years since 1967. However, the importance of teaching by direct instruction was pointed out in the report of the Central Council for Education (2008).

Generally, there are two approaches in the theory of science teaching: intellectualism and meritocracy. Meritocracy is further divided into two categories: discovery learning and reception learning. Science education in Japan has undergone various transitions, however, it was always based on meritocracy, except for a certain period.

Now, a new concept has been added in order to achieve a new goal to foster a new academic ability. In this paper, an overview of the process, until this revolutionary change was affected is given. At the same time, the background educational concept for “teaching by direct instruction” is also clarified.

The progress of this new teaching theory of reception learning is reviewed, and finally, an example of learning through problem solving using reception learning is presented.

1. Transition of teaching methodology in Japan

The curriculum of all elementary schools in Japan is specified by the Course of Study for Primary Schools formulated by the Minister of Education, Culture, Sports, Science and Technology. The content of textbooks that pupils use is determined based on this Course of Study and the Manual of the Course of Study for Science issued by the Ministry of Education, Culture, Sports, Science and Technology (hereinafter referred to as “MEXT”).

As a result, the content and method of education of schools are basically defined by the Course of Study and the Manual of the Course of Study, although there remains some room left for discretion by individual schools or teachers. The Course of Study has been revised almost every ten years. The revisions may sometimes be substantial, introducing a completely new approach, or they may be minor.

In this section, the transition of science education in Japan is described in terms of revised Course of Study.

a) 1948 to 1958

The first Course of Study was announced in 1958, featuring “problem-solving learning using life-related units”, based on the educational methodology proposed by Dewey (1900). Classes were conducted by picking up problems surrounding the children’s lives, letting them solve such problems by themselves.

In this approach, the problem-solving method was so emphasized that entrenching of fundamental knowledge was insufficient. In this period of Japanese history, the nation had been ravaged by war, which is one reason for the insufficiently improved educational environment. So in this period, although spontaneous learning was respected, a decline in scholastic achievement was notable.

b) 1958 to 1967

During this period, a new approach “systematic learning” was adopted for the purpose of improving the deteriorated academic performance. The focus was placed on obtaining knowledge. Experiments and observations were greatly decreased and science classes in the form of lectures using blackboards and chalk became prevalent.

c) 1967 to 1977

In America, the modernization of education
had progressed since the 1950’s. A spotlight was cast on “discovery learning” by Bruner (1960). Japan was no exception.

The Course of Study revised in 1967 introduced this educational concept which was emerging in America and the modernization of Japanese science education was encouraged.

There are a number of implications proposed in “The process of education” (Bruner, 1960), which can be summarized in three major principles as follows:

1. Teach major points only without concerning about minor details
2. Earlier introduction of topics may be possible, depending on how to teach.
3. Teach by means of discovery learning.

Classes were carried out using the “problem-solving through discovery” method. Discovery learning was recommended to start from the 1st grade of elementary school.

Ausubel & Robinson (1969) proposed “meaningful reception learning”, but this was after the revision of the Course of Study, and it did not enter the mainstream of education.

Under this Course of Study, science education moved forward with substantial reforms.

However, this Course of Study had some problems. Specifically, under the banner of modernization, it allotted content which was too difficult for children in lower grades to understand. This means emphasis was put on the 2nd point mentioned above in deciding the curriculum.

d) 1977 to 1989

While conducting science classes in accordance with the Course of Study revised in 1967 it became evident that “some contents, too difficult for children, were assigned to low graders”. In this period, it was intended to correct such a trend. The contents were transferred to higher grades. In the meantime careful review of contents was implemented.

There was no change in the teaching method. “Problem-solving learning by means of discovery” continued in this period.

e) 1989 to 1998

A new subject, Life Environment Studies, was launched for the 1st and 2nd grades of elementary school.

The main reason for this was that the importance of integrating children’s spontaneous activities, including play time, into school education was recognized. It was seen as an opportunity for greater personal contact among children which had considerably decreased due to the changes in social structure that had reduced spontaneous activity for children, who were not able to experience playing together in their childhood any more.

In parallel with starting this new subject, Science and Social Studies for the 1st and 2nd grades were abolished. The disappearance of Science, which had been consistently offered since 1948, was a major change.

Teaching methods remained the same, with problem-solving learning by discovery continuing.

f) 1998 to 2008

The objective in this period was to foster a “zest for life”. To that end, it was believed that an activity to learn and to solve problems was indispensable, and the “Period for Integrated Study” was created for the 3rd and higher graders of elementary school.

As this new subject was added to school educational activities, the contents and the number of classes for other subjects were reduced to secure the hours for these new lessons. Science, too, lost some of its contents.
and lesson time. The idea was that the cultivation of a “zest for life” could be achieved by curtailing the contents for each subject and realizing “cram-free” education, respecting children’s attitude to learn by themselves.

During this period, the results of PISA and TIMSS indicated a deterioration in the academic performance of Japanese children. Public opinion was very negative, with people insisting that this was the result of “cram-free” education and that the teaching of each subject should be improved. Presumably considering public opinion, the MEXT partially amended the Course of Study in December 2003, one year after the revised Course of Study had been implemented, encouraging “the teaching of content which was not included in the Course of Study”.

Furthermore, in January 2008, the Central Council for Education defined clearly the direction of reform for the next Course of Study, specifying the “enhancement of mathematics and science education” as the second major areas for improvement, which was realized in the next modifications.

**g) 2008 to present**

The Course of Study revised in March 2008 (currently in effect), features “acquisition of basic/fundamental knowledge/skills”, although still fostering a “zest for life” as an educational objective. In Science, new teaching content has been added to a large extent. The number of classroom hours were also increased.

Further improvement has been made in terms of teaching methods. According to the Report of the Central Council for Education, MEXT (January 2008) on “Amelioration of the Course of Study and others for kindergarten, primary schools, lower secondary schools, upper secondary schools and special needs education schools”, it was indicated that verbal activities are important such as “providing explanation using inductive and deductive approaches” in “(2) Enhancement of mathematics and science education of Item 7, Major improvement items regarding educational content”. Here it was stressed that a “deductive way of thinking” is important.

Let me explain the improvements of this teaching method.

Human thinking is comprised of inductive thinking processes and deductive ones.

However, as science education in Japan focused on discovery learning, the inductive way of thinking has attracted attention.

The primary cause of this is that the Course of Study revised in 1967 was deeply influenced by the modernization of science education in America with a strong emphasis on discovery learning as advocated by Bruner. Discovery learning is to derive a law from experiments and observations, which means making an induction. As the first theory which backed up science teaching in Japan was discovery learning, emphasis has been placed on problem-solving through the discovery process in Japanese science education, which remained basically unchanged until 2008.

The latest revision (2008) of the Course of Study stated that “verbal activities are important such as “giving an explanation utilizing inductive/deductive approaches”, which encouraged the introduction of deductive thinking to science classes.

This adoption of deduction signifies a substantial change in science teaching in Japan. It goes without saying that because of the prior outcomes, it is important when MEXT modifies its national policy. In the following section, I will examine what is the background to this change.
2. Indication of limitations of learning by problem-solving through discovery

In the previous section, an overview of the Japanese science education since 1948 was given. From the point of view of educational methods, only during the period between 1958 and 1967, was a knowledge-centered approach the focus of teaching. Other than that period, performance-based teaching was always implemented. After 1967, science classes have been consistently given based on discovery learning, centering on problem-solving by induction.

Then, the Course of Study revised in 2003 introduced a deductive thinking process. In this section, the research and way of thinking of educators who attach a high value on deductive thinking are presented, up to the present date.

a) Empirical study on classes placing emphasis on deductive thinking

Empirical study using deductive thinking in science teaching was started by Kawakami & Sugiura (1985). Later studies by Kawakami & Tajika (1987), Tajika & Kawakami (1988) and Kawakami & Tajika (1990) followed. This series of studies proved that the introduction of “advance organizers” contributed not only to establishing fundamental knowledge but also to fostering application ability to cope with new problems. Moreover, the research results showed that this approach is especially effective for low-performing children.

Since then research has continued (for details, refer to Kawakami & Watanabe (2010) in Japanese.). Consolidating all these previous researches, “Science Classes to Re-empower Teaching” was written and edited by Kawakami (2003). The outline of this book is provided in Kawakami, Watanabe & Matsumoto (2012). The series of researches were verified by science classes. The outcome of the research is summarized in the following three points:

1. Reception learning proved to be effective in encouraging children’s understanding in the grades and teaching units indicated in the “material” section.
2. Reception learning proved to be especially effective for children who are not good at science.
3. As the result of combining it with advanced learning, children’s level of interest was high.

b) Reception learning

Teaching methodology based on “deductive thinking” includes “meaningful reception learning” by Ausubel & Robinson (1969). At that time, Bruner advocated discovery learning. Ausubel’s reception learning and Bruner’s discovery learning were regarded as opposites and no attempt was made to use both of them according to the situation. Consequently, science classes were implemented based on discovery learning.

In Japan, the Course of Study revised in March 2008 finally hit upon the idea of integrating both inductive and deductive approaches, that is, choosing inductive and deductive learning activities depending on the content.

Concerning discovery learning, as many practices have been compiled up to the present, there would be no need to look anew to explain.

In the following section, the method of introducing reception learning to science classes is given.

b-1) What is “reception learning”?

Reception learning is a method providing “an advance organizer” to learners and to proceed through problem solving by means of experiments and observations based on the advance organizer. The process of problem solving is deductive, because it is substantiation of what was taught.
An advance organizer is defined as “information that is presented prior to learning, and it is more general, abstract and inclusive than learning itself.” (Ausubel & Robinson, 1969). Since both reception learning and problem-solving learning include the word “learning”, these concepts are often regarded as parallel, however, reception learning is a subordinate concept of problem-solving learning. More specifically, problem-solving learning basically consists of a process of solving a problem inductively (inductive reasoning) and a process of solving a problem deductively using the hypothesis obtained by induction (deductive reasoning). In other words, induction and deduction are used properly when performing problem-solving. Therefore, discovery learning can be defined as “a problem-solving learning by means of discovery learning based on inductive reasoning” and reception learning is “a problem-solving learning by accepting a hypothesis and conducting deductive reasoning”.

b-2) How to perform reception learning?
Reception learning is especially effective when teaching high level contents which are difficult for learners to understand.

The key point in reception learning lies in how to provide advance organizers.

It is considered that learners can smoothly solve problems when a class is taught using the steps shown in the following figure. (Kawakami, 2003 & Kawakami et al., 2012)

In the first step, learners are led to have strong problem-consciousness such as “I do not understand.” or “Why does this happen?” regarding on-going phenomenon.

Then, in the second step, teachers offer an advance organizer when strong problem-consciousness emerged in learners’ mind.

In the third step, learners think about the new phenomenon, adapting the advance organizer to it.

Then they can explain the new phenomenon, with the help of the advance organizer. The learner cries “Eureka!”, from the joy of understanding. Motivated by this satisfaction derived from reaching understanding, his/her interest will be further enhanced.

c) Approach placing emphasis on deductive thinking
Among various research papers on the methodology of science classes, there are many which indicate the limit of discovery/inductive learning and which refer to the significance of deductive learning. Such papers are as follows:

Imamura (1996) states: “I understand teachers conduct experiments, placing emphasis on exploratory activity by students, which is one of the features of science education. However, isn’t this approach biased toward just one aspect of scientific research? It is doubtful how far scientific thought can be fostered if teachers try only to effectively conduct observations and experiments described in the textbook.”, contesting induction-centered classes. Imamura also points out experiments/
observations do not connect to knowledge, stating that “children are supposed to obtain knowledge and grasp a concept through explorative activities such as experiments/observations. However, in current science classes, experiment/observation activities have lost touch with scientific concepts.” So he insists that “compiling repetition of induction and deduction is important.”

Nishikawa (1999) says “Prior to studying science, learners have already had their own science models. For example, ‘electric current cannot be preserved.’ or ‘As the weight becomes heavier, a pendulum swings faster/slower.’ Learners do not fully understand these facts even when experiments are presented.” He believes that conducting experiments/observations does not lead to understanding concepts correctly.

Shindo (2002) insists that “The domination of science education by simply applying the discovery principle has led to the educational weighting between ‘the transmission of knowledge’ and ‘the creation of knowledge (discovery)’ leaning heavily towards the latter… and one of the fatal impact was that it led to a trend of regarding ‘the transmission of knowledge’ as taboo in the world of science education.

From a psychologist’s point of view, Miura (2003) indicates that “constructing knowledge based on the specific experience of each child requires a lot of time and the making of many mistakes. In order for children to sense the joy of learning a subject and to acquire basic academic skills, meaningful reception learning should be effectively carried out so that children can be sure to master the particular method, using the related body of knowledge as a tool. He adds, “if children already have many misunderstandings and insufficient knowledge, then teaching should be implemented in a way to correct their misunderstanding. If they have little related knowledge, then one might assume that teachers can present basic principles and build an organized structure of knowledge in the children which they can then apply to reality.” In this way he pointed out that teaching methods need to be changed in a flexible fashion depending on the content of the subject or the condition of children.

Kaburagi (2003), referring to a lesson for 6th graders designed to teach that “there are some types of water solution which change metal.”, reports that there was a class in which the teacher asked the children; ‘Why did bubbles appear when a piece of aluminum was put into this transparent liquid? Let’s think why.’ However, there were no children who raised their hands because they had no basic knowledge. This is a scenario in which a teacher should directly teach children and not let them simply think for themselves.”

Regarding learning about a water solution in which gas is dissolved, Ogisu (2004) points out the difficulty of discovery learning: “Children do not know how to verify the fact, even though they are taught that carbon dioxide dissolves in water. They do not understand unless the teacher explains a certain phenomenon, defining that this is what we call “dissolution”. They may understand that sugar dissolves in water or salt dissolves in water, however, they cannot readily understand that carbon dioxide dissolves in water.”

Yuzawa (2004) introduces an experiment for illustrating the change of weight which occurs when iron is burnt, during a lesson designed for the 2nd grade junior high school students on “chemical reactions and molecules/atoms”.

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Students burnt steel wool, blew on it and then measured the weight of iron oxide. When they plotted it on a chart, it was not linear and most of the students made a line plot. On the other hand, he explains: “First, teach the law of definite composition to students, then carry out an experiment of oxidation applying the law. Because the students had already learned the law, they are better able to cope with the errors from the experiment. Being provided with knowledge in advance, the students are able to handle errors correctly.” In this way, junior high school teachers practice meaningful teaching.

Tonishi (2004), referring to the limitation of discovery learning in science classes, asks: “Is it essentially and intellectually possible for students who do not have conviction to experience vicariously the scientists’ research process by letting them experience the same process without losing the essence?”

Yamaguchi (2004) states that “Regarding the relation between plants and sunshine, children may make various findings based simply on appearance. However, they have never thought of the mutual relationship between sunshine, plant leaves and starch. This is something unthinkable for them. Therefore, as a specific activity the teachers suggests; ‘Let’s see if any starch exists in leaves in the sun.’ But, as a matter of fact, the relation between sunshine, leaves and starch is, for children, an unfamiliar topic (concept). Searching for starch in such an atmosphere can be merely a task even if they do it correctly.” When children are asked to check if any starch is formed when leaves catch the sun, they do not understand the purpose of the experiment, so they cannot develop a hypothesis. Therefore, an experiment becomes meaningless for the sake of discovery learning because children do not explicitly understand the purpose of experiment.

Ichikawa (2005) also argues that “a class without teaching but simply letting children think for themselves’ in which ‘a problem is presented at the beginning of a course unit to encourage discovery by oneself and cooperative solution’ is a very risky teaching method though this type of class is often regarded as ideal for carrying out acquisition or problem-solving of high-level concepts in mathematics and science. In a classroom where children who have already studied the content in advance at a cram school and those who cannot discover by themselves are mixed, such an approach cannot make an interesting class for either group. As a result, large number of children who do not understand even basic content will be produced after consuming an immense amount of teaching time.”

Extending the proposal by Shindo (2002), Hidaka (2007) published Teaching science classes without hesitation to teach in which he points out that conventional science teaching centered on an inquiry process left the discovery of laws entirely in the hands of children and so many children felt confused, asking “Teacher, how should I think?”. Such bewilderment has generated science phobia. He states that first of all teachers should be responsible for conveying plain and fundamental structure of science clearly to children by means of “knowledge communication – case example learning”.

In the case of Shimizu and Yamaura (2007), they surveyed the thought process of junior high school 1st grade students, using learning of flower structure as a case example. The result obtained from the survey indicates that...
“more students have successfully formed a conception of flower structure in the group that learned deductively rather than in the group that learned inductively, and that the effectiveness of deductive learning was implied.”

Thus, here are papers which refer to the limitations of both discovery learning and inductive learning, while showing the significance of deductive learning.

Responding to these researches, the Course of Study revised in March 2008 stated that ‘verbal activity such as explanation using inductive/deductive approach is essential’ and that the importance of ‘deductive approach’ was pointed out.

3. Problem-solving learning using discovery learning and reception learning – a case of teaching flower structure to 5th graders

In this chapter, the procedure of teaching flower structure to the 5th graders of elementary school, applying both discovery learning and reception learning based on the research by Kawakami and others(2012). This approach introduced new concept to the conventional one.

The target of learning in this unit is “Let’s learn the structure of various flowers.”

a) Basic learning

In the beginning, teaching materials attracting children’s interest and easily understandable are selected. (In Japan, “Brassica napus” (colza) is used in many cases) The problem of flower structure is solved by means of discovery learning. The learning process is as follows:

Teacher: “Let’s observe a brassica flower and clarify the flower structure.”

Student: (They observe brassica flowers.)

T: What shapes do you find?
S: (They found out minute organs.)
T: They are called a pistil, a stamen, a petal and a sepal respectively.

T: How many are there, each of them?
S: 1 pistil, 6 stamens, 4 petals and 4 sepals.
T: Next, we will try a flower of ’morning glory.
S: 1 pistil, 5 stamens, 1 petal and 1 sepal.

A flower has pistils, stamens, petals and sepals. Their shape and number are different, depending on the species. (generalization)

Notes: The learning process mentioned above is a problem-solving learning by means of discovery. Here, based on the observation result of two different flowers, brassica and morning glory, a conclusion on flower structure has been generalized. (inducted)
This learning process is applicable to a few plants. Therefore, there is a problem that it is difficult for learners to understand the structure of the flowers in their surroundings.

In order to solve this problem, the author adds the following learning steps (b). This is reception learning using advance organizers.

b) Generating problems

T: (Showing flowers of which understanding the structure is difficult, such as tulips, lilies and dandelions.)

Which are the sepals of tulip and lily? How many petals does dandelion have? Which are stamens and sepals of dandelion? How many petals does Commelina communis have? Where are their stamens? In this way, teachers leads students to have questions.

c) Introducing advance organizers

T: Showing the chart below, “Flowers evolved from leaves. The top leaf became the pistil, next one, stamen, then the one under it, petal, and the bottom one evolved into a sepal. Therefore, although the shape of flower is varied, depending on the species, the order of pistil, stamen, petal and sepal remains common to all flowers. So, when you observe flowers, you can start investigating any flower from the center, This is the “key point” when studying flower structure.”

d) Adaptation a

Observation of tulip flowers

T: Where are the sepals?
S: There are no sepals.

T: Yes, there are no sepals. Observe the flower, using the “key point”.
S: I understand. Out of 6 petals, 3 are petals and the other 3 are sepals, aren’t they?”

T: You are right.

e) Adaptation b
S: The flower of lily, like tulip, out of six petals, outer three petals are sepals.

f) Adaptation x
T: Let’s observe these small flower, using the “key point”.

g) Adaptation y
T: You will discover the structure of Iris japonica, if you apply the ‘key point’.”

S: So the largest and the most conspicuous part is a ‘sepal’. I am surprised!”

h) Adaptation z
T: As for orchid including cattleya, pistil and stamens are integrated. Petals have two different shapes.”

i) Conclusion
Flowers consist of pistils, stamens, petals and sepals. Their shape and number are different. (generalization)

Observe flowers, applying the “key point”. Then you will find the structure even if it is a flower you have seen for the first time.

j) Consideration
Carrying out a class as mentioned above, learners’ understanding is enhanced considerably.
In conclusion, advance organizers benefit all students. It is especially effective for students who are not good at learning.

Postscript
Science education in Japan has been gradually changing with the times. In particular, since 2008, the importance of “direct instruction” has been pursued. Among others, the significance of reception learning draws attention. It is believed that reception learning is effective for learners with abundant knowledge. For that reason, it is effective for students of higher grade. From that viewpoint, science classes at elementary school are carried out with focus on discovery learning and inductive learning. However, adding meaningful learning to these
methods will further improve students’ ability. The above-mentioned case study of learning flower structure indicates how effective this learning is. In Japan, it is also required to introduce advanced learning and supplementary learning in order to respond to each student’s capacity. Various proposals are made to improve and enhance science classes in Japanese elementary schools and they are put into practice through diverse training sessions. It would be much appreciated if you give attention to the educational reform in Japan.

Reference


