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〈論文〉

Consideration of Science Education in Japan in the 21st Century

SAKAKIBARA Yasushi : Science&Math. Education, Faculty of Education, Shinshu University
KASAI Toru :　Okaya Technical High School, Okaya City

21世紀の日本の理科教育を考える

榊原保志　信州大学教育学部理数科学教育講座
河西　亨　岡谷工業高校

理科教育のあり方について 4 つのことを提言した．(1)第 2 次世界大戦後，豊かになりたいという明確な学習の動機付けがあったが，豊かな社会になるにつれてさまざまな教育に関する問題が生じている．学校だけが努力してもこどもを健全に育てるには限界がきているだろう．これからの学習指導は学校が中心であることには変わらないが，社会が学校教育をサポートする環境づくりが必要である．(2)高等学校では，校内研修に取り組む体制を確立することや「教える内容」ばかりでなく「教える方法」に研修に力を入れることが求められる．(3)大学や高等学校では，社会で必要とされる「コミュニケーション能力」「問題解決・分析能力」「企画創造力」「データ処理・事務処理能力」などに教育の重点を置くべきである．(4)小中学校では，総合的な学習の時間を設けないで，基礎基本の定着に重みを置き，必要に応じ考える力や学び方・調べ方等の能力の育成を各教科の授業の中で行うべきである．

【キーワード】理科教育　教える方法　総合的な学習の時間

1. Introduction

The reform in education has been an urgent need both in Japan and in the United States. However, the U.S. has a somewhat longer history in it. When Prof. Ezra Vogel published the famous book, 'Japan as number one', the United States had begun to have some problems with their economy; some of the high-technology areas such as automobiles and cameras which the U.S. had traditionally so much pride in was not doing well. Several conferences were held to deal with this situation. A famous one was the 'Education Summit' where President Bush called the governors from all over the nation to the state of Virginia. At the beginning of the following year, 1991, the President proclaimed in his State of the Union Address that American pupils and students should have the best achievement in science and mathematics among all the nations in the world. This suggests how the issue of science education became political as something that would affect the future of the nation.

On the other hand, the science education sector in the U.S. began its quest for a better curriculum in late 1980's. (Hitomi, 1999). There were three reform projects that it came up with, and a project by S.S.&C. (National Science Teachers Association) was one of them. It said in the report in 1993 that "Less is more", and tried to warn that if the content of study increased too much, the students wouldn't either understand or digest it.

In an NHK documentary program broadcast on TV this spring, it was reported that only about half of the students entering Tokyo metropolitan high schools could graduate, and less than half of the graduates could either get jobs or pursue their study at schools of higher education. We asked a teacher working at a Tokyo metropolitan high school about this, and found that nearly half of the high schools were in a similar situation. What does the fact that so many students leave school without finishing their course of study imply?

It is a quite known fact that even studious students do not raise their hands and speak up in class in high schools and universities. However, the students we saw at St. Charles elementary, middle, and high schools in Illinois, U.S.A. during our visit last May were the opposite; they raised their hands and wanted to make their opinions heard by the teacher and the other students. We met the superintendent of St. Charles board of education at a graduation ceremony. He said that their aim for the students was that they graduate schools with the knowledge and the will to continue their study in the society. This will and desire to study in the true sense of the word, we feel, is something that our Japanese students lack in many cases.

In the following, We will deal with how science education should be, now that we are about to have the new course of study in the year 2002.

2. Educating the students to be interested in science and in scientific occupations

According to the result of the Third International Math and Science Study (TIMSS), the achievement of Japanese students in science was higher than those of foreign countries. However, the percentage of the students who answered that they either liked science very much or were at least interested in science was the lowest among many countries (Fig.1).

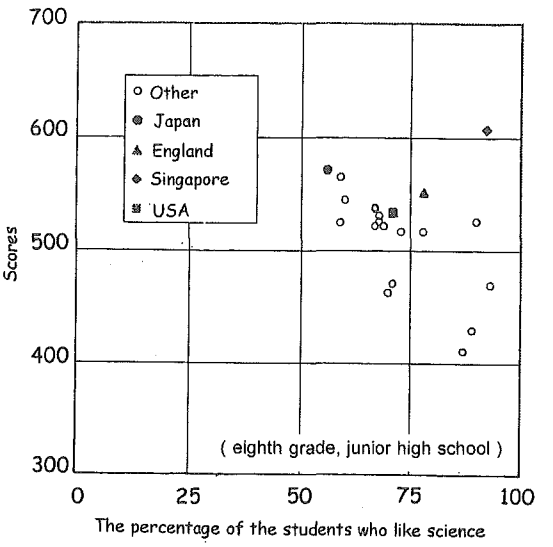

Fig. 1 The percentage of the students who like science and their scores (Matsubara, 1999)

Furthermore, the percentage of the students who considered science important in their daily lives

was 48%, which was the lowest score, 30% lower than the average of all the countries which were questioned. Likewise, the percentage of the students who wanted to be engaged in scientific occupations in the future was 20 %, the lowest among nations. We must consider the critical status , especially because our country has become what it is now owing to its achievement in science and technology and that will continue to play an important role for the further development of our nation.

Project 2061, one of the educational reform projects in the U.S., is trying to straighten out some misunderstandings about science through curriculum development, in order that the students will be interested in science(AAAS, 1993). It tells us that we should teach the students not only the knowledge of science itself but also the scientists themselves and the history of science. Some examples of the teaching points would be that (1) scientific discoveries have been made not through inspiration of some geniuses but through efforts and hard work of individual scientists, (2) generally accepted ideas sometimes turn out to be false, (3) old laws discovered many years ago sometimes still holds in the modern age, (4) people engaged in scientific works are far from being special; they are ordinary people, (5) it is very interesting to work on scientific researches.

We must also note that efforts are made to change and improve the misunderstood image of scientists. Fermi Accelerator Laboratory in the US constantly receives visits from school children. Fig. 2 is a picture drawn by a seventh grader who visited this facility. It shows how his/her image of a scientist changed after visiting there. As we can see, the scientist the child had imagined before visiting is in strange clothes, but he looks nice and cheerful in the picture after visiting. The following words are written as the child's comment about the pictures.

"*Scientists love their job. They wake up in the morning and are excited to come to work.* When you are a scientist, you come to work ready to explore and learn new things; things that may change the world someday, maybe not today, maybe not tomorrow."

Dr. Lederman, the Nobel prize scientist who was a director at this institute, believed that the outcome of the research must be known and children must be the first to know it. This is how the institute built the education center in the facility and started to invite children into it.

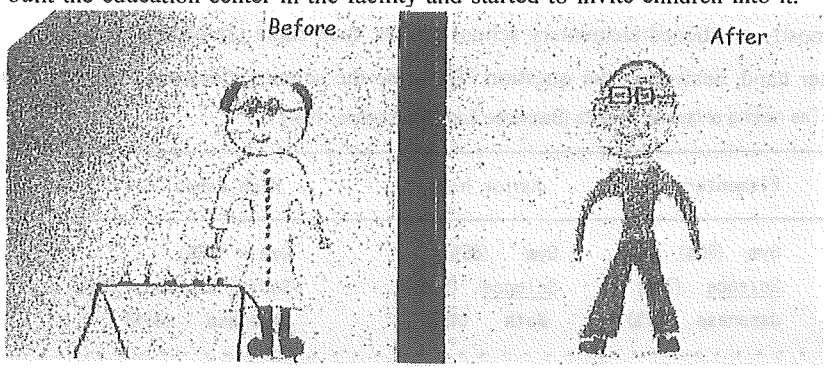

Fig. 2 portraits of a scientist drawn by a pupil(Sakakibara, 2001)

One of the finest research facilities in the world like Fermi Lab actively involves itself with children, tries to show them what science and the works of scientists are all about and tries to tell them that the works of scientists are interesting. This fact gives us some insights. We hope similar efforts will be made in Japan, too.

After the World War II, students had a strong incentive to study, because people believed that hard work and patience would bring them wealth and prosperity. But this is a thing of the past in Japan now. Since the society cannot give students an incentive to study in Japan now (perhaps studying for entrance examinations being the only exception), efforts by schools would not be enough for bringing up children soundly. The school will always remain to be the center of academic study, but it should be supported by every sector of society in its efforts to educate children.

3. The need for study and training about how to teach better as well as what to teach

According to a survey conducted by Bennesse Education Institute in 1997, the popularity of science obtained the second place among elementary and junior high school students. However, it was the least popular subject among high school students (Table 1). We'd like to call your attention to the wide gap between junior high and high school students.

We did a related survey of science classes in elementary, junior high, and high schools with the students of Shinshu University, Faculty of Education in 1999 and 2000. One hundred and fifty two sophomore, juniors, and seniors answered the questionnaire. The science courses that the majority of students took in high school were biology and chemistry, while earth science was taken by the least number of students.

We asked them to describe the kind of science classes they had liked in their elementary, junior high, and high schools. They were not required to mention anything about the grade, but many of them made a distinction by writing, "As for the science class in junior high school" and so on. Some wrote about more than one kind of class and the answers are shown in Fig.3. As we can notice, they mostly mentioned elementary school classes, then came junior high school.

On the other hand, answering the question "Describe the science classes which you didn't really

Table 1 The ranking of favorite subjects (Bennesse Education Institute, 1997)

	Elementary	Junior high	High school
First	Gym (80%)	Gym (65%)	Gym (65%)
Second	Science (71%)	Science (52%)	Social Studies (45%)
Third	Japanese (61%)	Math (45%)	Japanese (42%)
・・・			
Ninth (the lowest)			Science

like", the students talked about high school science classes much more than the other two (Fig.4).

As we can see in Table 2 which shows the example of their answers, the classes which they "didn't really like" did not interest the students. Many of these answers were about high school science classes. This result can be explained by three reasons; (1) Since the students don't follow the teachers' instructions and don't pay attention in class, the teachers have more or less given up on the students. (2) The teachers are interested in what to teach, but not in how to teach. (3) The teachers are not interested in what they are teaching.

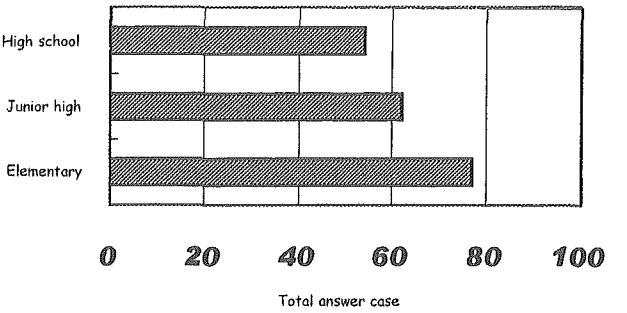

Fig.3 The number of answers for the classes which the students liked

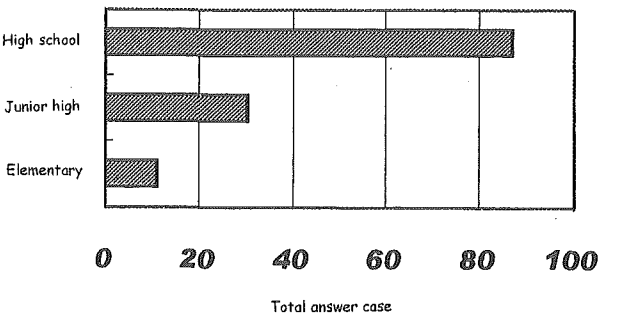

Fig.4 The number of answers for the classes which the students ' didn't really like'

Let us consider the above reasons one by one. Judging from the high schools our students attended, the reason (1) seems to be irrelevant in this case. As for the reason (2), obviously there is no difference between the new teachers of high schools and those of elementary or junior high schools. However, in elementary and junior high schools, there is a system of in-school training initiated by the principal, where new teachers have chances to be better skilled in how to teach. On the other hand, in high schools, the improvement in how to teach is basically left in the hands of the teachers themselves. Although there are many eager teachers working hard in schools and there are various study-groups among teachers, there is no system established by the school to train the teachers in how to teach in a more effective way.

In addition, some high school teachers do not seem to think much of sharing ideas about how to teach with other teachers. As for the reason (3), we cannot deny the fact that there are some teachers who fall into that category, but at the same time there are quite a few teachers who are not like that at all. It's true that high school science classes are far above the other schools in the number of cases which the students "didn't really like", but the number of classes which they thought were good is not much smaller than the other schools at all.

We must note that there are high school teachers who are conducting quite interesting and exciting classes. As we can see in a student's writing about a class where he could tell that the teacher obviously liked biology very much, it is a characteristic of some high school classes that the

teacher's attitude toward the content of the subject attracts the students (Table 3).

One student wrote, "My teacher said that he would leave the stuff for entrance examinations for the supplementary lessons and instead talked about various interesting things in class, such as birthstones, zodiac signs, the precious crystal the school had, his doubt about the existence of the archaeopteryx and so on". So we can see that it is quite possible to conduct a class which is interesting to the students if only the teacher tries to change the conventional way and come up with some ideas.

Table2 Examples of the answers about the classes which the students 'didn't really like'

- a class which ends in haste
- a class where only boys do the experiments
- The physics class was too difficult for me, because I didn't understand the vector.
- a class which was authoritarian (I was fearful.)
- a class where the teacher distributes hand-outs and only explains about them
- a class where the students are to memorize things for entrance examinations (The students don't have to think for themselves.)
- science for entrance examinations
- a students where only the teacher keep on talking
- a teacher who teaches over tea
- a class where the students are shown videos, and do not do experiments
- a class where the teacher write on the blackboard, the students take notes, and then the teacher explains about it
- a class where the teacher writes a lot of numerical formulas and explains like a monologue, without a dialogue with the students
- a class where there is only one experiment in a year
- a class where the teacher writes the content of his own notebook which he had prepared, and he speaks very little
- a class where the teacher reads the textbook, explains, and then gets the students to solve the problems, but the students do not get to do experiments
- a class where there is a lot of calculating, and reading the textbook all the time
- a class where the students have to memorize a lot of things, but cannot do experiments
- a class where there are experiments on the days for school visitation by parents but on the rest of the days the students watch videos or TV, or read the textbook.
- a class for the tests
- a class for taking entrance examinations
- I had the impression that we were merely cramming in knowledge, and wondered how it would be useful in the future life. In high school, science turned out to be the subject to study only for the center test.
- a class where the students took notes from the writing on the blackboard into the blanks of the hand-outs.
- a class where the teacher solely how to solve the problems on the blackboard

Table 3 The examples of the classes 'which they thought were good'

- the dissection of frogs
- a class where we could understand the ions from the experiment in the electrolysis of copper chloride solution
- a class where the students could tell the teacher liked biology very much
- a teacher who was good at drawing
- a teacher with a well-organized notebook
- a class where the teacher showed us things of his own making
- a class where the students could understand how typhoons and the weather were related to our every-day life
- a dedicated teacher
- "My teacher said that he would teach the things necessary for entrance exams in the supplementary lessons and instead told us various interesting things in class, such as birthstones, the zodiac signs, the precious crystal the school had, his doubt about the existence of the archaeopteryx and so on".

4. The content of study (teaching material) to meet the demands of the society

The Japanease economic report published the other day placed the IT revolution as the vital factor for the further development of our country and pointed out that in addition to 'capital and labor' which have traditionally been two indispensable constituents of the economy, 'technology and knowledge' would be very important from now on. What do 'technology and knowledge' refer to then?

If we look at the survey conducted by the Japan Labor Organization, many of the respondents who have been working in the society for about ten years since graduating from universities think that they acquired a good amount of theoretical knowledge of humanities, social sciences and natural sciences during their university years. On the other hand, they do not think that they acquired abilities good enough for communication, problem-solving and analyzing, planning and imagination, data-processing and handling clerical work (Fig. 5). These kinds of abilities are supposed to be basic for working in the society, so they should be trained in high schools as well, where half of the graduates will get jobs.

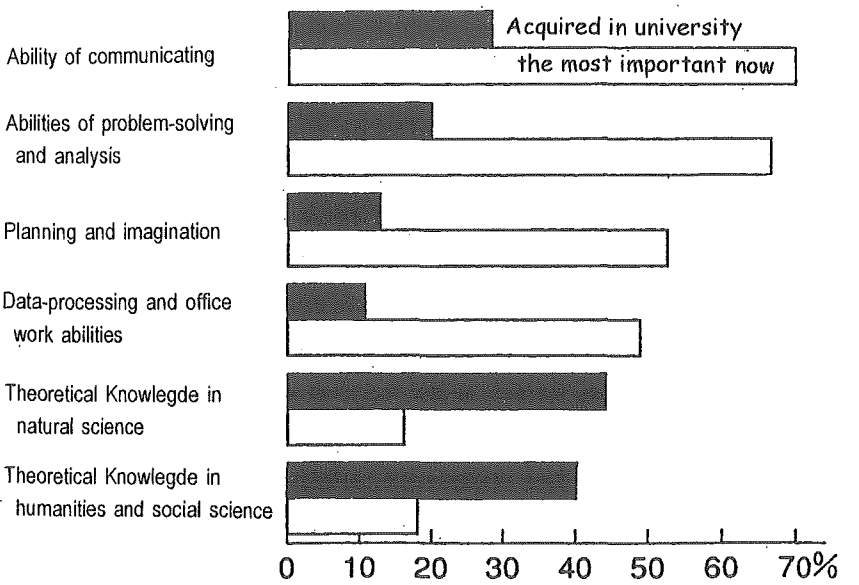

Fig. 5 the abilities the students acquired in university and the abilities of vital importance for social life(EPAJ, 2000)

For example, in earth science classes in high school, the cultivation of such abilities through earth science should be considered more important than merely giving the knowledge of it to the students. One way of doing it is suggested by Sakakibara(2000). To explain it briefly, the students separated into several groups build up a hypothesis, and then carry out a research study. They investigate what rules or tendencies can be found in air temperature, relative humidity, the direction of wind, the wind velocity, and atmospheric pressure etc. throughout the year by studying the weather observation records of meteorological observatories. They were given the data by the

medium of floppy disks which recorded the hourly observation records in 1994. In order to conduct an objective analysis through a vast amount of data, they had to use computers, learn the functions of a spreadsheet program such as retrieving, sorting, graphic facility, functions, etc., and finally come up with a report examining the hypothesis they had initially set up. Ten ninety-minute class periods were allotted for this project. The theme of the class activity was in the content of earth science, but it was designed to train such abilities as communication, problem-solving, analyzing, planning, creativity, data-processing, handling clerical work, etc.

5. The importance of equipping the schools with proper facilities to develop the students' thinking abilities and the importance of the change in the mindset of teachers

We should note that the new course of study also calls for developing the abilities mentioned above. There is an urgent need for setting up a school environment fitted for developing such abilities. The installation of computers and the equipment for the Internet are in progress under the leadership of the Ministry of Education of Japan. As a result, most of the schools are now equipped with computers and the environment to use the Internet is being prepared.

The schools in the United States have a room called the 'resource center', where there are books, tables, and computers. Though talking is not permitted in ordinary libraries, the students can consult the teacher, the librarian, the aid, or the technical staff, and they also consult or talk among the group members.

Students can develop their interpersonal skills in the form of group study, and this method is adopted in many subjects. In such classes, students are engaged in a research study as they play their own roles in the group. The teachers are there to help and support the students. This method is adopted because it is thought to be useful in a society where the students will be required to work within a group, playing their roles responsibly. Preparing a room like this should be beneficial to the development of the problem-solving ability.

If we are to conduct this kind of class which focuses on how to teach, we need to change our mindset as teachers, too. When we visited St. Charles High School in Illinois, U.S.A., Mr. Haymond, the head of the resource center, explained to us about their approach as follows; "We put emphasis on research activities in classes, and have the students write a lot of essays based upon the researches. The themes vary from easy to difficult, the essays from short to long, depending on what grade and which level of academic achievement, but every student, from freshman to senior, has to find a topic, do his own research and make his argument with the evidence that supports it. What is important is not to follow and agree with the teacher's point of view but to have his own argument based on a solid foundation. Obviously, our activity has to be based upon knowledge,

and it is important. But we do not agree with the idea of learning knowledge for the sake of memorizing. That's why we have the students read primary source and write about it in their own words when we teach 'knowledge' in the classroom. It takes a lot of efforts and time. Teachers are required to have the capacity to carry out the hard job. But even so, we believe that this kind of ability will be needed to succeed in the society."

From the year 2002, the so-called comprehensive study periods will be introduced to the school curriculum in Japan to meet the needs of an information-oriented society, an internationalized society, and environmental problems (Ministry of Education, 1998). The main objective will be to get the students to learn how to learn rather than to achieve. In other words, the process will be more important than the result.

So far, in elementary and junior high schools, attempts have been made to create classes where not only the knowledge but also the development of the ability to think, participation, experience, and research are emphasized. Compared with the textbooks of some other countries, Japanese textbooks apparently try to get the students to think, through interesting explanations of experiments and so on. Nevertheless, it is true that the teaching of basics should still remain to be the center of elementary and junior high school education.

With these situations and the status in mind, We cannot help doubting the legitimacy of the plan to introduce 110 periods of comprehensive study to the curriculum of compulsory education, because the class periods of the school subjects will be greatly reduced.

In the new course of study, the class periods of the school subjects will be reduced by 10 % with the introduction of a five-day school week. But actually, they will be reduced even more because of the comprehensive study periods which take up a lot of time. This decrease in the study hours will inevitably lead to a decline in the basic scholastic ability of the children and the students. We must note the fact that the scholastic ability of university freshmen have already been deteriorating in the recent years because the class periods have been decreasing as a result of the policy to make or to allow some free time 'yutori' and 'space' in education.

Furthermore, we don't agree with the idea of separating the roles of the classes between the school subjects and the comprehensive study; in other words, the idea that teaching the basics should be done in the school subject classes, and teaching how to think and the cultivation of the mind should be done in the comprehensive study classes. In this way, the school subject classes can be dull or uninteresting, with perhaps a lot of lectures. However, if the development of the thinking abilities and the learning of how to learn and how to research are done in the school subjects along with the 'teaching of knowledge', the teaching will be done all the more effectively for it than otherwise. In addition, since the instruction for 'the development of the thinking abitities can be done in the stream of the class, the class can be the more efficient without the necessity of reviewing for its own sake.

Above all, in the compulsory education, the acquisition of the basics is a matter of the utmost urgency. We can say it has been successful in traditional education in Japan. The instruction of how to think, how to learn, and how to research should be done in the context of school subjects without providing the comprehensive study periods. It makes more sense to carry on the school subject classes more comprehensively.

6. In conclusion

We have given our consideration to how science education should be conducted in this age. In the 21st century, the Japanese society will be even more internationalized, and the tides of the IT revolution will certainly come in big waves. What is requested for the students to succeed in such an age is to determine what kind of ability or skills should be developed by the time the students finish high school, which is practically the end of the compulsory education now, and to develop a curriculum fitted for cultivating such abilities in the whole context of science education from elementary school through high school. The abilities to be developed include the ability of communicating, problem-solving, analyzing and planning, the creativity, data-processing and office work, etc. And also, especially in high school and university education, a conversion of an emphasis in instruction is being called for, from the teaching of knowledge to the cultivation of the thinking ability.

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