

Students' Independent Research and Natural Science Literacy

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Abstract: Nara Women's University Secondary School is an integrated system of junior high and senior high schools. We consider the independence of each student as the school ethos. Since 2005, our school has been designated as Super Science High School (SSH) by the Japanese Ministry of Education, Culture, Sports, Science and Technology. We have been doing research on scientific and mathematical education. Our hypothesis on this program is "In order to nurture Super students in science and mathematics, it is necessary for every student to acquire Natural Science literacy." In other words, without the Natural Science literacy, we cannot grow students who are good at science and mathematics. Under this hypothesis, we have established curriculum as follows.

1. 1st and 2nd grades—to ensure the acquisition of fundamental and basics
2. 3rd and 4th grades—to improve the ability to think scientifically
3. 5th and 6th grades—to apply science in ordinary life

We also provide the students who are strongly interested in science and mathematics with the study environment to support their own research. Our goal is to develop each student's abilities to the maximum. As a result, a lot of students have been awarded top prizes in many contests in science and technology held not only in Japan but foreign countries, since 2007. We find that those students have acquired strong communication skills and broad knowledge of science through discussions among other students about science and mathematics. We will keep working on scientific and mathematical curriculum to nurture students with broad knowledge of science and mathematics and effective communication skills.

Keywords: Super Science High school, Natural Science Literacy, Independent research

Introduction

Our school became Nara Women's University Secondary School in 2000. We had already introduced an integrated system of junior high and senior high schools since the 1970s. Our students spend meaningful six years under the school spirit of "freedom," "autonomy," and "independence." In our traditional school festival, students work cooperatively and make the best use of connection of each grade. They display interesting exhibits, perform plays on stage, and set up different kinds of booths.

We have been offering students a unique curriculum and led to satisfactory results in the learning aspect. However, teachers feel that a lot of students today take strong interests in only solving problems and requiring knowledge efficiently and quickly. A growing number of students lack ability to solve problems by combining their knowledge and also lack having tenacity to think matters deeply. It can be said not only in the classroom but also in their school life. That is to say, more and more students cannot tackle applied problems or face difficulties in their real life. This is one of the reasons of students' moving away from science or mathematics. If many students lose interests in science and mathematics, it will take a huge toll on the civil society in the 21st century. We set our task of stopping students' alienation from science and mathematics, and we nurture students who are good at those subjects and have responsibilities to be global citizens. In order to execute our task efficiently, we applied for Super Science High School(SSH) certified by the Japanese Ministry of Education, Culture, Sports, Science and Technology in 2005. In this project, we studied teaching method and develop the curriculum for science and mathematics.

Method

In order for students to develop readiness for practical questions and the ability to resolve the issue students face today, we drew attention to "natural science literacy." "Natural science literacy" is used in Programme for International Student Assessment(PISA), made by Organization for Economic Cooperation and Development(OECD). The PISA test asks students to apply their skills and knowledge to solve

problems set in various real-world contexts. To investigate those abilities, PISA aims at testing literacy in three competence fields: mathematics, science, and ability to solve problems. PISA defines “natural science literacy” as abilities to put those three competence holistically to practical use. We assumed our students solve difficulties they face in their life by acquiring the natural science literacy, so we determined to bring those three categories into our school curriculum. We took advantage of our school spirit and characteristics of six year-integrated system. Our curriculum was divided into three sections and define each section’s goal as follows.

1st and 2nd grades—to ensure the acquisition of fundamental and basics of all the subjects and not to favor science and mathematics

3rd and 4th grades—to have students interested in learning and motivate them to learn more

5th and 6th grades—to practice advanced math and science education by working together with universities

As above stated, we put those goals into practice as below.

- (1) To acquire the fundamentals and basics of all the subjects
 - “Inquisitive mathematics”: the curriculum for learning mathematics entirely
 - “Basic science”: the curriculum for acquiring skills for experiment and observation
 - “Basic course in science”: to set up lectures to obtain basics to nurture natural science literacy
- (2) To nurture mathematical literacy
 - “Heuristic approach for geometric learning”: lessons to nurture students who are willing to learn and good at finding their own questions by using tools for making diagrams
 - “Experimental function learning”: lessons whose goal is to have students understand what role mathematics play in the real life by using a graph calculator
- (3) To nurture scientific literacy
 - “A guide to a research on a given subject ”: the unit is to develop students’ scientific way of thinking
 - “A research on a given subject”: the unit is to research phenomenon that happens around students by using scientific way of thinking
- (4) To develop skills to solve problems
 - “NSL(Natural Science Literacy) Course”: the course mixed with mathematics and science to nurture students’ natural science literacy
 - “Mathematical science”: the goal of the curriculum is to develop ability to analyze natural phenomenon as well as the real world
 - “A program for science and mathematics”: special lectures on advanced mathematics and science
- (5) To set up science laboratory and promote its activities
 - To set up science club and support students’ study related to mathematics, science and science technology
 - To provide the students who are strongly interested in science and mathematics with the study environment to support their own research

Table 1 SSH Curriculum for Six year integrated system

category		1 st grade	2 nd grade	3 rd grade	4 th grade	5 th grade	6 th grade
classes	fundamentals and basics	inquisitive mathematics		environmental studies	world studies	information studies	
		English classes with fewer pupils		Integrated English		Topic studies	
		information basics	information and expression	expression			
	mathematical literacy	Heuristic approach for geometric learning	Using a construction tool for geometric learning		Experimental function learning using a graph calculator		
	scientific literacy	Acquiring skills for experiment and observation		A guide to a research		Research	
abilities	ability to solve problems	Integrated study "exploratory study"		Environmental studies	World studies		Mathematical science
				Academic guidance		Focused Studies	
				NSL (Natural Science Literacy)			
ss	fundamentals and basics	Basic course in science					

Results and discussion

We have been practicing our curriculum for SSH study since 2005. It is difficult for us to know how effective this curriculum has been for the students in those five years. It is because the skills of solving problems students acquire in our school will be proved its worth in higher education and professional careers. Here, we can state how the students have changed and what they have accomplished in those five years.

(1) To ensure the acquisition of fundamental and basics

We have implemented “basic course in science” twice a year and found the changes in the students. This course is set in two different ways. One is the optional and the other is compulsory course. The reason we set the compulsory course is that we wanted as many students as possible to have interest in natural science. It is noteworthy that the number of the students who participated in the course in their own will increased greatly. (table 2) In the first year, there were 23 students, and five years later, 60 students participated in the course on a voluntary basis. It is more than twice the students compared to the first year. It can be said that the students’ interest in natural science have improved greatly. We can also say that the theme of the lecture was not only about science or mathematics but various fields such as archaeology, and it motivated more students to have interest in taking part in the course.

(2) Natural Science Literacy

We showed our lessons to other teachers and they observe the lessons in two different aspects, “mathematical literacy” and “scientific literacy.” Our goal was to have all the students to nurture natural science literacy and not to divide humanities course and the science course. The main target to develop those literacy were from 1st grade students to 4th grade students. In order to investigate how those students acquired natural science literacy, we used “literacy test” for 4th grade students. Based on the test made by PISA, we made exam(some part of the exam was quoted from PISA directly) and analyzed examination results. In mathematical literacy test, we were able to know in which stage students made mistakes since we put a lot of essay questions. Students had abilities to solve mathematic problems but they lack abilities to apply those skills to the real life. In scientific literacy, students were good at analyzing graphs of data, but they were poor at stating their own opinion by using the consequence. In both literacy, students lack the ability of scientific consideration. It is because those skills are hard to acquire in only four years. However, the students who are the member of science laboratory showed outstanding result in acquiring abilities of scientific consideration.

(3) Science laboratory

When we were designated SSH, we have founded science club called “Science laboratory.” They became visibly active and made significant results outside our school. This study group is divided into 5 groups, physics, chemistry, biology, earth science, and mathematics. Teachers were advisors of each group and supported students. First, we could only do experimental and practical activities. In the second year, students set goals for their own study and conducted their study. This could be done because we have made the curriculum which gets students interested in science and mathematics. We also took good care of providing the students with the study environment to support their own research. When the

students who have the similar interests in the same topics gather, they have meaningful discussion and deepened their study. Those efforts led to be awarded many prizes.

Table 2 theme of the lecture in basic course in science

date	theme		Participants
2005/10/08	Archeology and natural science	Optional	23
2005/11/10	To think about our life	Compulsory	242
2006/05/27	Folk tales of circles and squares—to figure out unexplained phenomenon of Japanese history using geometry	Optional	44
2006/11/17	Gorillas and society	Compulsory	364
2007/05/26	When science change into fake science	Optional	31
2007/11/13	The story of John Napier and the birth of logarithm	Compulsory	368
2008/05/31	To see ancient Japan scientifically	Optional	44
2008/11/12	Science of snow and ice	Compulsory	369
2009/05/16	To investigate historical heroes scientifically	Optional	60
2009/11/10	To solve the mystery of protein	Compulsory	434

Table 3 award-winning

date	Name of the contest and prizes
2007	
March	The Physical Society of Japan 2007 spring Junior Session (the top prize) Physics group “The New type Robot development using an orange as a mouse button”
April	46 th Japanese Society for Medical and Biological Engineering The Chemical Competition for High School Students (the top prize) Physics group “The new mouse system using motion capture system”
August	SSH Japan Student Research Presentation (the top prize) Physics group “development and application of Motion Capture System”
September	The Zoological Society of Japan Poster Session for High School Students The top prize Biology group “Solution for Giant Mechanism of Blepharisma sp.”
December	Japan Science & Engineering Challenge 2007 JFE Steel Award(the top prize) Physics group “Development of Shopping Cart with Automatic chasing system” 51 st Japan Student Science Award (the top prize) Physics group “Development of Cubic Control”
2008	
April	10 th Kansai Junior High School Research Presentation Competition the top prize “Are Deer dung contribute for greening? ”
December	Japan Science & Engineering Challenge 2008 Grand Award Physics group “Development of an Instrument to Measure EMG Signals & Applications” Japan Science & Engineering Challenge 2008 Agilent Technology Award(the top prize) Biology group “Development of Herbicide using deer dung”

2009	<p>January The Society of Biological Sciences Education of Japan Poster Session for High School Students The top prize Biology group “Planarian Death of Bleaching ” “Coexistence of lactic bacterium and plant”</p> <p>November Techno-I 2009 High School division Poster Session the second prize Physics group “Operable Touch Panel without physical contact”</p> <p>December Japan Science & Engineering Challenge 2009 Grand Award “Development of an Instrument to Measure EMG Signals & Applications II ” Japan Science & Engineering Challenge 2009 Outstanding performance award Biology group “ecosystem created by deer dung” 52nd Japan Student Science Award Junior High School division the top prize physics group “development of wearable controller ”</p>
2010	<p>May Intel International Science And Engineering Fair 2010 Grand Award 3rd prize, Agilent Technology Award(the special prize) All American Intellectual Property Association (the special prize) “Development of an Instrument to Measure EMG Signals & Applications II ”</p>

Conclusion

As we mentioned, our goal was to have all the students to nurture natural science literacy and not to divide humanities course and the science course. It is to develop students with citizenship and will be civic-minded people in the future. The result of SSH program can be proved by conducting follow-up investigation on students. And we need to keep it after students graduate from our school and it will be a long way to go. However, since we have been working on research and development, we have gained educational benefits in those five years. While we were working on effective lessons, we have made many original textbooks of our own; “experimental handbook” to ensure the acquisition of fundamental and basics of experiment, textbooks for “mathematical science.” By setting up and running a program for “science and mathematics” and supervising students in science laboratory, we could enhance the partnership with other universities and research facilities. We could also facilitate coordination between our school and Nara Women’s University. The most important fruit we have got is students’ applying scientific principles in their real life.

After we founded “Science laboratory,” there are some students who are strongly interested in science and mathematics in each grade. If they continue their research actively, other students in our school will also be influenced by them and more students will be interested in their research. However, today’s science laboratory is not widely open to everyone. Only the students who belong to this laboratory seem to enjoy their activities. The problem we have to solve is that how those students influence other pupils who are not so interested in their activities. Another important treasure we have got by founding science laboratory is that students are learning more than they do in their ordinary class. They have done as impressive research presentation as university researchers and have abilities to discuss the scientific problems with them. Those students have turned their attention not only in their school but to the outside the school and we couldn’t find those kinds of students before. Their research process is that they discuss the issue and deepen their knowledge first. After that they make plans for their research, and prepare for the presentation which audience can understand easily. Also, they search information they need even outside the school, and it has made them to acquire wide vision. This process is very useful when they go out in the world. We will work on nurturing students with those abilities continuously.

Reference

Nara Women's University Secondary school. 2010. The Report of Super Science High school research and development(5th)

