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Scientific and Technical Education in Japan's Junior and Senior High Schools

13 years have passed since the launch of "Super Science High Schools," or SSHs, which provide students with advanced education in science and mathematics. To date, more than 200 schools have been designated as SSHs by the Ministry of Education, Culture, Sports, Science and Technology. In this issue of *My Vision*, we examine the outcomes produced by the SSHs system, and consider the ideal direction for scientific and technical education in Japan's high schools.

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How should Japan's Junior and Senior High Schools Best Approach the Fostering of Scientific and Technical Human Resources?

13 years after the inauguration of the Super Science High Schools (SSHs) system, how should we evaluate its outcomes? How should we approach junior and senior high school education in order to foster human resources who will drive progress in science and technology? In this issue of My Vision, we discuss these questions with the President of the Japan Science and Technology Agency, a researcher focusing on methods of instruction for science education, a former university president who worked to reform the university entrance system, a high school teacher responsible for technical education (*), and the CEO of a games company who has been certified as a "genius Programmer."
(*) At the time of the interview

Interviewer: Mari Kawamoto, NIRA Research Coordinator & Assistant
Editor: Kazuyoshi Harada
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New mechanisms for the fostering of scientific and technological human resources

Michiharu Nakamura
President, Japan Science and Technology Agency (JST)

The important thing in scientific and technological education is that it encourages children to have dreams for the future. At the age when we first become aware of the world around us, we are all scientists in the making. No matter what the subject, we are filled with curiosity, asking "Why is that?" This changes around high school age because students begin to doubt the usefulness of science and mathematics for their future. This makes it all the more vital to communicate to children the importance of the study of science and mathematics to themselves and their society, and to stimulate their dreams for the future.

Today, Super Science High Schools (SSHs) are essential to science education at high school level in Japan. Schools designated as SSH design their own curricula, and their students set problems and conduct research for themselves. The outcomes are presented at a nationwide convention held once a year, and some are of extremely high quality. This provides an entrance to future research activities. The rate of graduates of SSHs proceeding to science and mathematics faculties and from there to graduate school is high by comparison with non-SSHs.

Projects and research efforts in scientific and technological fields often proceed on the basis of teamwork. Non-Japanese wonder why, given this fact, Japan does not provide education that cultivates the ability to work in a team. The "Science Koshien" competition, in which groups of students from high schools throughout Japan compete against each other in solving scientific and mathematical problems, provides an excellent example of the honing of teamwork, because students divide parts of problems between them in order to produce the answer together. From the year before last, we also commenced holding the "Science Koshien Junior" for junior high school students.

At present, we are continuing in efforts to promote joint activities between SSHs schools and surrounding schools, in order to spread the benefits of SSHs activities to other schools. At the same time, we have also commenced the Global Science Campus initiative, in which universities provide education to outstanding high school students. Against the background of the rise of China, India and other emerging nations, we seek to comprehensively move ahead with the fostering of the next generation of global human resources who will drive Japanese science and technology. ■

Dr. Nakamura is the President of the JST, a key government organization charged with creating infrastructure for the stimulation of innovation. Seeking to continuously and systematically foster young people who will lead the next generation of science and technology, the JST provides essential support for the activities of schools designated as SSH.

The major problem is the polarization of science education

Shinya Morimoto
Professor, Faculty of Education and Human Sciences,
Yokohama National University

From the perspective of cultivating children who have strong ability in science and encouraging young people who will lead Japan in the future to enter university courses, the existence of SSHs is highly significant. Schools designated as SSHs conduct the type of education that all junior and senior high schools should be conducting – experiential, problem-solving learning through observation and experiment. Experiential, problem-solving learning in which they formulate their own hypotheses enables children to discover the fascination of science and develop an ongoing interest in it.

However, what is actually provided at the overwhelming majority of junior and senior high schools are classes that focus on collections of problems designed to prepare students for university entrance examinations. This polarization of education between SSHs and other schools is the major problem. Children who are only offered a one-way flow of information and hence do not develop a sense of self-efficacy in learning will come to dislike science, and will not think

or express themselves scientifically. Japan's high literacy rate, and the fact that almost all of its citizens had a grasp of science, mathematics and the Japanese language up to at least junior high school level, were major factors in its becoming a science and technology-focused nation. At the same time as cultivating a small number of superior scientists able to win the Nobel Prize, we must also cultivate a public that seeks scientific and technical knowledge and is able to share in these successes.

In order to do so, it will be important to spread SSHs initiatives to other schools and boost their outcomes. If we simply allow schools designated as SSHs to excel, without sharing the benefits, we will not raise the level of science education overall. There is also the concern that the schools will be criticized as elitist and become isolated from their communities, despite the excellence of their outcomes. It will be necessary to actively create opportunities to share the benefits of SSHs education, for example by making some SSHs classes public and encouraging communication between SSHs teachers and teachers at other high schools. It will also be important to build up a body of teaching methods at SSHs that can be applied at other schools. ■

In seeking to transform children's experientially-based thinking regarding natural phenomena into scientific thinking, professor Morimoto emphasizes the importance of the mutual relation between accurate evaluation of the ways of thinking that children are developing and the application of the optimal methods of instruction to promote learning.

Broad-ranging knowledge produces the ability to reason

Hiroshi Matsumoto

President, RIKEN

I think that asking what type of education we should offer at junior and senior high school levels in order to produce superior scientific and technological researchers is a foolish question. It is important for students to study a full quota of subjects, including music, art and physical education, and absorb a wide range of knowledge in their junior and senior high school years. We often hear the criticism that this is "Cramming education" (*tsumekomi kyoiku*), but it is only natural for junior and senior high school students to study fundamentals, and this does not necessarily imply cramming.

Historically speaking, fields of study were integrated, and during the Meiji period, people would interpret "science"as having a comprehensive and all-embracing meaning. It is said that when Hideki Yukawa was studying physics at Kyoto University, he would often visit the faculty of literature in order to discuss literature with the professors there. It was this wide-ranging knowledge based on a broad concept of personal cultivation rather than a single-minded focus on scientific knowledge that enabled Yukawa to conduct highly creative and original research and to make new discoveries that would ultimately lead to his winning of the Nobel Prize.

I feel that the SSH system, which seeks to cultivate human resources in scientific and technological fields, came into existence as an antithesis to the system that promotes study to pass entrance examinations. If students devote themselves to memorizing textbooks and reference books in order to pass entrance tests, even if they do get into university, their ability to think for themselves will be undeveloped. We should therefore begin from the idea that it is also essential to provide education that makes students think. In this sense, the SSH system has its place, but this is not to say that we would not produce scientists without it. The demerit of the system, that its students do not study subjects other than science and mathematics, is far greater.

We must change the university entrance examinations in order to ensure that junior and senior high school students are able to study all subjects at a fundamental level. Rather than entrance examinations that have students competing over one or two points, it will be essential to make the change to examinations that test whether students have studied the full range of subjects without bias and developed the ability to think independently. ■

From 2008 to 2014, Professor Matsumoto was the 25th President of Kyoto University. During his tenure, he supervised a number of reforms, including the introduction of a special Kyoto University entrance examination, the establishment of Institute for Liberal Arts and Sciences, and the creation of the Graduate School of Advanced Leadership Studies.

Placing the focus on education in *monodzukuri*

Kazuo Kadota

Assistant Professor, Faculty of Education,
Miyagi University of Education

Within Japan there are calls for the promotion of innovation towards making the country a leading technological nation, but one would hesitate to say that scientific and technical education in our schools is meeting the challenge. Scientific and technical education is not only science and mathematics – it is essential to also set aside time for education in '*monodzukuri*' (the ability to create functioning machines from mechanical elements in order to solve specific problems).

Overseas, students are able to study technical subjects even in normal high schools. In Japan, by contrast, many students proceed to study engineering at university without having studied any technical subjects at senior high school level. In junior high school, technical-vocational work and domestic science are offered together for only two hours a week. Few countries devote such little time to education in technical matters during the years of compulsory education.

Unlike the problems presented in science and mathematics classes, technical problems do not have absolute answers; the ability to find the optimal solution by using the right materials in the right way is demanded. This ability to find an optimal solution and embody it in something that works effectively is one that is important to a student's future life in the real world. Despite the fact that Japanese schools offer their students access to computers, these are used only for word processing and Internet access, rather than for education related to science and technology.

3D printers and programming have recently attracted a considerable amount of attention. U.S. President Barack Obama stated in an address that his government would allocate 3D printers to 1,000 primary schools throughout the U.S., underlining the importance of education in making things and education in programming. By contrast, in Japan, we are not responding to the changes in the times, and only the children of well-off families with a strong concern for education participate in activities such as technical-vocational workshops or robot-making classes, because their parents pay for them. The growth of disparities in this area is a concern. It will be essential for us to compare Japan and other countries, and to seek to respond to the problem through teacher training, in addition to adding new subjects to our curricula. ■

Dr. Kadota is involved in a variety of educational activities focusing on machines and robots, with practice and research in the area of mechanical engineering education as the central axis. He is focusing attention on education in the area of 3D printers and other digital-based tools.

Programming will become a basic life skill

Ryo Shimizu

President and CEO, Ubiquitous Entertainment, Inc.

If the Roomba and Pepper robots evolve, and in addition to cleaning and serving tea, robots become able to perform all types of daily tasks as required by their owners, everybody will have to be able to program their own robots. For example, to instruct the robot via a program to go to the correct part of the house and get some particular thing. Experience of using computers from childhood will be an important factor in making this possible.

The main reason why junior and senior high school students are drifting away from science subjects is that they do not understand why they should be studying them. Unlike other subjects, most people do not have any direct experience of their study of mathematics or physics having been useful to them in their work or their lives, and they do not feel that they received any benefit from their study. The fact that the subjects are being taught to students who do not understand their value to them is the biggest problem for science education at present.

Programming education is extremely effective in increasing students' interest in science and mathematics. Experience of programming enables students to discover the meaning in aspects of science and mathematics that at first seem meaningless. For example, if one tries to program a robot to move or to create a game, one sees the meaning in studying trigonometric functions and equations of motion.

When you understand what something can be used for, study becomes a pleasure, and you make the knowledge your own. When the social paradigm shifts to one in which we use robots to create what we need when we need it, programming will be an everyday skill and an essential part of life. Unless we revise our ideas about what should be taught in schools, we will lag behind the progress of 21st century civilization. ■

Mr. Shimizu is the founder and representative of Ubiquitous Entertainment, Inc. His company produces games and other entertainment content based around advanced Internet and network technologies. In 2005, Mr. Shimizu was certified as a Genius Programmer by the Information-Technology Promotion Agency, Japan (IPA).

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NIRA bears full responsibility for the translation presented here.
Translated by Michael Faul.

About this Issue

Scientific and Technical Education in Japan's Junior and Senior High Schools

There can be no disagreement concerning the fact that the cultivation of human resources is essential to the welfare of a nation, whether it is large or small. Advanced and emerging nations all give passionate attention to educational initiatives, but it does seem that nations with smaller populations have an advantage in this area.

Comparatively small nations and regions, including Hong Kong, Singapore, South Korea, Taiwan, Estonia, and Finland, cluster in the upper ranks of results in the OECD's Programme for International Student Assessment (PISA) test, which evaluates academic achievement among 15 year-olds around the world (most recently, Shanghai took the overall top position; Japan's results were also good, with the nation in 4th to 7th position in different fields of the competition). Details of measures employed in each of these nations may differ (the introduction of advanced ICT education, teaching methods that emphasize autonomy and reasoning ability, measures to improve the quality of teachers, etc.), but they share a strategic focus on the fostering of human resources.

Given the fact that scientific and technological capability drives economic innovation and acts as an engine of national growth, numerous nations place an emphasis on scientific and technical education as part of this strategic focus. If it is able to produce human resources who can contribute globally through science and education, even a small nation can bolster its soft power and have a significant influence politically and culturally.

In addition, many commentators predict that increasing mechanization and the evolution of artificial intelligence will eliminate up to half of all existing jobs in 20 years' time, putting large numbers of people out of work. It is uncertain whether or not this scenario will actually manifest, but what is certain is that we are entering an era which will be favorable to individuals possessing scientific and technical knowledge, whether their natural inclination is towards the humanities or towards science. Scientific and technical education is also a fundamental condition for the realization of a fair society, in that it enables individuals to transcend the particular environments in which they are born, increasing their possibilities and presenting them with challenging opportunities.

In Japan, Super Science High Schools were introduced more than 10 years ago as a new measure to boost scientific and technical education. How do experts who have studied education for many years see the outcomes of this venture? In this issue of My Vision, we focus on scientific and technical education in Japan's junior and senior high schools, and offer a broad range of opinions regarding how we should attempt to foster scientific human resources who will lead us into a new era, and how junior and senior high school education should be approached in order to make this possible.

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