INNOVATIVE METHODS IN SCIENCE EDUCATION IN JAPAN - STRATEGIC METHODS ON SMOOTH TRANSITION FROM UPPER SECONDARY SCHOOL TO THE UNIVERSITY

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This paper presents a brief introduction of the science education in Japan with an overview of the educational contents and standards laid by the Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT). It highlights the results of the International Education Association (IEA) on science education in Japan at upper secondary school level which revealed that science was still not being learnt directly from natural things and phenomena. In order to investigate the strategic methods on the smooth transition of science education from the upper secondary school to the university, an overview of school education in Japan is presented including the accompanying issues and concerns. The examples and criteria for good practices together with the syllabus on the related subjects are discussed. The keys to improve teaching and learning on the contents and methods were integration, scientific literacy, close relations with daily life, communities and families, audiovisual or information and communication technologies (ICTs) and relevant pedagogy to motivate and expand students' own views coping with the changing society. Finally, four recommendations are described to address the general concerns so as to improve university science education in Japan.

Background

In Japan, the mission of the university provides for the completion of elementary to secondary education as well as the preparation of students towards a society of lifelong learning citizens. Presently, the requirements from the Japanese workplace tend to focus on "what and how students learn in the university" rather than on the university's established reputations and standards.

In order to consider the problems and issues regarding Science and Technology Education in the 1^{st} and 2^{nd} year or the teaching and learning as general education, the current Science and Technology Education planned for general education in the university, has to be reviewed, since the general education or education in the first and second year should in principle strongly reflect the education from elementary to upper secondary (Brown, Clarke & Tiomno, 1964).

As society changes from an agricultural-based to an information-oriented one (Toffler, 1980) via industrialization, this has also brought a change on the learners. The Ministry of Education, Culture, Sports, Science and Technology (MEXT) has revised the curriculum almost once in every ten years since 1947. The revised 'Courses of Study' were done in the kindergartens, elementary schools, lower secondary and upper secondary schools respectively.

Brief Introduction of Japanese Education

Education System and Enrolment Rates

After World War II in 1947, the education system was drastically changed and the new system of 6-3-3-4 was introduced. The elementary education is over six years and the lower secondary education is over three years and both are compulsory. However, in 2003, the advancing rate of the same age population in the upper secondary schools had increased to 96.1% including the colleges/ universities and in junior colleges to 49.0% (MEXT, 2004). These high rates coined the word 'universal' in the upper secondary schools and in the university as well.

Educational Contents and Methods in Schools

In Japan, MEXT determines the educational contents and the minimum number of school days per year. These include subjects in the elementary, lower secondary and upper secondary schools as well as the standard number of annual school hours for each subject. In addition, except for a few private schools, the five school days in a week has been enforced by government regulation. MEXT also specifies the objectives and content standards of each subject area or school activity in the Courses of Study by presenting the national curriculum guidelines for each of the four school levels namely: kindergarten, elementary school, lower and upper secondary school. The content of the Courses of Study for all schools is prescribed and outlined by MEXT based on the recommendations of the Central Council for Education.

In this regard, each school has to organize and implement its own curriculum in accordance with the provisions and relevant status on the Courses of Study, by considering the school location, the characteristics of children enrolled and the stages of their mental and physical development.

In terms of the university requirements the students have to meet certain credit requirements for the completion of a specific course. MEXT only provides the optimum national establish standards for the different types of higher education institution. In other words, in the universities the content and methods of teaching are at the discretion of individual institutions and faculty members in the light of education offered from elementary to the upper secondary schools according to societal needs.

On-going Curriculum Organised by Schools

The on-going Japanese curriculum in every school is based on the Course of Studies revised in 1998 and 1999. The key concept is known as a '*zest for living*' or '*spirit to live*' in an uncertain twenty-first century with education aimed to: (1) help children acquire a "zest for living" and to cultivate a sound mind that can positively them prepare for a new era; (2) help children cultivate rich humanity that includes a sense of justice and moral, and consideration for others; and (3) strengthen the moral education applicable to the whole society.

Knowledge acquisition that was considered as the first priority for the past several decades is no longer emphasized in Japan today. Rather, both the quality of knowledge acquired by students and its processes have become the most important at all school levels.

As far as Science and Technology Education is concerned, the 'Science' subjects at the elementary school are first included at third grade according to the present Course of Studies. For students in the first and second year, 'Life Environment Studies' is taught to promote experience-oriented learning activities including human relations and environment which are closely related to the family, school and local community .

The time alloted for *'Science'* for the third, fourth, fifth and sixth year students are 70, 90, 95 and 95 hours respectively, and is relatively low compared to *Mathematics.* The *'Periods for Integrated Learning'* which consists of five areas, namely *'Informatics', 'Environment,' 'Welfare,' 'Health,' and 'International Understanding',* allow teachers to organize cross disciplinary activities. However the shortage of time for conducting scientific experiments had been a crucial problem.

On the other hand, the International Education Association (IEA) survey revealed that presently in Japan, the science education in the upper secondary schools has not yet carried out the standpoint of learning directly from natural phenomena. Instead, there is a tendency for instruction to be conducted as a one-way transmission of knowledge from the teacher to the students. As a result, students invariably tend to rely excessively from the passive form of learning. Students have not necessarily acquired the ability to investigate nature through self-initiated inquiries through natural phenomena nor have they developed a positive attitude towards the study of nature.

The formal school education is strongly expected to cultivate abilities for coping adequately with changes in society, including the ongoing progress of science and technology and the advancement of information technology. This is one of the reasons why steps should be taken to improve and upgrade the content of science education along with the teaching and learning methods used. The aim of science education should be to foster the development of scientific thought, judgment and power of expression. This can be accomplished by cultivating a desire for self-education and in motivating students to undertake self-initiated activities to study and investigate natural things and phenomena.

The latest revision on science education contents in the lower secondary schools pointed out that more attention should be given to the relationship between nature and students' everyday life and things in their immediate surroundings. Further, there is a need to foster a stronger interest in intellectual excitement and curiosity about natural things and phenomena through science education activities. First, from observation, this viewpoint should be specifically incorporated in the improvements done on the contents of the Course of Study. Secondly, one important aspect on teaching students about the relationship between nature and their everyday lives is to promote a better understanding of natural phenomena. This will help improve students' understanding of abstract and difficult scientific facts when presented in the classrooms.

Thirdly, the principles underlying the revision of lower secondary school science education are the following points as emphasized by Shinohara (2001), namely:

1. Natural things and phenomena are the traditional disciplines of chemistry, physics, biology and physical geography. The contents of science education were organized to account for factors such as the students' stages of development, their aptitude for learning and the consistency of instruction at each educational level.
2. Greater attention is to be given to the selection, consolidation and organization of the Course Study contents based on constructivism and situated learning. This is done to foster the development of scientific perspectives and powers of thought providing sufficient levels to investigate nature through direct personal experience in the form of observation and experiments.
3. Instruction should not be conducted with over reliance on the transmission of factual information but rather, to foster the development of the students' abilities with a desire to enthusiastically find solutions to problems.
4. The contents should be organized with greater emphasis on the connections between familiar natural things and phenomena and students' everyday life showing the benefits and results of science and technology. This will make the science subject more appealing and interesting to the students when it is integrated with other subject matters; and,
5. Computers and information technologies should be used as needed to teach students about science. This includes ways to clearly identify the role of computers and information technologies in science education in the future where computers can be utilized suitably and positively in science instruction.

All of these are requirements to a university science education especially in the first and second year. Another reason is that universities are to some extent becoming *'universal'* not for the elite but with highest consideration of its mission.

In upper secondary schools, the subject area like *'Science'* consists of 11 subjects such as *'Basic Science,' 'Integrated Science A,' 'Integrated Science B,' 'Physics I,' 'Physics II,' 'Chemistry I,' 'Chemistry II,' 'Biology I,' 'Biology II,' 'Earth Science I,' and 'Earth Science II.'* Students have to take two subjects including at least one of *'Basic Science,' 'Integrated Science A,'* and *'Integrated Science B.'* For these three subjects the standard number of credits are 2 units each, while the others are 3 units each. In addition, with the less number of credits required, the time and periods for the demonstration and experiments in science education have also become quite limited.

Problems in the University Science Education in First and Second Year

In Japan, problems regarding science education in the university are closely related to trends such as the 'selection-oriented' by learners and to some extent decreasing the 'contents' offered from elementary to upper secondary education. All these reflect the values of a changing society and students' attitudes together with the new education policy of five school days a week. In addition, the nationwide University Entrance Examination System conducted by MEXT and its related agency were also thought to have brought about crucial problems in the General Science and Technology Education in the universities. For example even in the medical universities there are many who do not take Biology I and II in upper secondary schools. In the Physics Education Departments in the education universities, many cannot understand the importance of considering relevant framework about examining any phenomena, which is taught in *'Basic Science,' 'Integrated Science A,' and 'Integrated Science B'* with few experiments being carried out.

To meet the needs and changes caused by the various kinds of students entering the university, the contents and methods of teaching university science education need to be revised especially for the first and second year students or in the General Science Education in the universities.

The keys to improve the contents and methods includes integration, scientific literacy, close relations with daily life, communities and families, audiovisual or information and communication technologies (ICTs) and relevant pedagogy to motivate and expand students' own worlds in coping with the changing society, some of which are described previously (UNESCO Bangkok, 2005).

In Japan, the spread of the anti-science movement is also a big issue. From Japan's experience with the atomic bomb, many citizens tend to receive anti-science critique through various kinds of mass media that further points to the deteriorating environment as a result of development of science and technology. The improvement of medical care especially targeted on the human brain and the aged is also constantly and sensationally announced through the same mass media.

Furthermore, from the views of the education faculty in the university, the following were also pointed out, namely:

1. In the pre-service education curriculum more subject matter and time should be related to experimental study and practices, and;
2. Coping with the restructuring of school education Course of Study such as the integrated study periods, where policies to train students in teacher education universities who can provide the integration will also be highly considered.

Good Practices in Science Education in the Universities

In the light of the new trends in university education in general, Shinohara (2003); pointed out the following:

1. The knowledge economy is changing the nature of national universities such as:
   a. More and more corporate research and development institutes outnumber the national universities in knowledge production. The universities are no more the centres of knowledge production and distribution,
   b. The percentage of employment after graduation is decisive for recruiting better students in most national universities, thus the customized curriculum is designed based on the needs of industry and,
   c. Procedural knowledge is preferred by the corporate employers rather than propositional knowledge, thus the general education in the universities is being substituted with practical education as seen in law schools and teachers' professional school.
2. The lifelong learning paradigm is changing the role of the universities such as:
   a. Universities are represented as locus of continuing education as well as initial education,
   b. Universities are becoming the centre of local regions with close connection to local private companies,
   c. Non-credit extension programmes are provided to the local residents to promote and activate local communities, and

d. Recurrent education is customized and provided to the graduates as seen in the development of education and learning network or el-net; www.mext.go.jp/a_menu/shougai/elnet" www.mext.go.jp/a_menu/shougai/elnet,

3. Non-traditional universities are emerging such as:

   a. Cyber universities – accredited universities providing lectures only through the internet. Residential universities operate cyber universities as a "branch" of the university.

   b. Traditional and cyber universities have partial cooperation in the curriculum; residential university students can transfer credits from cyber universities as seen in http://www.setagaya-ecollege.com/" http://www.setagaya-ecollege.com/,

   c. Corporate universities – located within the boundary of companies that endow baccalaureate and/or associate degrees as seen in http://www.lec.ac.jp, which is completely managed by the company.

4. Global Challenge and Regional Partnership such as:

   a. Small private universities network with western universities for survival (Joint degree conferment), and

   b. Global partnership with world leading universities; GMSVU (joined by 6 countries in Great Mekong Sub-region), Asian Cooperative Unity Blocks or Asia-Pacific Unity (e.g. under the Asia Pacific Rim Universities, 34 top research oriented APRU universities meet each year).

Coping with such globalized and competitive society, the Japanese Government is taking the initiative to restructure universities or higher education in general. One of its National Programmes, the *"Good Practice Programme"* was launched by MEXT in 2004 aimed to revitalize the university activities in general. A total of 86 projects out of 559 proposals submitted by several Higher Education Institutions were approved and funds were granted in the field of:

1. Contribution to revitalization of the region,
2. Promotion of education for intellectual properties,
3. Cultivation of the Japanese citizens to utilize English in their work,
4. Strengthening of the education functions through the integration and linkage with other Universities,
5. Collaborative education through exchange of human resources, and
6. Practical distance education utilizing IT and e-learning.

Although there were no indicators found in the National Programme to identify the good practice in Science Education for the first and second year students of the universities, the author selected several practices by considering his own above mentioned criteria to construct a personal framework for the present and future Science Education of the university. This included the challenges and innovative ideas laid in the selected projects to meet the needs of the present and future society in changing students' attitude generally.

In this regard, category 1 constitute (1.1) humane and environmental science education in Northern Region Programme, (1.2) development of e-learning materials for science Education in Collaboration with students and school teachers, (1.3) implementation of environment education programme focused on the development of the region for the future, (1.4) pilot study on the medical education linked to the region, and, (1.5) promotion of college-centred activities for the regional prevention of disasters as identified in the university science education related good practices.

Category (3), includes (3.1) innovative education system to develop the staff in medical affairs, and (3.2) establishment of English for the promotion of English language programme for medical students.

For category (4), (4.1) the establishment of field education system through the linkage with the faculty of agriculture in the universities for the western regions in Japan will be selected.

In category (6), (6.1) integrated education in medical affairs utilizing web-based training, (6.2) development of resource Materials for IT use and promotion of IT education, and (6.3) energy and environmental education for the twenty-first century to expand networking in the teaching and learning as identified in the good practices of the university science education.

University Science Education as Good Practices

The development of science and technology has reached a new stage in the recent years. It has not only brought great changes in the environment but has increased many new subjects in scientific research, setting a higher demand on science education at the university. The conventional education methods and course contents are obviously not suitable for this situation. The development of science and technology demands modifying the teaching of fundamental physics especially to strengthen modern physics and to enhance students' ability when physics education is concerned.

In order to meet the needs on the development of science and technology and to raise the quality of teaching, the author did several pilot reforms since 1980 in this respect in the field of physics education and teacher education as well. The reforms provided some effects so far. On the other hand, it was deemed very important to conduct research in physics education and to study the reforms in physics teaching from the perspective of a changing society and students as described above.

Suggested Methodologies in the University Science Education

In order to respond to the changes in the students' attitude and to encourage their involvement in the teaching and learning process in the university courses, the important factors can be derived partly from the activities in science education in elementary schools. It is similar to the development of lesson plans, which are carried out both in pre-service and in-service teacher training in Japan. The faculty development (FD) activities in the university (1) provide students with freedom, (2) provide students with resourceful and structured environment, (3) establish responsive environment or a response to students' approaches, and (4) support students' intellectual development through frequent interactions.

In addition, the principles of management of strategic teaching and learning activities utilizing students' intellectual curiosity are summarized as follows; namely, (1) to enhance student's' observation skills, and motivate their questioning skills. In carrying out this process, the activities to stimulate students are tried based on information gathering that lead them to solve problems by collecting relevant information, and (2), activities with related strategic approach to stimulate student's intellectual curiosities, (a) utilization of students beliefs and preconceptions, (b) showing phenomena which are contrary to their drawn expectation and beliefs, (c) making students find inconsistencies and/or by letting them consider the belief as much as they want, which the author describes as 'jolting strategy,' (d) providing students with a knowledge which might be a hint, and (e) making students recognize the differences in their acquired knowledge.

An example for strategy (b), using phenomena contrary to students' expectations, is as follows: Even university students tend to think that air has no weight. A simple experiment can be used to demonstrate this by comparing an air-filled bottle with a vacuumed bottle. An example for (c) the 'jolting strategy' is related to water flow. Normally water flows from the upper region to a lower region but water moves up when a part of a piece cloth touches water. In using strategy (d), the students are first given generic or major laws. After students understand the principles they are provided with other examples/facts, which are not applicable to lead them to generalize the law. Another example is to first provide students with universal reasonable laws without commenting whether it contains universality and reasonability. In the process of examining their generalization students can try or consider asking questions whether it can be correct or not using the 'deductive thinking skills'.

With regard to (e), students can be provided with an '*open-ended*' type of problem, which requires that they consider conditions by consistently changing parameters applicable to the phenomena. Throughout the process, each students will come into the psychological conflict with their logical thinking.

Syllabus of the Subjects Related to Science Education

Examples 1 to 3 illustrate the author's efforts to implement good practices in Science Education from the author's personal perspectives in the universities. At the beginning of each class the author in principle introduces reference materials uploaded on his website, http://www.u-gakugei.ac.jp/~shinohar/

Example 1. Syllabus for the 'Integrated Science'

Title: Philosophy of science

Objectives: Through the introduction of Worldview found by the process of the creation of the modern physics, consider the scientific way of thinking, logical thinking, evidence of the truth.

Target: 1st year students in the Faculty of Education

Semester: Semester 1 **Credit:** 2

Schedule and agenda:

1. Substances and changes
2. Energy
3. Science and methods
   - 3.1 Methodologies in several sciences
   - 3.2 Method of Physics and law
   - 3.3 Role of mathematics in sciences
4. Logic and language
5. Existence and truth
6. Summary Discussions

Example 2. Syllabus for the 'Basic Physics'

Title: Basic Physics I

Objectives: Starting with the overview of the phenomena such as Motion, Force, Energy and Life surrounding human beings, several phenomena familiar with our daily life will be introduced so as to consider the fundamental scientific concepts. Students are expected to acquire knowledge and simple skills to design and conduct experiments and to foster deep and sound attitude to nature and human being.

Target: 1st year students in the Faculty of Natural Sciences

Semester: Semester 1 **Credit:** 2

Schedule and agenda:

1. Motion, Force, Energy, and Life
   - video viewing
   - discussions
   - reporting
2. Matter: Forms and properties
   - video viewing
   - discussions
   - reporting
3. Wave motion - Acoustics
   - video viewing
   - discussions
   - reporting
4. Summary Discussions

Example 3. Syllabus for the 'Basic Physics'

Title: Basic Physics II

Objectives: To follow 'Basic Physics I,' several phenomena familiar with our daily life in the field of electricity and magnetism will be introduced to consider the fundamental scientific concepts. Students are expected to acquire knowledge and simple skills to design and conduct experiments and foster deep and sound attitude to nature and human beings.

Target: 1st year - Faculty of Natural Sciences

Semester: Semester 2 **Credit**: 2

Schedule and agenda:

1. Electricity and Magnetism
   - video viewing
   - discussions
   - reporting
2. Wave motion – light
   - video viewing
   - discussions
   - reporting
3. Peaceful Uses of the Nucleus
   - video viewing
   - discussions
   - reporting
4. Summary Discussions

Aside from these efforts, the universities' good practices in science education should urgently consider curriculum development for knowledge utilization with closer links between schools and museums, curriculum for the promotion of logical thinking, creativity and originality on the use of ICTs, and curriculum for the science communicators. It should also focus on the integration of experiences into learning and in the curriculum coordination on subject matters from elementary schools until the university levels.

Conclusions and Recommendations

Based on the recognition of a changing environment where the university is no longer a place just for the elites, the university should (1) carry out entrance examination based on its mission, (2) offer quality science education and (3) produce students who are prepared for the future society.

Furthermore the university should reconsider (1) the subjects related to science and technology to be a part of the examination and (2) the need for an evaluation system such as GPA similar to procedures in the United States to be applied, even though it is a very difficult task since the university culture or the attitude among the university faculty members will have to be changed.

In addition, in order to respond to the low achievement of university students, the most important aspect is the improvement of the university science education. This issue has been the concern of all universities throughout Japan facing globalization and structural changes in an economic-oriented society.

Besides the general concerns to improve the university education, others include (1) evaluation done by third parties, changing the evaluation scale from the '*deviation value*' to multi-dimensional levels like research contents and its level, lecture contents and methods, facilities, life in the campus, and quality of graduates, (2) evaluation of classroom activities by students on lectures by professors and, (3) improvement of instructional methods – Faculty Development (FD) for the improvement of science education in the first and second years of the university.

The following actions are recommended:

1. University faculty members should visit elementary and secondary schools to understand the teaching methods and students as well.
2. University faculty members should visit other institutions and companies for exposure so that their thoughts, excellence and needs can be derived from real situations.
3. To cope with the changing needs of society and students, the lectures and demonstrations should utilize the surrounding phenomena offering students' real experiences that are familiar to them, besides the utilization of the ICTs including video materials and books on a variety of topics in scientific and technological phenomena.
4. University faculty members should have experiences in the development of lesson plans, which include teaching strategies and pedagogies as well.

In addition, with specific regards to the improvement of scientific literacy, (1) the reform of Japanese language education in the elementary and secondary schools focusing on communication skills should include presentation skills, logical thinking and writing skills, and (2) the English language education in lower the secondary schools should also be improved.

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