Engineering Education System in Japan: Observations in Study, Teaching, and Research

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Abstract

The proposed speech covers an overview of a long term study, teaching and research experience of the presenter in Japanese universities (Osaka University, Kumamoto University, and Kyushu Institute of Technology) from 2002 to 2011. First, a general view on the official education system (from pre-school to University) of Japan is given, and then the speech is focused on the structure of universities and the schools of engineering. Engineering education in both undergraduate and post-graduate levels is discussed. The role of laboratories (KENKYUISHITSU), and the advantages of the Japanese engineering education in comparison of the other existing regional and world-wide education systems are emphasized. Finally, the reasons and secrets behind developing of the high-technologies in Japan over the years are explained. The speech is supplemented by pictures, memories, and short video clips.

Keywords: Japanese Education system, Engineering, Laboratory, Team working, On-the-job training

1. Introduction

The author has been in an active connection with some Japanese national universities, research centers, and companies for a bout one decade. While attending Japanese universities as PhD student (Osaka University), Postdoctoral research fellow (Kumamoto University), visiting professor (Kyushu Institute of Technology), and professor (Kumamoto University); the author observed many unique aspects and characteristics of engineering education in Japan.

After passing the entrance examination to the Osaka University, one of Japan's national universities, I went on to become one of the first Kurds to obtain a PhD degree in engineering from Osaka University. During the two years it took to earn a PhD degree in electrical

engineering, the author encountered many experiences that caused him to reflect on the strength characteristics of the educational systems and philosophies in Japan. Based on the author personal experience for a decade in Japanese high education system, as well as research and development laboratories, most of these characteristics point toward six interesting themes: hardworking and preparation, team works and fraternity, high discipline and mentorship, research-based education, high social position of professors/instructors, and, close relationship between universities and industry.

In this presentation, the author will present the above characteristics in detail, and discuss the effects of them on the Japanese engineering education system, and industry. Over the last few decades the nation of Japan has produced a remarkable army of highly trained engineers. This vast corps of professional engineers guarantees a valuable resource for Japan high technology products and its economy. The Japanese accomplishments over the years have been such that we may well ask if there is anything we can learn from their experience.

The first attempt to establish a modern university based on the European model was made following a political revolution in 1868, known as the Meiji Restoration. In 1877, the government established the University of Tokyo by consolidating and restructuring several of the westernized institutions of higher learning [1, 2]. The first faculties of engineering were added in 1891.

It is noteworthy that Japan was a developing country for more than 20 years after World War II and at that time there were a lot of industrial products imported from developed countries such as European countries or United States (economic reconstruction period). In the 1980s Japanese success in using technology to produce high quality, low cost, and innovative products led to a sudden interest in the engineering education and training of engineers (high economic growth period).

For several years, Japanese industry had the motto of “Catch up and overtake!” [3], without understanding well what to do after overtaking. 1990s were the time for Japanese industry to start developing world newest products to get large share in world wide market, and Japan succeeded to change its industry from a developing country industry to forerunner country industry (globalized and stabilized economic period). Now Japanese companies and university education are changing to collaborate in making a strong competitiveness to develop the world newest engineering and high-tech products.

About every ten years, the Ministry of Education issues a new standard course of study, which is a set of detailed, written guidelines for each subject taught in elementary and

secondary schools. Suggestions for curricular revisions are made by various committees that include curriculum specialists, university professors, classroom teachers, members of local boards of education, and others [4].

Study of the Japanese engineering education system imposes a number of questions about the unique aspects of this education system, the reasons behind the Japanese high-technologies, and, the relationships between universities, industry and society. Some existing unique characteristics are the causes of Japanese culture, the result of education type, or the result of personnel practices within specific firms? In the present lecture, it is tried to find appropriate answers for these questions. Furthermore, the Japanese engineering education system is compared with available education systems in other developed regions, as well as the Middle East countries.

2. Education System

Let us begin with a brief overview of education in Japan, from pre-school to higher education. Fig. 1 shows the major types of publicly supported schools [4]. The foundation of the modern Japanese educational system is the nine-year compulsory education core, *gimu kyoiku*. Included in the compulsory core is a six-year elementary school, *shogakko*, and a three-year lower secondary school, *chugakko*. After completing compulsory education, more than 95% enter upper secondary school. Japanese enter upper secondary school at age 15, where the focus is on preparation for the nationwide college examination center test and subsequent university entrance examinations.

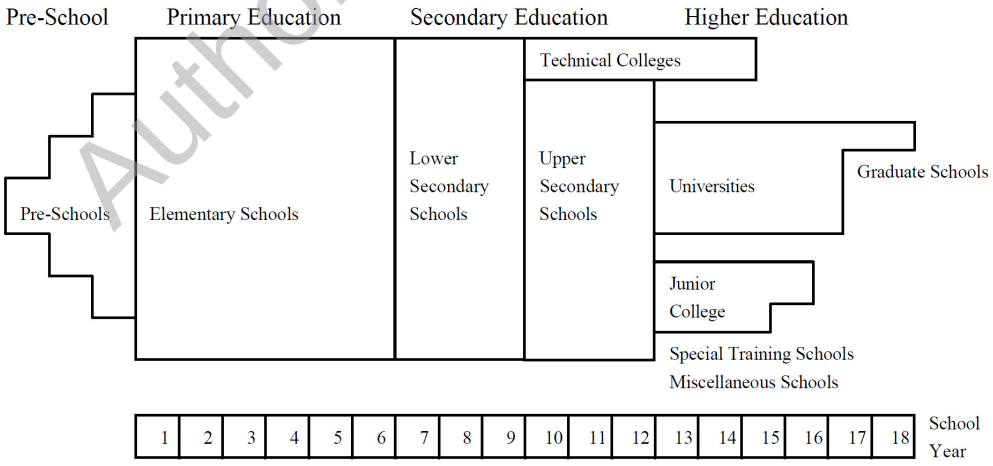

Fig.1: Organization of Japanese school system [4]

Since 1962, junior colleges have been recognized as a permanent part of the higher education system. In the same year, the colleges of technology (technical colleges) were created as a new type of institution. The colleges of technology admitted students from among those completing lower secondary schools and provided them with a five-year semi-professional education focusing particularly on engineering and mercantile marine studies.

Admission to universities (specifically national ones) is highly competitive and mainly based on the results of two separate rounds of entrance examinations in January and February. During a two-day period in January, students all across Japan who wish to enter universities take the standard nation-wide examination test. This test covers Japanese language and literature, social science, mathematics, science (physics, chemistry, physical geography and biology) and English. In February, the examination concerns engineering, mathematics, science and, in some universities, English. Japanese refer to the examination time as *shiken jigoku*, means examination hell [5].

Therefore, in addition to the nation-wide examination test, each individual university organizes an examination for those who have applied for entrance to that particular university. If a student is unsuccessful in entering the university, he/she is required to take special private institutes/colleges courses and then apply again in the next year. Many students gain entrance after their second or third try. Japanese believe that entering a university is hard but graduating is easy.

More than 60% of Japan's students continue on to a college (two year sub-degree courses) or university (four year degree courses and postgraduate courses), while in 1995, only 10% of students went on to the higher education. The academic year in Japan is divided into two semesters. The first semester begins in mid-April and ends in late September. Summer vacation interrupts this semester from early July to early September. The second semester begins in mid-October and ends in March, although examinations are usually finished by the end of February. Winter vacation extends from late December to early January. A percentage of students enter graduate school after completing their undergraduate studies and taking an entrance examination that is specific to each program at each university. The required time for Master degree is two years, and completion of almost 30 credits of advanced study and research (thesis) is needed [5].

A doctoral program usually requires three years. Submission of a dissertation based on original work and attending few courses are needed to complete this program. In many universities, acceptance of at least one journal paper is also required. Number of higher education institutes (including national, public, and private) and number of students in 2009 are

given in Table 1 [2]. All of government-funded universities, which included many of influential universities, have been privatized starting in April, 2004. In 2009, about 73.3% of university students were enrolled in the private universities, and 77.6% of students were enrolled in the private higher education sector. Since 2004, an independent corporation status was also given to all national universities. In accordance with this reform, the national universities became autonomous corporations with their own managing board, and chief executive (president) with authority over budgets, planning, and staff salary scales.

3. Engineering Education (EE)

Focus on the engineering/technology education in Japan, even for the high schools has a long history. From 1958, technology education (*gijutsu ka:* gijutsu means technology and *ka* means subject) has been introduced as a required subject in all lower secondary schools. A total of 105 hours in each of the three grades of lower secondary school was allocated for technology education. In upper secondary schools, students enrolled in vocational technical education were required to take fundamental subjects such as “Fundamentals of Industry”, “Mathematics in technology”, and “Practice”. In 1960, the Japanese government set out to double the number of technical high schools. During this era, five-year technical colleges for the graduates of lower secondary schools were established by the Ministry of Education. To respond to the shortage of skilled technical teachers, three-year teachers' colleges for technical education were established. These colleges were attached to faculties of technology at the Japanese national universities [4]. The *college of technology* as a new engineer educational institution was founded in 1962.

Table1: Type and number of higher education Institutions (2009)

Institute type	Number of institutes	Number of students
University	773	2,845,908
Junior college	406	160,976
College of technology	64	25,135
Specialized training college	3,348	624,875
Total	4,591	3,656,894

Fig. 2: A Lab work course (Motion Control) for electrical engineering, Osaka University, 2003-2004

In the late 1980's, new computer literacy course is also introduced in technology education programs in lower secondary schools. One of the most significant revisions in upper secondary technical courses is the introduction of integrated problem solving courses, such as “mechatronics”, “applied mechatronics”, and independent/assignment project study. These courses included basic machines and devices, sensors, A/D conversion, logic circuits, actuators, mechanics, power transmission devices, and projects. Examples of projects usually include the design and manufacture of robots and remote control models [4]. Since 1980, in parallel with schools, colleges and universities; many companies have their own research laboratories for new employees from the other education centers to change their specialties from traditional engineering to new fields like semiconductor and information technology.

For many years, after social science (law and economics), engineering has been the next most popular choices for high school students in Japan [1]. The engineering bachelor and master degrees at the universities are a four and two years programs, respectively. The bachelor program mainly covers the engineering course work supplemented by lab work (Fig. 2). Course study for the first three years, and doing a research in the fourth year are the main task of the undergraduate students; while, the focus of the master program is research with a thesis. Seminars and discussion groups are also held among the course work. The doctorate degree is a three year program conducted in the same manner as the master program. It is essentially a comprehensive continuation of the master program by passing several courses in the class rooms (Fig. 3), and doing a deep research in a specific subject and documentation of the achievements via technical reports, papers, and thesis.

Fig. 3: Typical class room for postgraduate students, Kumamoto University, 2009

During a week (Monday through Friday), each day is divided into five periods of 90 minutes. Each course meets for one or two times per week. Successful completion of a course with one session (90 minutes) per week earns 2 credits, while the laboratory courses for the same time usually carry 2/3 credit. A passed course is evaluated by the grades *very good* (80-100), *average* (70-79) and *passing* (60-69). A lower grade than 60 cannot receive credit for the course; however, a failing grade is not recorded on the student final record, but the student may repeat the course as many times as needed to receive a passing grade. The student-to-faculty ratio is, on average, about 10 in national universities and two times more in the private universities.

Completion of an undergraduate four-year university course requires approximately 125 credits on the subject of particular field of engineering as well as general topics, foreign languages, and health/physical education. This number may slightly vary among the universities (In 1991, responsibility for setting the requirements for graduation passed from the Ministry of Education to the faculties of the universities. At that time, the number of credits required for graduation was about 160 [5]). Almost all students who enter a university receive a degree, although, it may take a longer time (than four years) for some students.

Graduate engineering students can become qualified as chief engineers, or teachers of engineering in the high schools. To become licensed as a chief engineer, one must receive credit for designated lectures (classes) and laboratory courses during study at the university and then work for few years in industry under a specific conditions. Based on the Japan's law, an engineer must have this license in order to apply, maintain and build facilities for public engineering utilities. To become licensed as a teacher of engineering in the high schools, passing a national examination is required [4]. Based on the Japan public system, some

graduates of two-year technical/junior colleges are permitted to become engineers later in their careers. But those students who want to obtain good engineering jobs right out of school have to attend a university.

The Japan Accreditation Board for Engineering Education (JABEE), established in November 1999, is responsible to addresses specific course accreditations in the engineering fields. Some of the large high-tech companies in Japan have also influenced JABEE guidelines. Since 1999, accreditation of engineering education programs has been actively promoted. Such subjects as engineering designing, engineering ethics, communication skill and international understanding are explicitly included in engineering curriculum. In the case of Japanese system, graduates from schools of these accredited programs are exempt of the first grade examination of Japanese professional engineers (PE) [3].

The JABEE commenced accreditation of programs leading to bachelor and master degrees in 2001 and 2007, respectively. Up to 2010, the JABEE has accredited 435 programs from 169 institutions, and the cumulative number of graduates with engineering programs accredited by JABEE is reached to 145000. The accreditation by JABEE not only assures the quality of fundamentals education for engineers, but also generates strong driving force for the improvement of university education.

The COE (Centre of Excellence) program (launched in 2001) by the Ministry of Education, Culture, Sports, Science and Technology (MEXT), is another effective plan in order to introduce competition among universities and to selectively fund the leading universities in the respective fields.

4. Japanese EE Characteristics

While attending Japanese universities for a long time; the author observed many unique aspects and characteristics of engineering education in Japan. The universities that the author studied and worked in, were quite different in several respects from the universities that the author was been there (Australia and Iran). As mentioned, most of these characteristics point toward six interesting themes: hardworking and preparation, team works and fraternity, high discipline and mentorship in universities and companies, research-based education, high social position of professors/instructors, and, close relationship between universities and industry. Following, theses characteristics are discussed, and more evidences are given in the presentation.

Education for engineers in Japan is a product of an entire educational, cultural and professional environment. Study and work in groups is expected of students from the first grade. The student population in Japan is much more homogeneous than other countries. They are well prepared with a fairly uniform level of knowledge (at least in mathematics and physics) and a unique culture before inter the universities. They have already learned the concept of team work and cooperation among a group. They have learned that every one needs an identity with a group.

The students spend almost all of time together. They enter the university together as a new group at the beginning of the school year. Within each engineering discipline they attend the same set of courses together [6], and go ahead with their group. The time of being together will increased, as the student join a specific laboratory (Kenkyushitsu) from the fourth year of bachelor study. Each professor should have his/her own lab, including a private office, secretary, and a research space for seating about twenty students. The students in these labs are a mixture of fourth year bachelor students (for completing their undergraduate project), master and Ph.D. students. Name of each lab is usually taken from the name of owner professor.

A lab is considered as a family in the university, and the professor is responsible to define research projects, organize the lab budget, making contract with companies, and all other issues. Even, he/she usually takes care of his/her students to find a job after once graduated from a degree. A teaching assistant, an assistant professor, and an associate professor may work in a lab and help the main professor. Within a lab, there is a strong sense of camaraderie and the senior students must help the new students and junior ones. The upperclassmen and professors are given the responsibility for mentoring the younger students.

This close mentoring is perhaps one of the great reasons of Japans engineering education success. The professor has also responsibility for mentoring the assistant/associate professor, making sure he/she succeeds in promoting and becoming a full professor. When it happens, new full professor should provide new lab in same university or in another university. Each lab is holding periodical meeting, and all members should attend those meeting. In each meeting one (or more) student presents his/her final research results and receives probable comments and suggestions from others (Fig. 4). This type of social structure enables average students to reach their greatest potential. In addition to the research, the lab members are together to perform sport teams, and to attend the annual university events, national ceremonies, and parties (Fig. 5). Each lab usually perform several events for the members such as welcome party for new comers, good bye (sayonara) party for graduate members. All students and even teachers share in janitorial and cleaning duties in the lab and university.

Engineering education in Japan is highly characterized by an emphasis on group work and a strong grounding in fundamentals in pre-university education, and by career-long on-the-job training through a mentor system, and rotation within the companies. In Japan on-the-job training is an essential part of an engineer's career, an essential component of the employee's relationship to his/her company, and leads to an understanding of design and manufacturing processes which not achievable in the university [7]. Some companies educate the graduates to get sufficient number of engineers to fit the newly growing fields. Sometimes it lasted for 3 years with 8 hours education a week in the fields such as semiconductors or information systems.

As already discussed, in addition to the universities, many Japanese high-tech companies have degrees in engineering. Once graduates from Japanese universities joined a high-tech company they would then embark on an intensive company-run education program designed to ready them for work. Therefore, university education is only one component of an organic whole of which a Japanese company's relationship to its professional employees is a key determinant.

Fig. 4: Lab meetings at Osaka University (2004), and Kyushu Institute of Technology (2011)

Fig. 5: Laboratory (Kenkyushitsu) members in research room and sport ground, Kumamoto Univ., 2005

Some characteristics of Japanese engineering education can be mentioned as follows [7]:
i) Orientation toward group work developed early in life is reinforced by corporate "acculturation" during on the job training.
ii) Intensive early memorization of facts and study of problem-solving methods, perhaps in supplementary private schools, and largely as preparation for university entrance examinations.
iii) Emphasis on fundamentals at the university.
iv) Extended on-the-job training, use of a mentor system, and job rotation facilitate understanding of company strategy and the production process, break down organizational barriers, and result in long-term institutional capture of technology-and also impart factual knowledge.

The importance of high-tech world class research is strongly emphasized by the government as well as Japanese high-tech companies. They include the competitive research funds such as grants-in-aid for academic research, the “21st Century Center of Excellence Program” (COE), and its successor, the “Global COE Program”, in which the government concentrates its financial support on a specific number of universities for building up world class centers of learning [2]. In this direction, the relationship between universities and industry is stronger than ever. Recently, prestigious universities have realized 20% of their operating budgets from external sources, such as contract research (Fig. 6).

The existence of a large number of universities and engineering graduates is considered as another major strength of Japanese engineering education system. In 2004, there were about 2.5 million engineers in Japan [8]. It is noteworthy that just from 8 major national universities about 8000 graduates are provided annually. As a result of this mass-production of engineering graduates, Japanese companies became extremely good at producing existing products at low cost and with high quality [9].

Fig. 6: Cooperation between university and industry, Research center at Kyushu Electric Power Co., 2009-2010

High quality and safety is an important characteristic of the Japanese engineering products. Some Japanese engineering standards are even stronger that similar standards in the world. Japanese engineering philosophy is based on the responsibility of engineers for safety and reliability of modern society which is heavily depends on the engineering products. This responsibility covers all planning, developing, designing, manufacturing, and operating phases. Following troubles in automobiles, and recent nuclear event (in Fukushima nuclear power plant), the responsibility to the public is more stressed in Japan's new law. Japan engineering society hopes to regain the public confidence on engineers and engineering achievements.

5. Challenges and Future Plans

Long time ago, Japan entered into the period of 'what to design' rather than 'how to manufacture'. This implies that the mentioned ten-year intervals between major education curriculum change are too long to reflect changes in technology and in the workplace. In 2005, the Central Council for Education issued a new report entitled "a future vision for higher education in Japan" to present a vision and overall design for the future of higher education in Japan over the period of 2005 to 2015-2020 [2]. This report emphasizes the importance of higher education in the 21st century as the age of the knowledge-based society in personal development as well as in national strategies.

An important challenge for future of Japanese education system is the decrease of population and in result decrease of young generation and students. Number of enrolled students in educational intuitions from 1977 to 2009 is shown in Fig. 7. Over the past decade alone the population of 18-year-olds has fallen from around 2 million to under 1.5 million; in fact the Ministry of Education predicts there will only be 1.19 million 18-year-olds in Japan by the current year (2012). In order to decrease the number of college and university applicants, the professional motivation among Japanese young people is also changed.

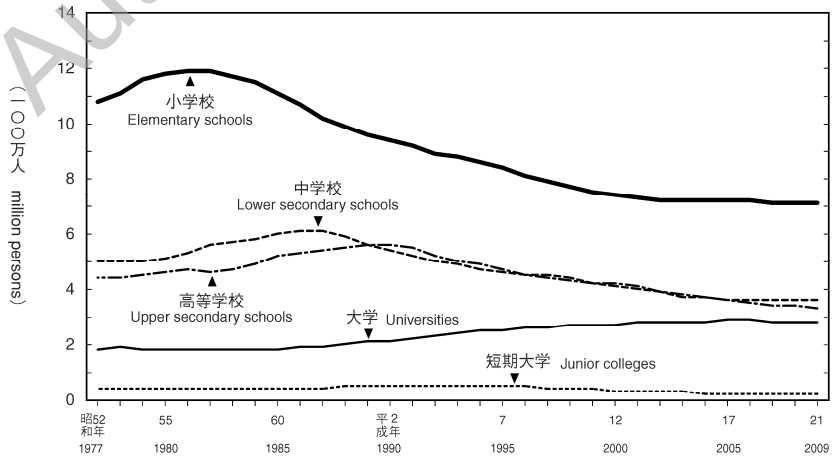

Fig. 7 : Number of enrolled student in educational intuitions from 1977 to 2009 (from MEXT website)

Another weakness of Japanese engineers which can be considered as a challenge in the age of globalization is a poor ability to communicate in English. One of the reasons that the Japanese are not good at English is that they are satisfied with the relatively large amount of Japanese engineering texts that are produced. Japanese engineers study from monograph and magazine style texts rather than from international academic papers and English style textbooks. This situation apparently represents a big difference between the English-speaking countries and Japan. Perhaps because of that, translated books generally do not sell well in Japan [9].

In response to above two serious challenges, Japan's education system follows several plans simultaneously, such as increase of foreign students, establish international colleges/universities, and English programs, as well as change in primary and high school teaching programs. In 2003 almost 110,000 foreign students were enrolled in Japanese higher education. In 2009, it reached 132,732. Among international students, about 10,000 are on a government foreign student scholarship program. About 80% of scholarship recipients are enrolled in graduate schools, especially in graduate courses in the science and engineering areas. Japanese government has announced the target of accepting 300,000 international students by 2020 [2].

As mentioned in the previous section, due to the relatively huge number of engineering graduates in Japan (in comparison of many countries), it is expected to be very good for Japanese companies at producing low cost and high quality products. Despite the mass-production of engineering graduates, a serious problem is that most of the major Japanese companies have built their new plants in China (and some east Asian countries) and sent supervisors, engineers, and technicians there for supervisory roles [9]. This may imply a redundancy on the high cost Japanese engineers.

6. Conclusion

Focus on the engineering education in Japan, has a long history. Japan has a long tradition of respecting learning and teaching. Japan with a successful background in high-tech engineering production has entered into the period of designing rather than manufacturing. This success attracts world-wide interests on the unique characteristics Japanese engineering education system.

In this speech, the reasons and secrets behind the mentioned development, as well as existing challenges and future plans are presented based on the author long time study, research, and teaching in three Japan national universities.

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Speaker's Biography

H. Bevrani received the M.Eng. (Hons.) degree from K. N. Toosi University of Technology, Tehran, Iran, in 1997, and the Ph.D. degree from Osaka University, Osaka, Japan, in 2004, both in electrical engineering. From 2004 to 2006, he was a Postdoctoral Fellow at Kumamoto University, Kumamoto, Japan. From 2007 to 2008, he was a Senior Research Fellow at Queensland University of Technology, Brisbane, Australia. In 2009 he has been invited as a professor to Kumamoto University (Japan). Since 2000, he has been an academic member at University of Kurdistan (Iran). Currently, he is working as a visiting professor in Kyushu Institute of Technology (Japan). His special fields of interest include intelligent and robust control applications in electric and electronics industry. He has published two international books, eight book chapters and about one hundred international journal and conference papers. He is a senior member of Institute of Electrical and Electronics Engineers (IEEE), member of the Institute of Electrical Engineers of Japan (IEEJ) and the Institution of Engineering and Technology (IET). More details and his extended CV is available in the following link: *www.bevrani.com*.