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Adapting Engineering Education to Better Serve Japanese Industry

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Japan experienced a 'miraculous reconstruction' after World War II partly due to the far-sighted support of the victors, especially the USA, and China, who did not divide the country or demand reparations, and partly due to the unique inherent qualities of the Japanese people. The Japanese race has developed its national identity from a combination of the country's location, climate and the circumstances of its some 1000-year history. As a result the people of Japan are truly a single race, for the most part uniform in experience, culture, and language, with a strong domestic orientation. From an educational viewpoint, the Japanese are historically 'good learners'. However, they are traditionally bad when it comes to generating new ideas by applying theory for creative purposes. A simple process of (1) follow, (2) catch-up, and (3) equal or surpass describes the development of the high-tech industry in Japan. This process has made the most of the Japanese people's ability to absorb information as well as their single-minded determination to achieve goals and their propensity for concentrated effort. As the motor car and semiconductor industries illustrate, the Japanese have unequalled expertise when it comes to adopting technology from advanced industrial nations overseas, perfecting it, and making it their own. The challenge for the Japanese people, now that the catch-up process is all but completed, is to continue their progress by generating their own innovative ideas. In addition, the Japanese must develop a more global orientation and consider the needs of foreign markets in new product development. This evolution must take place in an atmosphere of international sharing, cooperation and partnership. In terms of education, the traditional 'good learner' with a domestic orientation must be taught how to be a 'good original thinker' with an international viewpoint. The engineering education system in Japan has been placed against this background and is examined from both an historic and a futuristic perspective.

INTRODUCTION

SINCE education is a long-term endeavor, it is difficult to ascertain which modifications to the educational system are progressive. In a field that changes as quickly and as unpredictably as hi-tech engineering, adjustments to the educational system are necessary if our Japanese universities are going to provide properly trained personnel for industry in the future. Just as manufacturing has developed along North–South lines in the past, so must today's engineers be prepared for progress as a result of the lessening of differences between East and West in the years to come.

Considering this background, Engineering Education 2000 must address the problems inherent in the rapid changes affecting industrial education.

JAPANESE UNIVERSITIES

The Japanese university system

After the Meiji Restoration in 1868, the Japanese government placed a high priority on establishing university facilities. Consequently, approximately nine national universities and a number of private ones existed prior to World War II. However, despite the fact that almost all the main cities in Japan had at least one university, there were very few with science and technology faculties. The number of universities increased rapidly after the war in response to Japan's increasing economic prosperity.

National universities have generally been established for the longest period. They receive financial support from the government and generally offer courses from three to five faculties. Tuition fees are usually lower than those of other types of universities. The student–teacher ratio is high and because of government funding, facilities are usually well equipped and comprehensive.

Private universities have usually been established more recently, with the exception of Waseda and Keio Universities. The larger part of their income is derived from non-government sources, though government assistance is not uncommon. The number of faculties within the universities ranges from one to three or four. Tuition fees are normally high and the number of students per class is generally higher than that for other universites.

Prefectural universities are supported by local government authorities. They tend to be specialist universities with only one faculty.

Table 1 shows a breakdown of university students by the type of university that they attend.

Although most graduates want to work in hi-tech related fields, for several years now the demand has simply been too high for all vacancies to be filled.

To complicate the situation, across-the-board labor shortages are encouraging graduates increasingly to opt for the more lucrative professions available to them. Common choices are positions in the banking and securities-related professions.

Table 1. Distribution of Japanese universities

	National	Prefectural	Private	Total
No. of universities	95	38	357	490
No. of students (millions)	0.49	0.06	1.44	1.99

Source: Japanese Government, 1989.

Classification of universities

Japan's élite universities. Of the universities mentioned earlier, all of those ranking in the highest echelon were established before World War II, including about 10 national universities and two or three private ones. Naturally, this group of Japan's élite has achieved its reputation by concentrating on only the brightest students, the best professors, and on good research facilities. The finest students—those expected to enter research-related fields—are educated and trained in this sort of environment, so there are no fundamental problems with their engineering education.

Problems in the second group of universities

The universities in this group have much larger classes, perhaps 70–150 students per lecture, and professors who are individually responsible for many more lectures. In the case of graduate research, it is not uncommon for each professor to be in charge of more than 10 students.

The problems are compounded by the caliber of students who attend universities in this category. The term caliber includes such factors as academic record, skill level, enthusiasm, motivation, and aspiration. Classes are attended mostly out of habit. In many cases the primary concern may be enjoying college life. The secondary one may be securing a job with a large company.

Of coure, many students are motivated, such as computer enthusiasts and people with an interest in creating, for example, mechanical objects.

Characteristics of Japanese education. The basis of educational method in Japan until the late 19th century, was 'terakoya'. Children gathered in a small building attached to the local temple. This traditional class usually consisted of one teacher and no more than 10 students.

The curriculum consisted entirely of the Japanese equivalent of the West's 'three Rs', called 'yomi-kaki-soroban'. 'Yomi' (reading), 'kaki' (writing), and 'soroban' (abacus) taught the fundamental skills for life.

The teaching of 'yomi' concentrated not only on the memorization of Chinese characters, but on the Chinese politics and morals for which they served as a vehicle. This has ultimately had a profound effect on Japanese moral and political thought ever since the introduction of the Chinese language to Japan.

The teaching of 'kaki', or brush writing, put a strong emphasis on aesthetic virtue, consistency and discipline. Students were expected to implement perfect posture, style, and concentration in their execution of the art.

Finally, 'soroban' taught the proper use of the abacus in the performance of the basic arithmetic functions. Here, speed and accuracy were stressed more than style.

The ultimate tenet of the 'terakoya' system was to follow both text and instruction, and to live one's life precisely as one was taught. It was this emphasis on structure, and de-emphasis on individual virtue and creativity, that led to an educational system which was not suited to the teaching of subjects that demanded creativity and free thought, such as engineering. This tradition-oriented education system offered no opportunity for experiment, no experience in problem solving and no practice at transferring theoretical information into practical application.

Engineering education in Japan was similar at this time to the guild system being employed in Europe and North America. Here again, the emphasis was on memorization and mastery, rather than theory and creativity.

Generally speaking, the examination system used to determine a student's entrance into a university is quite severe, but there is seldom any challenge from the time the student is accepted until the time of his or her graduation. Passing is the only objective, because the school's reputation and the student's connections are the primary determinants for the jobs offered upon graduation.

JAPANESE INDUSTRY

The internationalization of Japanese industry

The labor shortage. Japan is suffering from a shortage of labor that is quickly becoming chronic. There are a number of reasons for this trend:

- The low average pay-scale for blue-collar jobs cannot keep pace with the unusually high cost of living in Japan.
- Generally, labor wants the kind of physically easy work to be found in white-collar positions, so immigrant Asian workers are increasingly being relied upon to perform this type of menial labor.
- Production is increasingly being shifted overseas and discontinued domestically.

The increase in overseas industry. Japanese industry has been quick to move its manufacturing operation overseas for several reasons:

- With the labor shortage beginning to be felt in all manufacturing fields, all manufacturing is

increasingly being shifted overseas, a trend that will probably continue.

- Governments of developed countries such as the UK and the USA are attracted to Japanese manufacturing companies since they create employment and provide additional revenue for local and federal governments.
- Overseas manufacturing allows the manufacturer to get closer to the market, provide more responsive product development as well as service/support, and decreased transportation costs.

There is a delicate sense among the Japanese that seems to give them an interest and talent in working in minute detail. The applications for such talents in fields such as semiconductor manufacturing are immediately obvious.

As an example, a Japanese person might appreciate a painting from a distance, but then approach closely enough to look at the most minute features of the work, even to the point of using a magnifying glass to examine it better.

Such attention justifies itself, however, when comparison with different products shows the clear improvements of the new technology. This has helped Japanese products sell themselves, and has speeded the transfer of technology and manufacturing overseas.

The internationalization of R&D

The increases in R&D. The proportion of R&D devoted to hi-tech products has increased commensurate with the growth of hi-tech itself. This is most evident in semiconductor technology. To achieve such progress involved enormous investment, which continues at a rate of approximately 10% of sales, industry-wide.

But these developments ultimately depend on the quality of the people who work in the R&D labs, and the spirit of creativity and quality fostered by the company that employs them.

The internationalization of R&D talent. Since the number of potential research engineers that Japan can produce is dependent upon demographic limitations, Western talent, particularly from European and American countries, is being actively encouraged to work for extended periods in Japanese research labs. In addition, Japanese researchers are increasingly going overseas.

Having such a long history of isolation in international matters, Japanese researchers are suffering from their poor preparation and experience in such cooperative ventures. Barriers to understanding, which include language, culture, and lifestyle, make international research cooperation between Japan and the West substantialy more difficult than, for example, a US–German venture.

International personnel exchange. Recently, the numbers of non-Japanese travelling to Japan, and the number of Japanese travelling to the West for the purpose of business or academic exchange have increased dramatically. The figures from 1980 to 1988 are shown in Tables 2 and 3.

Table 2. Non-Japanese visiting Japan

	1980	1985	1988
Total	1.3 m.	2.3 m.	2.4 m.
Academic	10,300	39,000	68,000
Business	16,000	30,000	39,000

Table 3. Japanese travelling abroad

	1980	1985	1988
Total	4.0 m.	5.0 m.	8.4 m.
Academic	23,000	41,000	114,000
Business	483,000	700,000	1.025 m.

The number of academic researchers who actually stay in the host country for an extended period (more than one year) is still quite small, but increasing.

The shortage of software specialists. In 1984, Japan's Ministry of International Trade and Industry (MITT) conducted the last comprehensive study of the shortfall of computer-related specialists in Japan (Table 4).

Table 4. Shortages

Year	Systems engineers	Programmers
1985	17,000	26,000
1990	107,000	144,000
1995	240,000	272,000
2000	422,000	543,000

At present, some non-Japanese are coming to fill the gaps, but it is the responsibility of Japan's industry and its education system not only to provide the specialized education needed to fill these positions, but also to create the sort of environment favorable to academic research that will attract more talent from overseas.

EDUCATION VERSUS INDUSTRY NEEDS

Japanese industry requires internationally oriented technical education. However, traditional Japanese education places an emphasis on memorization and recitation of facts, rather than on generation of new ideas. In technical education, this manifests itself as an emphasis on theoretical, book-culled learning rather than practical applications. The diversity of technical education in Japan has necessitated a system whereby Japanese companies must provide expensive retraining for most new employees in technical areas.

GUIDELINES FOR RESPONSE

Based on the preceding factors, the following are my suggestions for how these disadvantages should be addressed.

For those students who attend the finest universities, the most important area for improvement is their response to the internationalization of Japanese industry:

- Students should think more in terms of generating innovative solutions to problems based on their own ideas.
- They should join foreign students for research cooperation.
- They should attend international conferences and interact with leaders in their fields.

For those students who attend the less privileged universities, the emphasis must be on practical education:

- Provide more practical, liberal education.
- Put emphasis on experience and experimentation rather than on book memorization.
- Encourage cooperative exchange with foreign students.
- Improve their fundamental engineering knowledge.
- Establish individualized education, utilizing newly developed educational technology such as CAI.

In regard to the previous points, the responsiveness of the teaching staff is critical.

CONCLUSION

Modification of an educational system is a long-term process. However, engineering education must offer effective, relevant training so that people are prepared for their responsibilities in the real world. Since Japanese industry is tending toward the international sharing of manufacturing responsibilities, the educational community must respond by emphasizing the following points:

- Internationalized engineering education, so students can learn to work cooperatively with colleagues from other countries.
- The inclusion of not only foreign language study, but foreign culture and lifestyle study as well.
- A focus on experiment, construction, design, and operation of devices.
- Basic education, which must place more emphasis on individual thought and creativity.

Despite the historical resistance to change, it must be understood that it is this process of improvement, rather than an arbitrary date or schedule, which is the essence of Engineering Education 2000.

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