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Engineering Education in Japan

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A critical assessment of engineering education in Japan is presented. Beginning with its origins in the latter half of the nineteenth century the history of engineering education is sketched. Supported by statistical evidence the problems of current engineering faculties are described. Student disinterest, poor facilities, and slow educational reform are being combated by new action programs for engineering education and by government and industry.

PREPARATIONS for establishment of a modern educational system in Japan started after the Meiji Restoration in 1868. From the beginning, a faculty of engineering consituted an important part of the Japanese university system. Establishing a faculty of engineering originated from the idea of science-based technology. Since then Japanese universities have placed greater emphasis on education in engineering than US and European universities.

During World War II, manpower for research and development, not to mention research facilities and laboratories, had suffered heavily, so that it became very difficult to conduct normal research when the war had finished. Then universities and research institutes slowly began to resume research. However, industry was in no position to wait for academic findings and took the initiative to introduce new technologies directly from abroad. The government also adopted a policy of encouraging industry to conduct applied research and development toward yielding new products from basic research carried out abroad. This policy proved successful, and Japanese industry made remarkable progress, proving its ability to adapt to changing demands, and to make the most of opportunities in the world market. This progress brought about serious trade friction in later years. A country like Japan, however, which has few natural resources, must remain a highly industrialized and technology-oriented country, if it is to maintain a high standard of living in the future.

HISTORY OF ENGINEERING EDUCATION IN JAPAN

After the Meiji Restoration in 1868, the new government recognized the importance of education and endeavoured to open as many elementary schools as possible, so that the number of elementary schools across Japan increased rapidly [1, 2]. Progress of the male/female enrollment ratio in compulsory education is shown in Table 1.

The government also gave high priority to the promotion of industrial development policy, and placed great emphasis on technical education. In 1871, a government official named Yozo Yamao proposed to establish the Engineering Institute within the Ministry of Industry for the purpose of training technical officials. He wanted to invite teachers from Britain, and asked Hirobumi Ito, a member of the Iwakura Mission and later the first Prime Minister of Japan, to find suitable people. The Iwakura Mission left Japan in 1871 and visited the United States and eleven European countries (Britain, France, Belgium, The Netherlands, Germany, Russia, Denmark, Sweden, Italy, Austria, and Switzerland) for about two years in order to observe and study the situation in those countries.

An engineer named Henry Dyer from Glasgow was selected as an instructor, and he came to Japan in 1873. Dyer, a 25-year-old mechanical engineer, was paid a handsome salary of 660 yen per month, when the salary of a Cabinet minister was only about 500 yen per month. During his trip from Glasgow to Japan, Dyer worked over his idea for the new Engineering Institute. On arrival, he submitted a plan to the Ministry of Industry. His proposals were accepted, and the Engineering Institute (Kogakuryo) started teaching in the same year. Six courses of study were offered, namely, civil engineering, mechanical engineering, architecture, applied chemistry, mining and telegraphy. Graduates were obliged to work as government officials for at least seven years after completing their education. In 1877, the Institute was renamed the Engineering College (Kobu-Daigakko).

At the same time, an educational institute named the Kaisei School (Kaisei-Gakko) was established in 1868. Its name was changed to the Daigaku-Nanko in 1869, and then to the University of Tokyo in 1877. The University of Tokyo had a Faculty of Science, which included Departments of Engineering, Chemistry, Geology and Mining. In 1895, departments in the fields of engineering, Mechanical Engineering, Civil Engineering, Mining and Metallurgy, Applied Chemistry, and Naval Architecture, were made independent of the Faculty of Science and a Faculty of Polytechnic was

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Table 1. Enrollment ratios in compulsory education (%)

Year	Average	Boys	Girls
1875	35.2	50.5	18.6
1885	49.6	65.8	32.1
1895	61.2	76.7	43.9
1905	95.6	97.7	93.3

created. Then in 1886, the Imperial University was established, and the Engineering College of the Ministry of Industry was amalgamated with the Faculty of Polytechnic of the University of Tokyo, to form a Faculty of Engineering which had seven departments: Civil Engineering, Mechanical Engineering, Naval Architecture, Electrical Engineering, Architecture, Mining and Metallurgy, and Applied Chemistry. Thus, the basic framework of an engineering education system in Japan had been built within only 18 years after the Meiji Restoration.

Japan's overall educational system was reformed to the linear 6-3-3-4 school system (primary, middle, high school, college) after World War II. Under this postwar system, a nine-year compulsory education system was established, giving further impetus to the national drive for equalization of educational opportunities. As a result, the school enrollment ratio in Japan reached a very high level even by international standards.

In the immediate postwar years, the nation's educational facilities remained in ruins, for the most part. Under such circumstances, there arose strong popular calls for the swift expansion of industrial education, as rapid progress in this field was essential for the nation's rapid ecnomic recovery, and for the advancement of science and technology.

Several US survey missions visited Japan, most of which were dispatched at the request of Supreme Commander of the Allied Powers. The most important mission, which exerted great influence on the improvement of engineering education in Japan, was headed by Professor H. L. Hazen from MIT. Upon arrival in Japan in 1951, the mission visited many engineering universities and exchanged views with numerous Japanese engineering educators for six weeks. Professor Hazen summarized his observations in a report submitted on August 25, 1951 [3]. The major points in his report are given below.

1. University education in Japan is less free of centralized constraints than in the United States.
2. Flexibility of university organization is necessary. Team work is very important. The chair system should be improved.
3. Too much emphasis on research in Japanese universities.
4. Student-faculty relations in Japanese universities are not satisfactory.
5. Care should be taken in the relationship between the professional-level university engineer and the sub-professional skilled craftsman or supervisor of industrial organizations.
6. University–industry co-operation in Japan is inadequate.
7. Financial conditions of Japanese universities are very poor.
8. Other suggestions:
   (a) Four-year engineering curriculum at university.
   (b) Establishment of the Japanese Society for Engineering Education.
   (c) Improvement of libraries.

In the 1950s, the Japanese economy achieved a rapid recovery, which made it possible to plan for the promotion of engineering education. The number of students enrolled at science and engineering departments of universities increased by 8000, in 1957, based on the 'New Long-range Economic Plan', and by 21 000, in 1960, based on the 'Twofold Increase Plan of the National Income'. In addition, a system of technical colleges, which offered five-year courses, was inaugurated in 1962. In consequence, during the period of 1964 to 1973, this increase reached as high as 27 000. After about 1975, efforts were made to establish courses in such new fields as urban engineering, environmental pollution and information engineering, etc. In 1976 a new type of university, a university of technology, was created. Such universities mainly admitted graduates of technical colleges to junior (third-year) level, and after providing undergraduate education for two years, offered graduate education for another two years in order to produce practical and creative engineering experts.

Since around 1985 the student enrollment rate has risen further, as the 18-year-old population was expected to peak in 1992. The trend of new entrants to universities and colleges is shown in Table 2.

PRESENT STATUS OF ENGINEERING EDUCATION IN JAPAN

In contemporary Japan, there are several different types of institution of higher education: univer-

Table 2. Trends of new entrants to universities and colleges

New Entrants to Universities	1965	1975	1985	1990
Engineering	50,853	84,468	82,131	97,317
Total	249,917	423,942	411,993	492,340
Percentage of Engineering Students	20.3%	19.9%	19.9%	19.8%

New Entrants to Master's Course	1965	1975	1985	1990
Engineering	3,268	7,116	10,710	14,752
Total	8,341	15,770	23,594	30,733
Percentage of Engineering Students	39.4%	45.1%	45.4%	48.0%

New Entrants to Doctor's Course	1965	1975	1985	1990
Engineering	559	761	832	1,399
Total	3,551	4,158	5,877	7,813
Percentage of Engineering Students	15.7%	18.3%	14.2%	17.9%

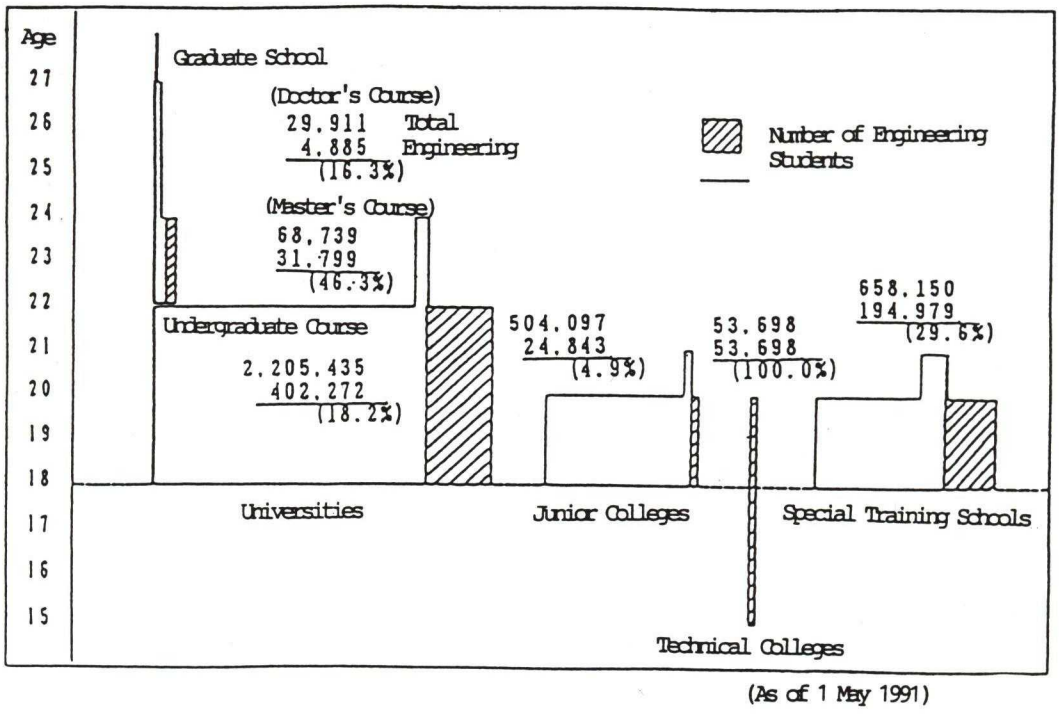

Fig. 1. System of higher education in Japan.

Table 3. Number of universities and junior colleges

		Number of Universities	Universities having Engineering Department	Universities having Engineering Master's Course	Universities having Engineering Doctor's Course
Universities	National	97	53 (54.6%)	46 (47.4%)	33 (34.0%)
	Local	39	6 (15.4%)	5 (12.8%)	4 (10.3%)
	Private	379	81 (21.4%)	51 (13.5%)	32 (8.4%)
	Total	515	140 (27.2%)	102 (19.8%)	69 (13.4%)

		Number of Junior Colleges	Junior Colleges having Engineering Department
Junior Colleges	National	130	43 (33.1%)
	Local	153	7 (4.6%)
	Private	1,245	53 (4.3%)
	Total	1,528	103 (6.7%)

		Number of Technical Colleges
Technical Colleges	National	54
	Local	5
	Private	3
	Total	62

sities (including graduate schools), junior colleges, technical colleges and special training schools offering advanced or college courses. The system of higher engineering education in Japan [4, 5, 6] is shown in Fig. 1.

The number of universities and junior colleges is shown in Table 3. In Japan, private universities are in the majority, but national universities play an important role in engineering education, especially in graduate-school education.

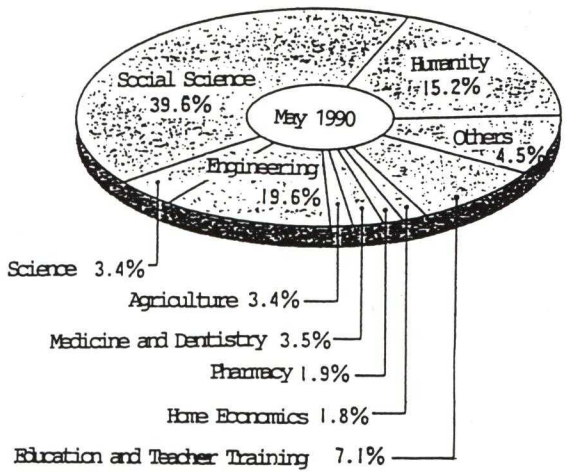

Fig. 2. Undergraduate students by field of specialization.

The distribution of students by field of specialization in the undergraduate courses is shown in Fig. 2. The number of engineering students is about 20% of the total students.

The number of new entrants to universities, junior colleges and technical colleges in 1990 is shown in Table 4, and the number of new entrants to various departments in 1990 and the percentage increase of the new entrants in 1990 compared to 1965 are shown in Table 5.

Table 6 shows the employment of graduates from engineering departments who graduated in March 1990.

TRENDS IN HIGHER EDUCATION IN JAPAN

In Japan, the 18-year-old population reached its maximum in 1966 and, since then, has decreased for about ten years. After 1977, the population of this group increased gradually again and reached its second peak in 1992. Then it will decrease rapidly. The enrollment ratio to universities, colleges and technical colleges increased up to 1975, and then has maintained nearly constant value of 36 to 39%.

A report of the University Council entitled *Systematic Planning of Higher Education after 1993* was

Table 4. Present status of new entrants to universities and colleges

	Total Number of New Entrants	Number of New Entrants to Engineering Departments
University, Undergraduate	492,340 National 100,991 (20.5%) Local 14,182 (2.9%) Private 377,167 (76.6%)	97,317 National 31,033 (31.9%) Local 1,739 (1.8%) Private 64,545 (66.3%)
Graduate School, Master's Course	30,733 National 19,894 (64.7%) Local 1,190 (3.9%) Private 3,948 (12.8%)	14,752 National 10,322 (70.0%) Local 482 (3.3%) Private 3,948 (26.8%)
Graduate School, Doctor's Course	7,813 National 5,170 (66.2%) Local 417 (5.3%) Private 2,226 (28.5%)	1,399 National 1,182 (84.5%) Local 31 (2.2%) Private 186 (13.3%)
Junior College	235,195 National 5,825 (2.5%) Local 9,931 (4.2%) Private 219,439 (93.3%)	11,000 National 1,087 (9.9%) Local 333 (3.0%) Private 9,580 (87.1%)
Technical College	11,127 National 9,574 (86.0%) Local 845 (7.6%) Private 708 (6.4%)	11,127 National 9,574 (86.0%) Local 845 (7.6%) Private 708 (6.4%)

Table 5. Students by departments

	New Entrants in 1990	Percentage of New Entrants in 1990 to those in 1965
Mechanical Engineering	19,155 (2)	161.9 (8)
Information & Communication Engineering	28,765 (1)	233.6 (4)
Civil Engineering & Architecture	18,772 (3)	202.7 (5)
Applied Chemistry	10,504 (4)	170.1 (7)
Applied Physics	1,132 (6)	94.0
Nuclear Engineering	310 (11)	287.0 (2)
Mining	244 (13)	81.1
Metallurgy	964 (7)	72.8
Textile Engineering	337 (10)	67.1
Ship-building Engineering	255 (12)	388.4 (1)
Aeronautical Engineering	747 (8)	
Engineering Management	5,155 (5)	176.3 (6)
Industrial Art	482 (9)	241.0 (3)
Navigation	222 (14)	68.3
Others	10,273	249.2

Table 6. Employment of graduates from engineering department

Industrial Classification	Number of Employees
Agriculture	8 (0.01%)
Forestry & Hunting	8 (0.01%)
Fishery	8 (0.01%)
Mining	140 (0.21%)
Construction Industry	9,926 (15.22%)
Manufacturing Industry	36,649 (56.20%)
Merchant Business	2,339 (3.59%)
Banking & Insurance	1,486 (2.28%)
Real Estate Business	317 (0.49%)
Transportation & Communication	1,665 (2.55%)
Electric Power, Gas & Water Supply Works	786 (1.21%)
Service Sector	8,631 (13.23%)
Official Business	2,918 (4.47%)
Others	336 (0.52%)
Total	65,217

Professional Classification	
Professional Engineer	59,625 (91.43%)
Researchers	245(0.38%)
Engineers	58,538 (89.76%)
Teachers	523(0.80%)
Engineers for Health & Medical Treatment	17(0.03%)
Artists	140(0.21%)
Others	163(0.25%)
Administrative Job	343(0.52%)
Business	1,956(3.00%)
Sales	1,908(2.92%)
Agriculture & Forestry	4(0.01%)
Fishery	0(0%)
Transportation & Communication	320(0.50%)
Technician	241(0.37%)
Maintenance Job	88(0.13%)
Service	431(0.66%)
Others	301(0.46%)
Total	65,217

submitted in May 1991 [7]. In this report, the numbers of new students in universities, colleges and technical colleges in the year 2000 are estimated on the assumption that the enrollment ratio would be 40.0 to 42.2%. The result showed that the number of new students in 2000 would be 12.0 to 7.6% less than that in 1990.

Contrary to the above trend, there is an urgent need in higher education for developing qualified human resources, capable of meeting the needs of future society. The change in number of personnel engaged in research and development in Japan is shown in Fig. 3. This figure shows a remarkable increase in the number of R&D personnel in the industrial sector.

It is widely recognized that science and technology are making rapid strides. Therefore the knowledge learned in the university tends to become obsolete very quickly. The demand for recurrent education was strongly expressed by the industrial community.

Moreover, the number of foreign students is increasing year by year. Taking into consideration the interdependence of nations, the globalization of economies, and the internationalization of technologies, we should accept as many foreign students as possible.

All these conditions led us to recognize that Japanese universities should be strengthened and improved.

Recently, however, there appeared a recognized trend that many young high school graduates did

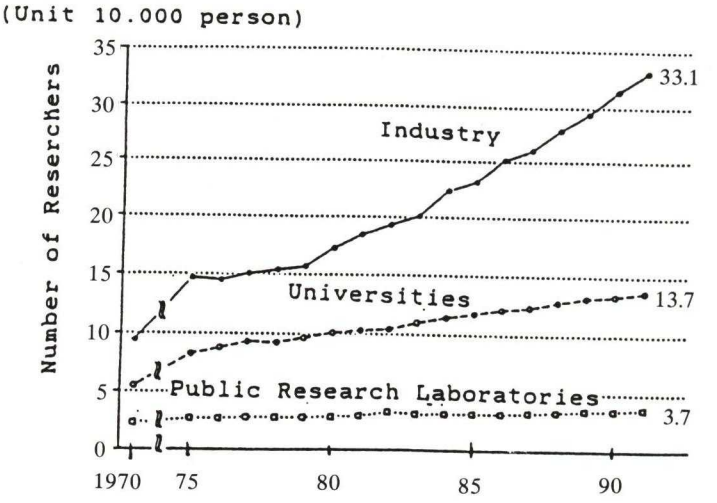

Fig. 3. Changes in the number of researchers.

not want to apply for universities or colleges in the field of science and engineering. Due to the recent economic growth in Japan many Japanese youths tend to choose easier employment than an engineering career, which is thought of as dirty, dangerous and demanding. Figure 4 shows the recent trends of applicants for universities and colleges by departments. In this figure, it is clear that, while the applicants for departments of economics, commerce and law are increasing, those for engineering departments decreased sharply after 1987. Recent trends of the employment of science and engineering graduates are shown in Fig. 5. This indicates that recently the number of graduates employed in the service sector including banking and insurance, is increasing very rapidly but the number of those employed in the manufacturing sector is not increasing proportionately [8].

In addition, as the research environment of Japanese universities has become run down compared to that in industry, many bright students are leaving universities and entering industry. Figures 6 and 7 show recent trends of number of students on Master's courses and Doctorate courses respectively. Although the number of engineering

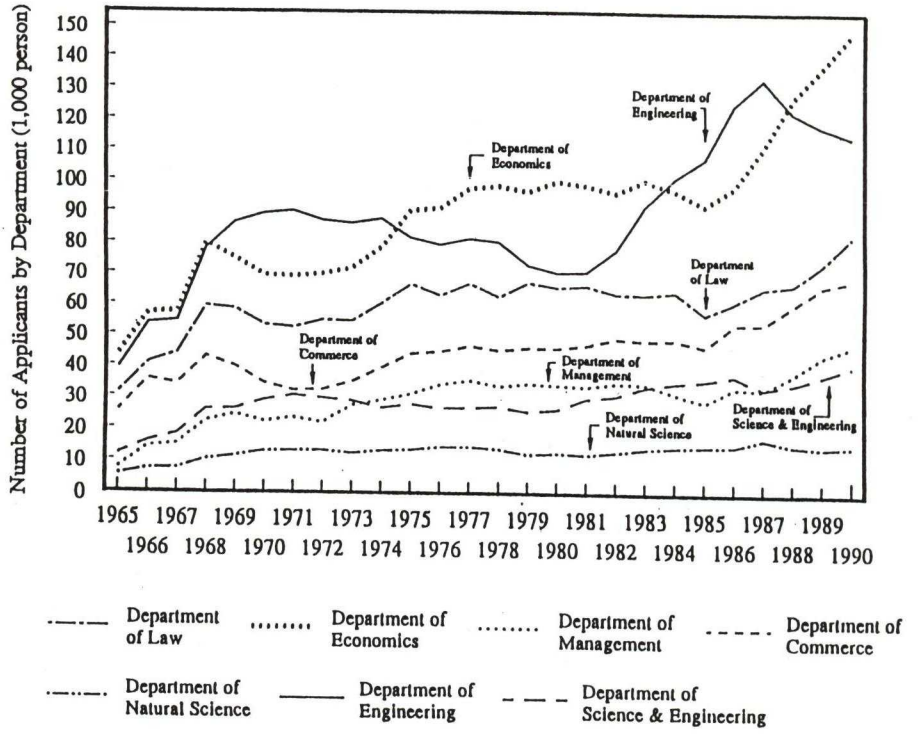

Fig. 4. Applicants for colleges and universities by departments.

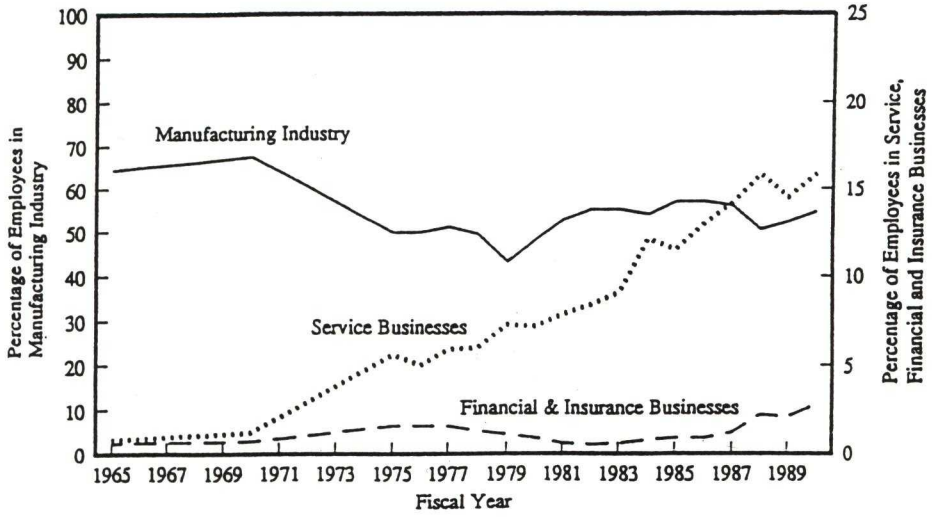

Fig. 5. Employment of science and engineering graduates.

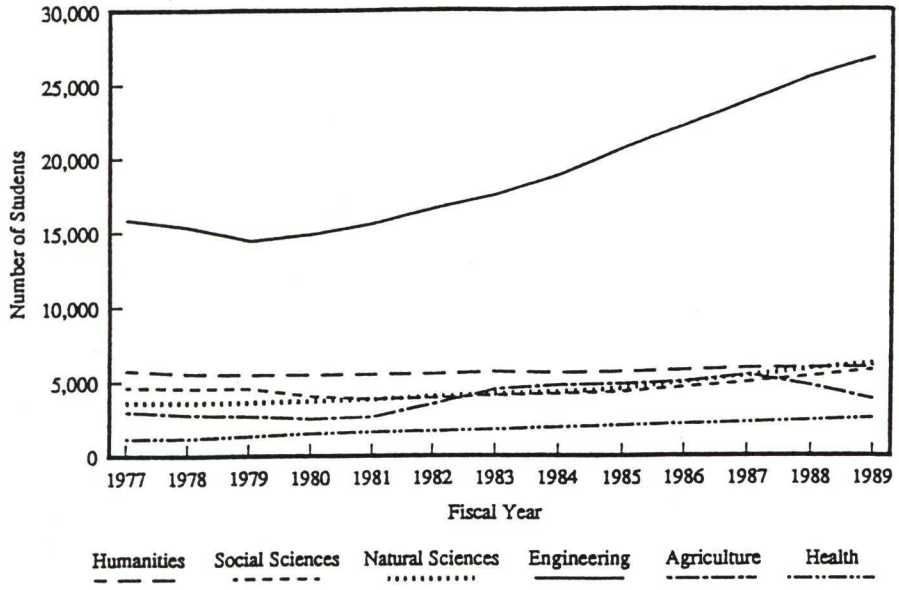

Fig. 6. Number of students on Master's courses.

students on Master's courses is increasing, the number of those on Doctorate courses is not increasing significantly.

MEASURES FOR IMPROVING ENGINEERING EDUCATION IN JAPAN

Taking into consideration the condition of Japanese universities mentioned above, many recommendations and opinons have been voiced from various corners in order to improve engineering education in Japan. For example, the Engineering Division of the Science Council of Japan, jointly with the Engineering Academy of Japan, published a report on *Problems in Engineering Education in Japan and the Necessary Countermeasures—Viewpoint from Industry* in March 1991 [9]. Gijutsu-doyuukai (Japan Society for Technology) published a proposal entitled *How to Strengthen Manpower Development and Research Activities in Universities* in October 1991 [10]. There have been a number of other proposals, in addition to these.

Keidanren (The Federation of Economic Organization) submitted a proposal called *Strengthening University Research Activities in Science and Technology*, in April 1992 [11]. A summary of the

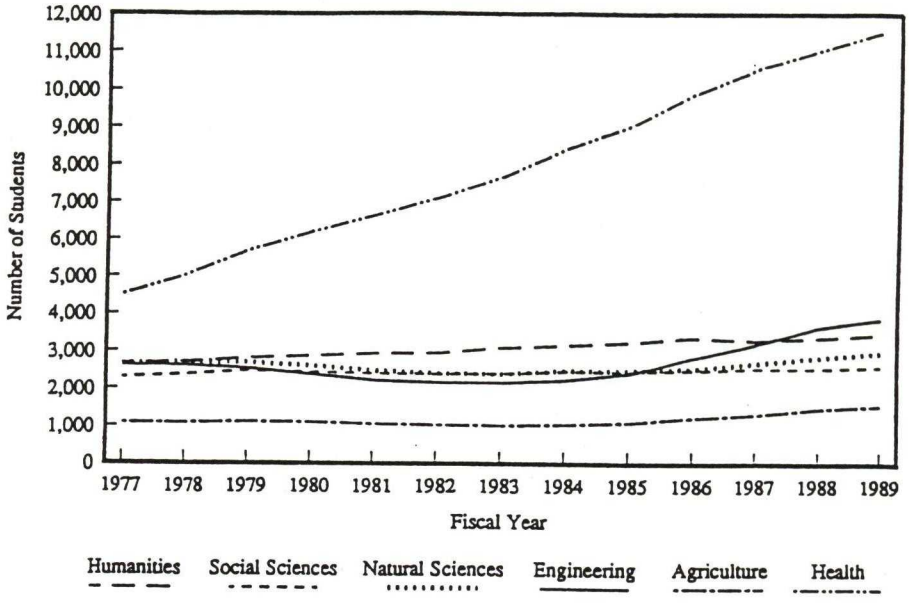

Fig. 7. Number of students on Doctorate courses.

proposal by Keidanren to strengthen university research activities is given below:

1. *Government* should try to improve the university system by encouraging universities to extend their own activities.

(1) Government budget for science and technology, and higher education should be doubled by five years from now.
(2) Deregulation of the educational system by the government, improvement of graduate schools and a more flexible system of employment of staff in universities are necessary.
(3) Providing various programmes to cultivate scientific and technological interest in primary and secondary education is important.

2. *Universities* must improve themselves in order to establish international reputations.

(1) Development of a management system which makes it possible to promote universities' originality and to keep up with the societal change is indispensable.
(2) Staff of universities must be by introducing a competitive principle in employment, promotion and evaluation of university staff is vital.
(3) University–industry co-operation should be encouraged.

3. *Industry* should support improvement of universities.

(1) University management, research and education by personnel exchange should be supported.
(2) Funds for expenditure on research and education are necessary.
(3) Methods to strengthen the graduate schools should be developed by giving aid to Doctorate students and by employing graduates.

In response to these opinions and recommendations the Government has been making efforts to improve universities especially in the field of science and technology. The University Council in the Ministry of Education, Science and Culture submitted the following three reports in May 1991: *Systematic Planning of Higher Education after 1993* [7], *Improvement and Strengthening of Graduate Schools* [12], *Amendment to the Standard Requirement of Establishing Universities and to the System of University Degrees* [13].

The cabinet adopted a resolution entitled 'General guidelines for science and technology policy', in April 1992 [14], which is in turn based on the recommendation of the Council for Science and Technology, presented in a report entitled *Comprehensive and Basic Science and Technology Policy Toward the New Century*, issued in January 1992 [15]. Then the Science Council in the Ministry of Education, Science and Culture submitted a report on *Comprehensive Measures for Promoting Scientific Research Looking Forward to the Twenty-First Century*, in June 1992 [16]. In these reports, the importance of promoting basic science and technology, and the need to intensify the research and development capability of universities, are clearly declared. In the past, however, reports of various ministries and agencies in Japanese government only announced these intentions with flowery words without making sufficient efforts to implement them. I sincerely hope that the government's attitude will change drastically in the future.

There may be various measures to overcome the above-mentioned difficulties. Naturally, improve-

ments of curriculum, methods of teaching, etc., are the most important ones. University professors, however, should be good researchers at the same time. Therefore an increase in R&D investment is required to attract the best professors to universities. If, however, young people are not sufficiently interested in science and engineering, it will be very difficult to attract the brightest students to engineering schools. Therefore an improvement in pre-college education becomes a necessity.

There are too many lecture courses in the present engineering curricula. Due to the recent rapid progress of science and technology, many professors try to start new lecture courses, but find it hard to eliminate existing outdated ones. Even if students receive sufficient knowledge through attending many lectures, it soon becomes obsolete in this rapidly changing technological world. The most important aim of engineering education is to train students to acquire the ability to solve engineering problems.

As mentioned above, the technological knowledge of an engineer in industry may become quickly obsolete due to the constant progress in science and technology. It is, therefore, essential for universities to contemplate appropriate methods to provide engineers working in industry with recurrent (continuing) education. A committee in the Ministry of Education, Science and Culture recently submitted a report [17], recommending the following

(1) improving methods for universities to accept engineers who work in industry;
(2) providing a curriculum suitable for recurrent education;
(3) producing programmes for recurrent education;
(4) granting an appropriate certificate to participants in recurrent education programs;
(5) furnishing sufficient information on the recurrent education programmes;
(6) creating a mechanism to exchange views between universities and industry;
(7) financial support to universities for recurrent education.

Finally it is reported that recently, young people in Japan are becoming less interested in science and technology topics, and are tending to refrain from selecting science and engineering courses. This may originate from the poor social and educational standards in science and technology before university. Efforts should be made to encourage the youth to dream about and have passion for science and technology by increasing the chance to acquire actual scientific experience, by encouraging practical science and observation in primary and secondary education. It is also imperative to cultivate the background in which people can become familiar with science and technology. This could be realized by increasing the chance of acquiring ongoing integrated learning about science and technology through, for example, science and industry museums.

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