PART I: HISTORICAL STATUS AND CURRENT PERSPECTIVE ON ENGINEERING EDUCATION IN THE UNITED STATES AND JAPAN

THE HISTORICAL DEVELOPMENT OF ENGINEERING EDUCATION IN THE UNITED STATES

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Engineering education in the United States began in the early 1800's for the purpose of promoting "the application of science to the common purposes of life" and, indeed, its entire history parallels the changing needs of a growing, continually developing nation for scientifically and technically trained personnel. Trends in engineering education have been coupled with industry's changing need for engineering manpower, which in turn has been driven by the social, economic and political conditions of the country.

The high value placed on individual achievement in the United States played a significant part in determining the role of education as preparation for the practice of engineering in early America. American industry in the eighteenth century relied largely upon the inventiveness of practical and enterprising men. Versatility and resourcefulness were prized above specialized training and the refinements of science, while the practice of any occupation, including law and medicine, was the prerogative of anyone who was willing to try.

The first schools of engineering in America focused their curricula on the design and construction of bridges, roads, and canals. Pragmatism was stressed in these early schools, as they attempted to meet the needs of the country for the development of public works and military fortifications.

In spite of its applied nature, engineering education in the United States was in all essential aspects a form of collegiate education. Instituted and directed by educators rather than practitioners, it was firmly established before the profession organized itself. Curricula in the various branches of engineering were developed and taught and degrees offered before the corresponding professional societies were formed. As a result, engineering education did not evolve from apprenticeship training; rather slowly replacing it, gaining the support of practitioners with considerable struggle.

EXPANSION OF ENGINEERING EDUCATION

In 1853 the territorial growth of the continental United States was completed when James Gadsden purchased from Mexico a strip of land that occupies the present southwestern part of the country. The previous 50 years had been marked by the acquisition of a vast amount of land and expansion of the borders of the United States. Now the time was right to settle and develop that land.

The year 1862 marks a major change in the development of engineering education and of the United States as a nation, owing to three significant events. In that year the U.S. Congress passed the Homestead Act, which gave 160 acres of land free to any head of a family who worked for five years to improve the land. This prompted a large westward migration, and in the same year, Congress granted a charter to Union Pacific to construct a transcontinental railroad from Nebraska to California. Most practitioners at this time still learned engineering through on-the-job experience. These largely self-taught engineers, however, were not adequate to overcome the difficulties inherent in spanning a region of desert wastes, wooded plateaus and precipitous mountains. The railroad, and the telegraph which accompanied it, created a demand for engineers with greater mastery of scientific resources. Engineering schools arose out of simple necessity.

The third major event of 1862 was the passage of the Morrill Land Grant Act, which laid the foundation for a comprehensive system of public higher education. This Act provided for the allocation of public lands by the federal government to each state and territory for the foundation and support of colleges, "particularly such branches of learning as are related to agriculture and the mechanic arts." The promotion of practical education had become extremely important for the utilization of the country's resources and the creation of industrial activities. The effect of this single piece of legislation can be seen by the fact that in a single decade the number of engineering schools increased from about a dozen in 1862, to 21 in 1871, to 70 in 1872, a rate of expansion without equal in American education.

A curriculum was developed with the distinguishing feature of a parallel sequence of humanistic studies, mathematics, physical sciences and technical subjects. This curriculum, which was then new to the country has marked American engineering curricula to this day. The time requirement for the new program increased from one to three years. Experience soon showed, however, that the new curriculum was in advance of prevailing preparatory education. To remedy this, a preparatory division of one year was provided, leading to the integrated four-year curriculum which became the accepted norm.

Large numbers of European immigrants -- as many as 800,000 in a single year -- entered the country beginning in the second half of the nineteenth century. An economic boom followed as the new citizens helped to provide needed labor, as well as to increase the need for housing, transportation and manufactured goods. This boom resulted in new services, new machinery, more goods and new types of business organizations. Markets and demand increased, bringing a great amount of new capital into the economy. By 1870 the northern and western states were in the full swing of a vast process of industrial expansion, railroad building, city development and land settlement. This industrialization and economic development greatly stimulated the demand for engineering services. In the older eastern states the transition from an agricultural to an industrial society gave a strong impetus to the subdivision and specialization of the engineering profession.

Prior to 1854, all engineering curricula were in civil or military engineering. Mechanical engineering was first offered in 1854, and was followed by mining engineering in 1857, electrical engineering in 1882, and chemical engineering in 1888. National engineering societies were established shortly after their respective curricula, reflecting the growing relationship between the profession and the schools of engineering, but also showing that the profession had not yet assumed the leadership and responsibility for professional education.

A PERIOD OF DEVELOPMENT

Engineering education prior to the 1860s was characterized by schools with very limited resources. Engineering laboratories were unknown, textbooks were few and mainly derived from abroad, and instruction was largely blackboard demonstrations prepared from texts followed by recitation and interrogation. In the last quarter of the nineteenth century, however, engineers rather than scientists took increasing leadership in education. An American literature in engineering began to develop through the authorship by faculty members of textbooks and of articles in the journals of the newly forming technical societies. Curricula diversified to meet the specialized needs for engineering talent, and the lecture system became widespread. The collegiate type of curriculum with its extended base of science, mathematics, languages and social studies became firmly established as the basic structure for engineering education in the United States. By 1885 shop work had attained its maximum position in engineering curricula, as measured by the time allotted for it, and considerably overshadowed the developing emphasis on laboratory instruction.

By 1890, the increase in urban population for the preceding decade was for the first time greater than the increase in rural population. Although it was not until 1920 that urban residents exceeded rural dwellers, the trend was clearly evident. Between 1870 and 1890, the internal combustion engine and the spark-ignition engine were developed, as were the steam turbine, electric generator, electric motor, storage battery, voltage transformer, incandescent lamp, phonograph and telephone. Major engineering works were proliferating. After the first commercially successful electric generating plant was put on line in 1882, there was a significant development of electric power for domestic and industrial use, and for street lighting and railway transportation. Steel became available in quantity as a result of the work of Bessemer and Siemens. Technological developments and a growing emphasis on standardization and production techniques set the stage for the establishment of mass production.

Engineering education retained a strong utilitarian emphasis, with undergraduate education stressing skills needed in specific industries. This appealed to a large segment of the American population. Graduate education also was begun, but in contrast to undergraduate education it was based on the German approach of connecting original research and advanced study, with an emphasis on science. By the end of the nineteenth century, most elements of the structure of the American system of higher education were in place. The numbering of courses, the credit system, major fields of study and departmental organization, the lecture, recitation and seminar mode of learning, the elective system and the administrative hierarchy involving presidents, deans and department chairmen had all emerged and were accepted with very little variation among institutions.

THE TWENTIETH CENTURY

With the arrival of the twentieth century, the country underwent a rapid population increase. From 1900 to 1914, 13.4 million immigrants arrived, helping to expand the population 30 percent in those years to 99.1 million. This growth created the necessary markets for manufactured goods and labor to operate the emerging industries. The engineering profession became deeply engaged in the industrialization of the nation, and focused its efforts on the improvement, operation and maintenance of a growing complex of devices and processes. The growing demand for engineering was a natural consequence of the decline in the agricultural population, the increase in the urban population and the rapid development of manufacturing. By the end of this period engineering education was well established, and it concentrated on preparing graduates who could accept jobs and be immediately useful — exactly what business and industry wanted.

The development of and demand for the automobile and airplane, the growing need for petroleum and electric power and the techniques of mass production, amplified by the requirements generated by World War I, brought engineering and engineering education into a new phase. From 1914 to 1940 Americans bought about three-quarters of all automobiles produced in the world. Between 1914 and 1940 the United States produced a total of 38,000 aircraft for the military and almost 40,000 more for civilian use. Departments of aeronautical engineering were created in the colleges. The airplane required precision engineering, high tensile steel, the machining of light alloys, the creation of fiber glass and plastic adhesives, new lubricants, high quality fuels and powder metallurgy, which had significant effects on other branches of engineering and technology.

America's involvement in the war and the prominent place gained by engineers in the management and direction of industry served to redirect attention to engineering education. Distinctive curricula to emphasize the administrative rather than the technical aspects of engineering were introduced widely. The place given to economics in all curricula was augmented, and business electives in engineering education were more generally provided. There was a noticeable trend away from specialization for undergraduates. In order to prepare engineers to serve in the full scope of technical, administrative and executive responsibilities, engineering schools developed general types of curricula that would be useful in a wide range of occupations. They were built on a foundation of science, humanities and social relationships, rather than on the practical techniques required for specific industries or occupations.

IMPACT OF WORLD WAR II AND SPUTNIK

The United States' involvement in World War II, from 1941 to 1945, brought about weaknesses in engineering education, particularly in the electrical and electronics areas. This stimulated a change from a strong emphasis on practical subjects having an immediate utility to industry to a stress on the scientific principles underlying the technology. The war also increased awareness of the importance of academic research, which, coupled with increased amounts of money from the military, led to the expansion of graduate education and the establishment of research programs conducted by faculty members and graduate students. The undergraduate curriculum was redesigned to serve the double purpose of preparing some graduates for immediate employment and others for graduate study.

The West Coast schools and industries, particularly in the electronics field, grew dramatically as a result of the war. A small group of entrepreneurs created a number of companies to develop and manufacture electronic equipment in the two decades before World War II. A major university-industrial relationship developed on the West Coast, primarily centered around Stanford University. This was similar to the relationships that had developed a few decades earlier on the East Coast, with M.I.T. and Harvard providing a stimulus and source of ideas for a large number of electronics firms that developed around Boston.

These movements received another thrust in 1958, when the Russians launched Sputnik. The resulting Soviet-American race for technological leadership, and the national goal to land a man on the moon, gave rise to a scientific and technological boom. Funds for science and engineering education suddenly became available from private foundations and from federal and state government appropriations. Faculty salaries rose, facilities and equipment improved, and research grants became plentiful. Academic standards were raised and course requirements became more stringent. Scientists and engineers assumed new roles in government leadership. The number of graduate degrees awarded annually in engineering had a parallel rise, with the number of master's degrees increasing from about 1,300 in 1940 to 4,800 in 1950 to over 15,000 in 1968, while the number of doctor's degrees increased from about 100 to 500 to 3,000 over the same period.

In the 1970s, engineering education moved into a new era of development. The United States shifted its priorities away from defense and more toward the human and social problems of the nation. The country had landed men on the moon and was no longer in a race with the Soviet Union for the conquest of space. There was a decrease in federal funds available for defense and space activities and an increase in funds for applying science and technology to domestic problems, such as housing, transportation, health care, education, pollution control and energy. Engineering graduates had to be more concerned not only with technical developments, but also with the impact of those developments on society.

The last ten years have witnessed significant changes in engineering education, as American industry faced severe competition both in its home and overseas markets for manufactured products. Between 1975 and 1985, undergraduate engineering enrollments rose 60 percent. Since 1980, the number of students studying electrical engineering and computer science increased so rapidly that they now comprise 40-50 percent of the engineering students in some schools.

The importance to industry of computers, biotechnology, computer-aided manufacturing, computer-aided design, and other high-technology subjects is creating pressures for the inclusion of new content and experiences in school. The trend toward a deeper, more fundamental understanding of technical subject matter, combined with a greater reliance on mathematical modeling and simulation and the desire for the inclusion of new technical-subject matter, is making it difficult to maintain a balance among science, engineering, design and non-technical courses. As a result, the average time to complete a four-year, undergraduate program in engineering now is four-and-a-half years.

In some, but not all engineering fields, the master's degree is becoming the preferred entry-level degree. Even when graduate education is desired, however, the substantial difference between graduate stipends and industrial salaries for new graduates discourages many capable American students from continuing their education. As a result, engineering graduate enrollments since 1976 have fallen by about 10 percent, while the number of United States citizens graduating from doctoral programs decreased from 2,500 in 1970 to 1,170 in 1983. This trend, combined with a strong desire of students from other countries for graduate education in engineering, has produced the situation that more than 40 percent of the Ph.Ds. granted in engineering in recent years have been awarded to foreign nationals with temporary visas. The United States is training significant numbers of doctoral-level engineers for leadership positions in universities and industries of other nations.

The large number of foreign students enrolled at the graduate level has affected the ability of U.S. schools to obtain adequate numbers of qualified faculty members. Today, about 1,200 positions on engineering faculties of U.S. engineering schools are unfilled, while the student/teacher ratio since 1976 has increased 35 percent. This is creating a gap in the quality of programs offered by the largest 50 engineering schools and the remaining 200 or so institutions. Each of these groups of schools educate about one-half of the new engineering graduates with bachelor's degrees.

SUMMARY

Engineering has always been a form of public service, aimed at meeting the needs of society by conceiving, developing and implementing solutions to technical problems of concern to society. While the work of engineers traditionally has been concerned with human problems, it is the degree of interaction and the greater perceived impact that engineering solutions are having on people that have increased dramatically in recent years. Technology is affecting virtually every aspect of life in the United States, and indeed in the world, from the gross national product, foreign trade and balance of payments, to the growth of cities and production of goods and national defense. More than ever before engineering must be viewed as a service to society, taking into account the interaction of the technical with the social, physical, cultural and political environments.

With all the change that has taken place in the last century and with the changes that are being called for now, engineering curricula, in one sense, have maintained a remarkable stability. In their more essential qualities, engineering curricula are today what they were one hundred years ago: distinctive types of college programs based primarily on the principles and applications of physical sciences and mathematics -- with associated studies in humanities and social sciences -- intended to precede and supplement, but not supplant, a period of professional experience. The present trend in engineering education is toward an emphasis on general educational values in undergraduate college work, followed by one or more years of graduate work for specialized training, periodically supplemented by continuing education throughout one's professional career.

HISTORY OF ENGINEERING EDUCATION IN JAPAN

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EDUCATION BEFORE THE MEIJI RESTORATION

It is well known that Japan's modernization process, including the establishment of a modern educational system, began in 1868, the year of the Meiji Restoration. In that year, the Tokugawa military regime, under which shoguns had ruled for nearly three hundred years, was replaced by a new government, called the Meiji Government. However, the rapid improvement of the educational system under the Meiji Government was made possible by progress in education made previously during the Edo period (1602-1867).

In the Edo Period, which preceded the Meiji Restoration, not only the central shogun government but also the clans across the country gave high priority to education. There were some 270 schools established by these clans (hanko), which contributed to the training of youths who belonged to the ruling class and thereby made it possible for those feudal families to employ highly talented samurai in their own fiefs. Students admitted to those schools were mostly from the samurai class, and each clan made it compulsory for its retainers to have their sons receive the education required of its clansmen.

The study of Chinese classics, particularly of Confucianism, comprised the main part of education in the hankos. The importance of reason in Confucian teachings made it easier in later years, when Japan came into contact with Western civilization, to assimilate Western thought in such fields as politics, religion and philosophy. This factor also contributed significantly to encouraging rational thought in the field of modern science and technology.

It is also worthy of note that the shogunate and clans alike attached great importance to general education for commoners. For example, commoners were admitted to some of the schools managed by clans, while in some fields small-scale teaching facilities were provided for the benefit of samurai stationed in remote areas as well as for commoners. In the mid-eighteenth century, meanwhile there was a great increase in private schools known as tera-koya (so called because classes were usually held at Buddhist temples) which played a vital role in the promotion of general education among the masses. The tera-koya was an informal place for education, where a small number of youngsters from local families of commoners gathered to learn the basics of practical skills such as reading, writing and arithmetic. A learned merchant, a retired or jobless samurai, or perhaps a monk did the teaching.

At the end of Edo period, several tens of thousands of tera-koya were estimated to exist across the country. The enrollment ratios varied from school to school, depending on the location of the facility, as did the composition of the student bodies of such schools. In general, however, no particular restrictions were imposed on enrollment, with the door left open to anyone who wanted to get an education. Students were mostly aged between seven and sixteen years. It is said that in the middle of the nineteenth century, forty to fifty percent of boys and fifteen percent of girls attended tera-koya or other schools. Clearly, these facilities helped a great deal in increasing the literacy and the arithmetic ability of the Japanese people as a whole.

Also in the Edo Period a Japanese system of mathematics, known as "wazan", developed rapidly, with the result that advanced elements of differential and integral calculus and analysis by matrix were invented before similar methods were discovered by Newton and Laplace. Moreover, some elements of these advanced mathematics, such as calculation by progression, were practiced as popular pastimes among citizens in the cities. The existence of mass education facilities in the Edo period provided a solid basis for the development of a nationwide primary education system under the Meiji Government.

ESTABLISHMENT OF THE ENGINEERING EDUCATION SYSTEM AFTER THE MEIJI RESTORATION

After the Meiji Restoration, rapid social and economic modernization as well as swift industrialization became the country's most important goals. To meet these national needs, Japan launched a modern educational system, adopting what it saw as the strong points in the educational systems of the major western countries. In its efforts to improve the educational system, the new Meiji Government moved very quickly. The Ministry of Education was established in 1871, and the Education System Order was promulgated the following year, in 1872. This Order provided Japan's first basic laws and rules for a modern educational system. Under the terms of the Educational System Order, three types of schools--elementary school, middle school and university -- were established.

In the beginning, the government endeavored to open as many elementary schools as possible, so the number of elementary schools across Japan increased rapidly. Progress of enrollment ratios in compulsory education is shown in Table 1.

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

The government also gave high priority to the promotion of industrial development policy, and technical education was stressed.

In the year 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 persons. 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) over a period of about two years in order to observe and study. 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 the handsome salary of 660 yen per month, when the salary of the Cabinet ministers was only about 500 yen per month.

During his trip to Japan from Glasgow, Dyer worked over his ideas for the new Engineering Institute, and on arrival, he submitted a plan to the Ministry of Industry. His proposals were accepted, and the Engineering Institute (Kogakuryo) began offering instruction 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 school. 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 again to the University of Tokyo in 1877. The University of Tokyo had a Faculty of Science, in which were included Departments of Engineering, Chemistry, Geology and Mining. In 1885, 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 Polytechnics was established. Then in 1886 the Imperial University was established, and the Engineering College of the Ministry of Industry was amalgamated with the Faculty of Polytechnics of Tokyo University, 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 established within just fourteen years of the promulgation of the Education System Order.

Another fact worthy of note is that various miscellaneous schools were developed. In these schools, subjects such as Japanese, Chinese classics, English, mathematics, handicrafts, calligraphy and bookkeeping were taught.

The progress of miscellaneous schools is shown in Table 2.

Table 2. Miscellaneous Schools

Year	Number of Schools	Number of Instructors	Number of Students
1876	115	129	2,333
1877	241	259	4,807
1887	1,738	3,393	81,633
1897	1,083	2,993	68,040
1907	2,172	7,700	150,609
1917	2,523	8,565	184,387

The progress of vocational schools is shown in Table 3.

Table 3. Industrial Education Institutes

Year	Vocational Specialized School		Vocational School		Technical Supplementary School	
	Number of schools	Number of students	Number of schools	Number of students	Number of schools	Number of students
1912	85	33,944	514	44,680	7,386	346,767
1921	108	52,233	687	96,888	14,839	995,532
1926	139	73,909	853	193,681	15,300	1,130,889
1930	162	90,043	976	252,965	15,248	1,227,338

These schools were very useful in the development of skilled workers.

IMPROVEMENT OF ENGINEERING EDUCATION AFTER WORLD WAR II

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

In the immediate postwar years the nation's educational facilities lay in ruins for the most part. Under such circumstances, there were strong popular cries for the swift expansion of industrial education, as rapid progress in this field was necessary for the nation's rapid economic recovery and for the advancement of science and technology.

Several U.S. survey missions visited Japan, most of which were dispatched at the request of the 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. The mission came to Japan in July 1951, and visited many engineering universities and exchanged views with many Japanese engineering educators for six weeks. Professor Hazen summarized his observations in a report submitted on August 23, 1951. The major points in his report are shown in Table 4.

Table 4

Observations of the Engineering
Education Mission to Japan

Professor H.L. Hazen
Aug. 23, 1951

1. University education in Japan is less free of centralized constraints than that in the U.S.

2. Flexibility of university organization is necessary. Team work is very important. The chain system should be improved.

3. Too much emphasis on research in Japanese universities.

4. Student-Faculty relations in Japanese universities are poor.

5. Care should be taken in the relation of the professional-level university engineer and the sub-professional skilled craftsman or supervisor of industrial operations.

6. University-industry cooperation in Japan is poor.

7. Financial conditions of Japanese universities are very poor.

8. Other recommendations

a) 4 years engineering curriculum at the university;
b) Establishment of the Japanese Society for Engineering Education;
c) Improvement of libraries.

In the 1950's, the Japanese economy made a rapid recovery. Therefore it became possible to plan for the promotion of engineering education. In 1957, the Central Council for Education submitted to the Minister of Education a report on measures for the promotion of scientific and technical education. The number of students enrolled at engineering schools or engineering departments of universities rapidly increased. At the same time, education and research activities in science and technology were strengthened at junior colleges and universities. In addition, a system of technical colleges, which offered five-year courses, was inaugurated. At present, sixty-five such colleges are in operation.

In 1957 and 1961, the number of the places for entrants into technical courses was increased. These places were allocated to newly-established courses in electronics and subjects related to nuclear technology, as well as to existing courses in such subjects as construction and mechanical, electrical, chemical and civil engineering.

In recent years, courses have been established in such new fields as urban engineering, maintenance and other urban problems, as well as in environmental pollution. More recently, courses on data processing, a subject which has gained importance with the advent of the information age, have been inaugurated, as have new courses made necessary by progress in science and technology. At the same time, efforts to improve the training of technical teachers in these new fields have also been strengthened.

HISTORY OF NSF INVOLVEMENT IN SCIENCE AND ENGINEERING EDUCATION: LESSONS LEARNED

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INTRODUCTION

This paper discusses the history of NSF involvement in science and engineering education, with particular emphasis on problems, prospects and lessons learned. Key issues that are discussed include:

1. How wide an impact (e.g., science and mathematics pipeline versus education for all) can or should a federal or national agency have on curricula and standards in education?
2. What is the proper role of the National Science Foundation -- an agency that primarily sponsors research -- in support of science and engineering education?
3. As education in the United States is primarily the responsibility of the states and local jurisdictions, how should the dividing line between federal involvement and local decisionmaking be drawn?
4. What constitutes effective implementation procedures for NSF-sponsored research and curriculum development in science education?
5. What should be the federal role in commercial distribution of curricular materials developed with federal support and how should copyrights and royalties stemming from such curriculum development be distributed?

HISTORY

NSF's initial response to its mandate to support the promotion of education as well as basic research in the sciences was in the form of fellowships for graduate education in the sciences. Thus during the first years NSF efforts in science education focused primarily on the training of graduate students, both through the fellowship program and through support of graduate students on research grants. Other activities through which the Foundation could make major contributions to strengthen science education were studied.

NSF recognized that one of its primary responsibilities in achieving scientific progress was the training of scientific manpower. This was to be addressed in the short term through graduate fellowships and research assistantships. However, an early additional conclusion of NSF was that improvement of the quality of science instruction in the schools should take place through a program for individual secondary school science teachers to spend summers at research centers for special seminars, and through the establishment of institutes for summer research. This effort evolved into the well-known NSF Summer Institutes Program.

NSF's Appropriation Act for 1956 established a floor on the availability of funds for the Summer Institutes Program, which continued until the FY73 NSF appropriation. This indicates the importance placed on this form of science education by the U.S. Congress. Later on, other forms of institute programs were mounted by the Foundation, including academic year and in-service institutes, and coverage was expanded from secondary school to elementary teachers.

While these various institute programs received great public and Congressional visibility, the Foundation's governing board asked in 1955 that NSF give primary consideration to the improvement of high school science curricula. NSF's FY 1958 budget highlighted for the first time programs for the improvement of science curricula as a separate activity. The launching of Sputnik gave added impetus to this thrust.

The fifties thus were a period of evolution as NSF worked to isolate the problems in science education it wished to address. By the end of the decade it was clear that substantial effort was needed in curriculum development. In addition, there had to be some way of introducing the educational community to these new ideas. As it moved into the sixties NSF educational programs continued with these two basic thrusts--training of teachers through the institute programs and the curriculum development effort. But the curriculum development activities and the various institute programs were to become inextricably intertwined. As new course materials became ready for classroom use, institutes were established to handle the orientation of teachers to these new curricula. These institutes enabled teachers to learn and see the relevance of the new subject matter in the courses they taught. By 1965 it was estimated that approximately 20 percent of the Summer Institutes had a major orientation towards one of the revised curricula. By 1973, the academic year institutes were totally devoted to providing "leadership" training for supervisors and curriculum specialists in implementation strategies and means.

Turning attention now directly to the curriculum development programs, the Foundation's 6th Annual Report in 1956 had identified science education from high school onward as a long range and continuing problem for American science. The initial entry of the NSF into the field of secondary school science curriculum reform grew from an idea proposed that year by Professor Jerrold Zacharias at MIT. Originally the proposal involved only a film course on physics which would at once update the curriculum and bring high school students in touch with distinguished scientists. This evolved into the Physical Science Study Committee, which developed the P.S.S.C. physics curriculum. Other substantial secondary school curriculum development efforts were begun in biology (BSCS), chemistry (Chem Study), and mathematics (SMSG), to mention just a few. Later on, social science curriculum development also was supported.

From 1960 through 1964 the Foundation also funded several feasibility projects at the elementary school level. Four of these later became major curriculum development efforts: the Science Curriculum Improvement Study, the Elementary Science Study, the Minnemast Project, and Science: A Process Approach. Other elementary curricula were supported subsequently.

Over the time NSF's curriculum development program was active (roughly 1956-76) a total of 54 projects, both elementary and secondary, were supported, in many different scientific areas. About $100 million was spent by the Foundation in direct grants to universities and nonprofit institutions to develop the materials, with another $88 million spent on implementation.

The guiding principles for the development of course content projects stated clearly that NSF would support research and development on the substance of courses and the tools of instruction. However, Foundation funds were not to be used to promote the adoption of any specific curriculum course or instructional materials; they were expected to compete on their own merits. Each teacher and school system must be free to decide if and how to use the products developed.

It became evident, however, that the diffusion and utilization of radically new curricula would not occur spontaneously. In the area of curriculum development, the Foundation tried not necessarily to lead but to follow the consensus of the scientific community as well as Congressional mandates. This sometimes forced the Foundation to walk a narrow line, as will be discussed later.

In 1973, following a reexamination and a reorganization of the Foundation's perceptions of its science education mission (a reorganization which included substantial inputs from the U.S. Office of Management and Budget), there was increased emphasis on the development of scientific literacy for all citizens and the establishment of an elementary and secondary school science literacy program. The program policy emphasized the complete freedom of the study groups to develop the materials according to their best judgment, with no implication of governmental responsibility for, nor endorsement of, the content or organization of the materials. At about this time certain problems surfaced in some of the NSF-supported curriculum projects, which caused adverse Congressional and public reaction. There was also some question as to the effectiveness of some of the large curriculum projects. These matters will be briefly discussed later. All of this led to a relative de-emphasis of the curriculum programs during the remainder of the 1970s. The long-standing Summer Institutes Program also was discontinued, as were the various other institute programs.

Major reductions in NSF's budget for science education in the early 1980s and a political climate hostile to a Federal role in education led to the temporary demotion of what had been a separate NSF Science Education Directorate to divisional status, layoffs in personnel, and a restricted vision of its mission or prospects. Sudden improvements in funding several years later and reinstatement of Science Education organizationally as a Directorate gave what was now called Science and Engineering Education (SEE) the wherewithal to proceed with more significant efforts, but start-up has been slow.

The past several years have witnessed an explosion of national energy and concern in the U.S. over the quality of school mathematics and science instruction. Motivated by both domestic concerns and international competition, this "movement" has expressed itself at all levels of formal education and government, as well as in the private sector. Local and state educational agencies have mounted efforts to attract or improve the quality of science teaching and revise their curricula; state legislatures have passed various reform measures; private foundations have mounted major efforts to develop an improved understanding of what should be taught or to develop new curricula; and professional and scientific societies have mobilized to analyze or otherwise address the situation.

The Federal Government as well has responded in kind, with the passage of the Education for Economic Security Act of 1983, which supported U.S. Department of Education efforts to improve the training of science teachers and increased funding for the National Science Foundation. Some of these recent developments mirror the post-Sputnik climate which led, three decades ago, to the mounting of the major NSF activities in science education reviewed above. The remainder of this paper summarizes some of the issues and lessons learned from these earlier activities.

HOW WIDE AN IMPACT CAN OR SHOULD A FEDERAL OR NATIONAL AGENCY HAVE ON CURRICULA AND STANDARDS IN EDUCATION?

Federally sponsored pre-college curriculum development programs were an important strategy for improving science and mathematics teaching in the post-Sputnik era. At least initially, the focus of these programs was the motivated, college-bound student, though not necessarily those intent on careers in science and engineering. The NSF pre-college science curriculum development and implementation programs arose out of the perceived need in the late 1950s for major improvement in the science content of public education. This was stimulated, in part, by the advent of Sputnik and also by the view of most scientists and educators that the scientific training of students entering college was weak and that the content of pre-college courses and texts was out of date. As a result, the initial courses supported by NSF were proposed by, and came to be directed by, scientists with extensive research experience and established scientific reputations but with relatively little experience in the elementary and secondary classroom environment.

This early trend led to some major successes but also created certain problems. Some of the early courses developed with NSF support were judged by schools to be too esoteric for a great number of students. Others were able to receive only limited distribution; local school systems were reluctant to adopt them because of the novel features, difficult content and the need for extensive teacher training or retraining. A 1977 survey of textbooks commonly used in secondary school science and mathematics courses revealed that, except for biology courses, relatively few schools were using the products of these national development programs. However, some programs and the materials produced had a marked effect on the quality of non-Federally supported text development. It does seem clear that the availability of good, contemporary course material had a generally positive effect on the quality of preparation of the relatively small numbers of secondary school students who went on to pursue careers in science and engineering.

The biggest problem, though, was that relatively little attention had been paid to curricula for those who were not intent on science or engineering careers. This trend has continued. Recent studies of the status of pre-college science and mathematics education and analysis of the content of commonly used textbooks and other literature lead to the conclusion that, at present, the content of science courses in both junior and senior high schools gives extensive and almost exclusive attention to preparation for future coursework leading to professional careers in science. The emphasis is heavily on the pure "structure of the discipline" form of science. Very little in the content of courses provides information related to personal or societal problems, technology and what engineers do, or vocational relevance.

The National Science Teachers Association puts it this way:

> ...much of the secondary school science curriculum is mismatched to the interests and needs of the majority of students in our schools who will not pursue scientific or technological careers.

In this sense, then, the earlier NSF efforts may be considered to have been essentially a failure. They succeeded perhaps so far as concerns their target audience, but in hindsight that target seems to have been too narrowly drawn.

WHAT IS THE PROPER ROLE OF THE NATIONAL SCIENCE FOUNDATION -- AN AGENCY THAT PRIMARILY SPONSORS RESEARCH -- IN SUPPORT OF SCIENCE AND MATHEMATICS EDUCATION?

In August 1981, the National Science Board (NSB) reaffirmed the responsibility of the Foundation according to the National Science Foundation Act of 1950 (42 USC 1862) to "recommend and encourage...National policies for the promotion of...education in the sciences" and "initiate and support...programs to strengthen science education <u>at all levels</u>." Also, Title II of The National Science, Engineering, and Mathematics Authorization Act of 1986 (P.L. 99-159) clearly enumerates policy goals and functional objectives for the Foundation to follow in organizing and maintaining science, mathematics, and engineering education programs. Thus, the Foundation now has a fairly clear commitment to play a role in scientific literacy and in renewal of the pool of technically trained manpower.

The currently strong support by the National Science Board -- the policy-setting body of the Foundation -- for science and engineering education programs at all levels is not reflective of the historical way in which this body has reached decisions relating to educational activities. The most consistent policy on science education held by the Board has been that NSF's primary responsibility in science education should be to train science professionals and to augment the conduct of basic research in universities, which means program support primarily at the doctoral and post-doctoral levels.

Observers have further commented that the Foundation and the Board are not comfortable with elementary and secondary school science education, and that education by educationalists is not appropriate in the world of science. The Congress has from time to time encouraged the Board to include more pre-college science educators as Board members. Overall, there has persisted a dichotomy in Foundation and Board thinking about science education, as reflected by the different worlds and different objectives of educators and scientific researchers. The definition and the scope of what constitutes science education is very different. For the scientist, the critical part of the enterprise is the training of graduate students through an apprentice system of working with university faculty who are themselves successful researchers. The Foundation may play a role in pre-college science education, but it must be very selective.

What we have today in Foundation policy is a very delicate balance between the research and education communities. Three factors are currently critical to the Foundation's mission in science education: (1) strengthening the human resource pool -- the number of qualified teaching personnel and science and engineering students at U.S. universities; (2) improving the educational quality of science and engineering teachers, students, and programs at all levels; and (3) research instrumentation--advancing the condition of university research equipment and facilities.

HOW SHOULD THE DIVIDING LINE BETWEEN FEDERAL AGENCY INVOLVEMENT AND LOCAL DECISIONMAKING BE DRAWN IN SCIENCE AND ENGINEERING EDUCATION?

Pre-college education in the United States is a highly decentralized enterprise with some 16,500 local school districts. Historically it has been -- and remains -- a major responsibility of states and localities, reflecting the deeply held belief that education should be responsive to the needs and views of the local community. Nevertheless, there has also historically been a considerable degree of national interest in pre-college education because of the belief that educated people are the backbone of a democracy. Today, the belief is widespread that a competitive, strong economy and secure society depend on the quality of scientists, engineers and technically trained personnel and that quality cannot be confined to the college level.

Problems in the relationships between national and local interests were not acute in early NSF programs. As we have noted, in the early years NSF concentrated on science curriculum development, on teacher training, and in the development of scientific manpower. In these activities, NSF focused solely on science and mathematics and operated mainly through the scientific community and through universities and colleges.

In the 1970s, however, as we have also seen, there was a reorientation of NSF science education programs, and emphasis shifted to broader sets of problems. By 1979, NSF was administering some 28 different programs in science and engineering education. Many were targeted at specific, limited problems and groups. What seemed to have been lost was a clear conception of the role of science engineering education in the research enterprise of the country. What was also lacking was a clear sense of what role NSF, or indeed the Federal Government should play in this.

Today it is generally agreed that the Federal Government has a leadership and catalytic role to play in science and mathematics education. The basic responsibility, however, lies at the local level, from parents to state and local governments. For example, NSF has a key role to play in the development and update of instructional materials for the teaching of various scientific subjects, and for testing these materials as they are developed. However, the choice of the materials, as well as the development of a set of these materials, has to be at the discretion of the local school districts.

Federal leadership in excellence in science and mathematics education is now an accepted tradition in the United States. The costs for financing this enormous undertaking are beyond the economic means of most of the states or the private sector alone. High leverage national programs along with increased local spending appear to be current trends.

WHAT CONSTITUTES EFFECTIVE IMPLEMENTATION PROCEDURES FOR NSF-SPONSORED RESEARCH AND CURRICULUM DEVELOPMENT IN SCIENCE EDUCATION?

While the legitimacy and parameters of a Federal role in this area now may be well-established, development of innovative curricular materials at the Federal level is not of course in itself sufficient to assure utilization at the local school level. Implementation is a complicated undertaking which begins soon after the development process is initiated. Normally it is considered to encompass both dissemination of information about and activities which may lead to the adoption by schools and school systems of new educational materials and techniques.

The Foundation began to re-examine some of its operating assumptions with regard to curriculum implementation in the late 1960s. NSF increasingly began to recognize that the development and availability of improved curricular materials did not of itself guarantee improvement of science education in the classroom, nor was upgrading of teacher competence in subject matter sufficient to effect improvement even if it were possible to reach all the millions of teachers with instruction in the various scientific disciplines represented in the new curricula. NSF concluded that these curricula had not succeeded in improving elementary and secondary school science instruction to the degree anticipated and needed. In large part this is because the curricular programs did not include effective procedures to bridge the gap between curriculum and innovation, which was under the leadership of scientists, and classroom instruction, under the administration of school officials.

Foundation policy in this area, from the first, recognized the necessity of avoiding the direct promotion of school system adoption of materials developed with NSF support. The Foundation recognized that full responsibility for the selection of curricula in the U.S. traditionally rests with appropriate local school authorities. Therefore NSF consistently refused to provide funds for sales promotion and activities of a similar nature. On the other hand, with its increasing investment in curricular materials, it became evident that the Foundation had to accept some responsibility for assuring acceptance and use of the materials to maintain a proper balance between these two somewhat competing considerations, with mixed results.

Foundation support for curriculum implementation tended in theory to correspond more with the earlier stages of implementation. One vehicle for providing substantial support of this nature was through the various institute programs, as we have seen. These came to be viewed as providing "leadership" training for participants in the new curricula. This led the Foundation further toward later stages of implementation than had at first been contemplated. Certainly holding institutes to provide intensive orientation of teachers in new curricula such as PSSC, BSCS and Chem Study involved more than merely upgrading their subject matter competence. The Foundation justified these activities on the ground that decisions to use the materials had been made by the teachers' local schools. At the same time, though, NSF supported a variety of activities aimed at widely disseminating information about the new curricula, not only to teachers but to local school boards, etc.

We see in the above the difficulty in making distinctions that can arise in Federal support for curriculum implementation activities. These distinctions become even more difficult when consideration is given to arrangements through which the new curricular materials enter the commercial marketplace.

WHAT SHOULD THE FEDERAL ROLE BE IN COMMERCIAL DISTRIBUTION OF CURRICULAR MATERIALS DEVELOPED WITH FEDERAL SUPPORT AND HOW SHOULD COPYRIGHTS AND ROYALTIES STEMMING FROM SUCH CURRICULUM DEVELOPMENT BE DISTRIBUTED?

In its curriculum development activities the Foundation always was careful not to provide direct support for implementation to the grantee-developer of curricular materials. The guiding philosophy was that these materials should enter the commercial marketplace through arrangements between the grantee-developer and private textbook publishers. But questions soon arose as to what these arrangements should be and who should prescribe them, given the Federal role (and investment) in developing the materials. It also was not clear on what basis publishers should pay royalties on these materials and who should receive them. There was also the copyright issue: were exclusive rights appropriate given that the materials had been developed with public funds? Yet without exclusive rights what incentives would private publishers have to publish and distribute the materials?

The Foundation struggled with these issues through the 1960s, arriving at several formulations of policies addressing them. None of these formulations were to prove fully satisfactory.

Additionally, troublesome questions arose in the context of the implementation activities the Foundation did support. In cases where materials were being marketed by private publishers, did not such activities (be they "information dissemination," "leadership training," etc.) in fact constitute promotion of the materials, to the detriment of competing privately-developed materials and the benefit of particular private publishers? Were the NSF materials truly competing solely on their own merits in the commercial marketplace?

As the Foundation increasingly moved into the field of curriculum development these issues came more and more to the fore. Matters came to a head in the mid-1970s, when a political controversy arose over a particular NSF-sponsored curriculum. This involved a fifth-grade social studies curriculum entitled "Man: A Course of Study" (MACOS), developed with NSF support by the Education Development Center (EDC) in Newton, Massachusetts. One of the curricular units dealt with life among the Netsilik Eskimos, a primitive Eskimo tribe. Critics alleged that by showing Netsilik practices such as infanticide and leaving the elderly to die, the course might be seen by children as "advocating" these values. NSF's role (and imprimatur) in the course development was singled out for particular criticism.

As a result, NSF science education programs, particularly in curriculum development, came under intense public and Congressional scrutiny. While the immediate MACOS controversy eventually subsided (the course is still in limited use today), the several ensuing internal and external reviews of NSF science education activities unfortunately found a number of irregularities (in granting procedures, publishing arrangements, royalty income disposition, etc.) in the curriculum development area, not only with MACOS but with some other NSF curriculum projects as well.

While detailed review of the particular problems and issues found and the way NSF responded to them is not our purpose here, they essentially derived for the most part from an inability of NSF staff and management over time to come to grips fully with the issues confronted. These issues, in turn, suggest more fundamental concerns in connection with the Federal role in this area. For example, how could NSF really avoid "promoting" particular curricula when it had invested considerable sums and staff effort over a substantial period of time in developing the materials? Indeed, why should it not promote the activities when the stated purpose of this investment was to develop improved curricula? A corollary of this involved the relationships built up over many years between NSF and particular grantee-developers. While NSF was careful to insist on an "arms-length" relationship, with continued support dependent on submission of renewal proposals subject to independent outside review, maintenance of complete objectivity in such circumstances obviously was a continuing problem for NSF. Finally, with limited staff and expertise in commercial publication, how could NSF adequately "police" the private publishing arrangements and the marketing of the materials developed with its support?

None of these questions have simple answers nor, in fact, is it clear they can be satisfactorily answered at all. They point to the larger uncertainties that surround the whole area of the Federal role in science and engineering education in the U.S. As once again the need for Federal government action is being increasingly emphasized in the U.S., it is perhaps useful to keep such earlier experiences in mind.

NOTES

1. This paper was prepared with the assistance of Catherine P. Ailes, SRI International.

2. The history of NSF involvement in pre-college science education is reviewed in Pre-College Science Curriculum Activities of the National Science Foundation, Report of Science Curriculum Review Team, May 1975, National Science Foundation, Washington, D.C.

3. The question of Federal impact on education is dealt with in Science and Engineering Education for the 1980s and Beyond, October 1980, National Science Foundation and Department of Education, Washington, D.C.

4. Foundation procedures and policies related to curriculum development are looked at in: Curriculum Case Studies are of Questionable Quality But Helped Precollege Curriculum Activities: National Science Foundation, Report of the Comptroller General of the United States, May 2, 1977, Washington, D.C. HRD-77-46; and in The National Science Foundation and Pre-College Science Education: 1950-1975; Report of the Committee on Science and Technology, January 1976, Washington, D.C.

5. Recommendations for action in NSF undergraduate and engineering programs are proposed in Undergraduate Science, Mathematics and Engineering Education; National Science Board; March, 1986; Washington, D.C.; and in Models and Programs in Science Education 1959-1976, NSF Program Report; Volume 1, Number 3, June 1977; Washington, D.C. NSF 77-35.

THE ROLE OF ENGINEERING EDUCATION IN THE JAPANESE SOCIETY

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INTRODUCTION

In the process of a country's development, it is generally true that the major driving force behind the achievement of economic development is technological growth. The growth and modernization of Japan, which was initiated only about 120 years ago at the occasion of the Meiji Restoration of 1868, is actually a typical example. It is quite often pointed out that Japan owes its success in developing into a modern nation to its traditional education system, in spite of the fact that few courses in engineering were offered within that system, which would appear to limit technological growth.

The attitudes toward education as well as the effects of learning depend largely on national and social characteristics. In Japan, most people enter high school and a large percentage of high school graduates receive higher education, at a rate much higher than the international average. On the other hand, little attention has been paid to the efficiency of educational methodology or systematization of the curriculum; nor to the social or economic demand for what is being taught at the universities.

The expected roles of education are changing almost continuously, in accordance with the economic and political situation of society. It should also be noted that the attitude or philosophy of study seems to be changing, also reflecting societal trends. The present paper attempts to analyze characteristics of engineering education carried out at Japanese universities.

HISTORICAL TRENDS IN ROLE OF EDUCATION

The "closed door" policy in Japan, which lasted for 300 years, ended at the time of the Restoration, triggered by the visit of the famous "Black Ships," led by M.C. Perry in 1853. This modernization, or westernization, has taken place at a remarkable pace dating from the Restoration, where the aim was to build a country with a socio-economic structure modelled on Europe and the United States. Though the administrative and bureaucratic structures did change, they were, to a certain extent, understood and supported by the traditional people of the Shogunate. In cultural activities, such as works of art, the traditional Japanese arts had been well-established and highly evaluated by those such as E.F. Fenollosa (1853-1908), though the Japanese methodology or approach was different from that of the West.

The fields of natural science and technology were, however, a different story. Industrial development was most critical for the government, since Japanese leaders who visited western countries were very much impressed by western technologies which were totally new to Japan. The new civilization was symbolized by the invention and applications of electricity and steam. In order to introduce western technologies and promote industrial activities, the government established the KOHBUSHO, to be translated as the Public Works Department or Ministry of Industry, which were responsible for inviting foreign engineers or technicians and for founding the SOHBUDAIGAKKO, or Technical College, for training Japanese engineers in 1873. This can be regarded as the first attempt made by the Japanese government toward providing engineering education.

Engineering education in Japan was started by the "Employed Foreigners" program, sponsored by the Japanese government. The system of Employed Foreigners originated even prior to the Restoration. It is reported that the Sogunate hired more than 40 foreigners in the year 1866, most of whom were technicians. After the Restoration, the number of educators gradually increased, as well as the total number of hired foreigners. According to a directory published in 1872, the number of Employed Foreigners was 214. As seen in Table 1, the number of foreigners decreased rapidly after reaching a peak in 1874, which reflects the fact that Japanese successors gradually were able to take the foreigners' places.

Since engineering education was initiated in 1873, the emphasis has changed many times. It seems appropriate to categorize the stages of engineering education; at least in Japan; into the following six phases:

- <u>Introduction of Engineering Education</u>

  With the introduction of foreign educators, selected people were trained intensively, both in Japan and abroad, under the auspices of the government.

- <u>Education of Engineering Leaders</u>

  KOHBUDAIGAKKO, the first technical college, has recently become a part of the University of Tokyo, where the most important role of education has been traditionally recognized as cultivation of the elite. This function was particularly appreciated during the period of industrialization, which would correspond to the time up to the 1930s.

- <u>Education of Researchers</u>

  The need for innovative activities was strongly recognized in technical industries where industrialization had been achieved to a certain extent, but particularly was noted during times of war, when technical information could not easily be obtained from foreign countries.

- Carrying out Research Work

  The university has been in the most suitable position to carry out research work, since theoretical as well as technical information could be best acquired there and experimental equipment would sometimes be available only at universities. This situation seems to have been reversed recently, and the major part of the large-scale research work is now carried out at the initiative of industry, where manpower and talented researchers are abundant and fairly large amounts of financial resources are available for investing in research work.

- Supplying Common Engineers

  Higher education had become restricted to a limited group of people, but is now supposed to be open to anybody, regardless of the structure of social demand. As a consequence of an increase in the number of engineering graduates, industry tends to regard the graduate as a specialized task force rather than as a future managerial candidate.

- Education of Foreign Engineers

  The prime minister once declared that Japan would accept 100,000 students from foreign countries in the future. Even at this moment, the number of foreign students is said to have exceeded the teaching capacity, due to the special considerations needed with respect to language barriers, educational background, and social mismatch.

  Table 3 indicates current trends in the number of foreign students accepted by the Tokyo Institute of Technology.

SOCIAL DEMAND FOR ENGINEERING EDUCATION

In a period of time when college graduates were scarce, the engineer expected, at the time of recruitment, that he would be guaranteed regular promotions throughout his lifetime employment with the company. This assured gradual seniority within a company sometimes led to lack of motivation on the part of the employee.

In the old university system before World War II, much more emphasis was put on general education than on specialized knowledge. In the new educational system efforts were initiated to systematically investigate and reform the engineering curriculum. Though approval of the curriculum and credits is regarded as one of the most important issues in faculty meetings at each individual university; inter-university communication about this problem is not necessarily well-established. Efforts to investigate prototypes of curricula are sometimes made in such organizations as engineering societies. But these efforts do not yet appear to be functioning well enough to encourage university personnel to make a comprehensive study of engineering curricula throughout Japan.

It is noteworthy that one of the large differences between the U.S. and Japan concerning student admissions may be found in the selection procedures. As is well known, the system of entrance examination in Japan is very well-organized, and fairness is of the first priority. This fairness is based upon university admittance derived solely from the scores received on entrance examinations. One unavoidable consequence of this system is that a distinct ranking of universities has occurred. It is obviously advantageous for industry, in recruiting graduating engineers, to rely upon the results of the comprehensive entrance examinations carried out by the government and consequent university and college rankings, rather than conducting its own testing.

Another remarkable difference between the universities of the two countries is in the methodology of training. This might be attributed partly to Japanese universities being inclined more towards personality development, but professors in Japan tend to educate their students with more theoretical knowledge and to put less weight on exercises or assignments. Also, there are persuasive arguments that engineering education should not be a too narrowly specialized field, but should cover the fundamental sciences; so that students can adapt themselves to on-going innovations in technology.

RESEARCH WORK IN UNIVERSITIES

As is true in most other countries, research activity is the most important function of the Japanese university, partly because technical information is more readily collected and theoretical considerations can be properly made as a result. The crucial reason for this research orientation is, however, that the education of researchers can be performed well only through "hands-on" research work. In most engineering courses, even under-graduate courses, thesis work is compulsory. It was true up until the 1960s that the university was the nucleus of research work and technological development.

As seen in Table 4, the overall balance of technological trade tends to equilibrate, but a large amount of surplus is observed for newly contracted trade. This indicates that Japan's capability in technological development has been successfully promoted. On the other hand, the regional imbalance of trade is remarkable, as seen in Table 2.

It is often said that Japan is good at experimental development, but relatively weak in fundamental research. This does not however, necessarily indicate the potential incapability of Japanese people in the field of fundamental research, but rather the results of a predominant emphasis on industrial development in an era of economic growth. Now that Japan has become a leading country economically, it is becoming increasingly obvious to both government and industry that in order for Japan to maintain its competitive advantage, an ever larger amount of resources must be devoted to fundamental research. Universities must play an important and critical role in carrying out this basic research.

Cooperation between industry and academia in research work is encouraged these days, wherein the university is expected to take a part in conducting fundamental research. Judging from the present situation, however, it is difficult to say that industry-academia cooperation would work out effectively. Research work on the so-called "frontier technologies" would generally require installing very expensive equipment and a large task force. The general attitude of industry toward research consists of a reluctance to invest money in projects which are unlikely to show profits in the near future.

According to the annual report of the Faculty of Engineering at the University of Tokyo, general research contracted with companies amounts annually, on average, to 175 million yen ($1.2 million) for 81 activities. Though this figure does not include all contracts, 2 million yen ($13.3 thousand) for any individual contract appears to be the maximum. As to the budget for routine research work, the total amount has been slightly increasing, as shown in Table 5, but now appears to be levelling off. Table 6 indicates the proportions in R&D budgets for different performers (government, public and private) for fundamental, applied research and experimental development.

CONCLUDING REMARKS

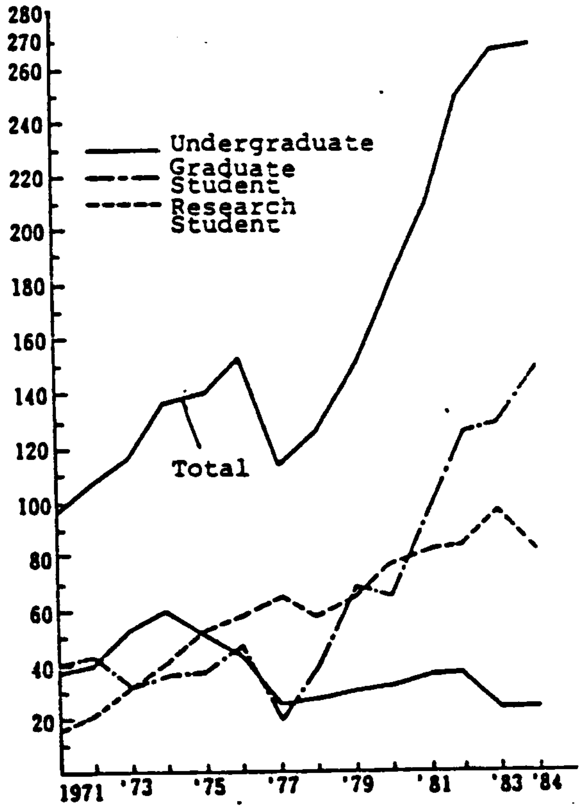
In the present paper, an attempt was made to point out some characteristic problems in engineering education at Japanese universities. Under such conditions as the rapid pace of technological innovation, there are, of course, many problems in common with those of foreign universities. The roles expected of engineering education are manifold, so in order to bring about changes, a systemized coordination of these various roles and expectations is essential.

Table 1 Number of Employed Foreigners

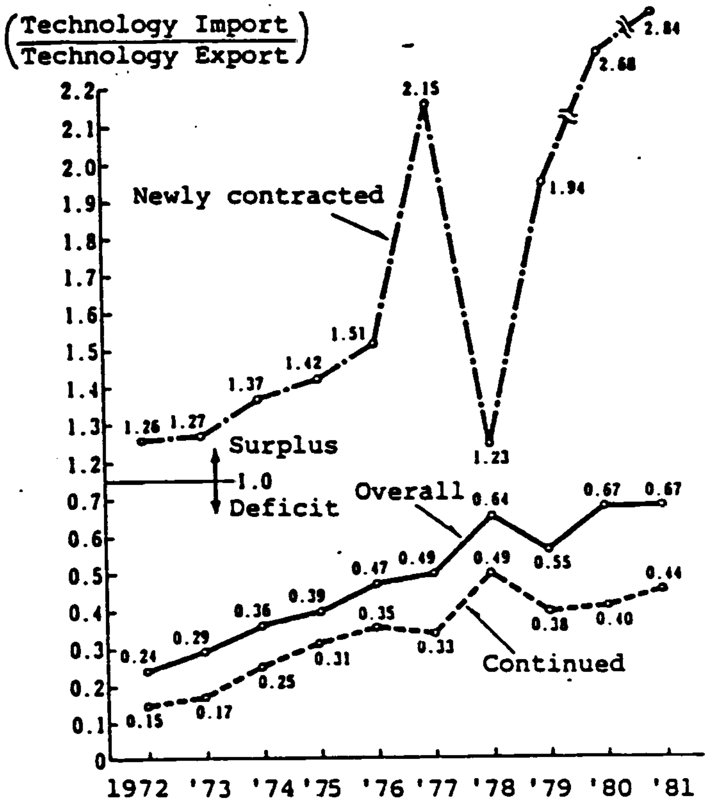
year	1874	1877	1882
educators	151	109	53
technicians	213	146	51

Table 2 Regional Balance of Technological Trade(M¥)

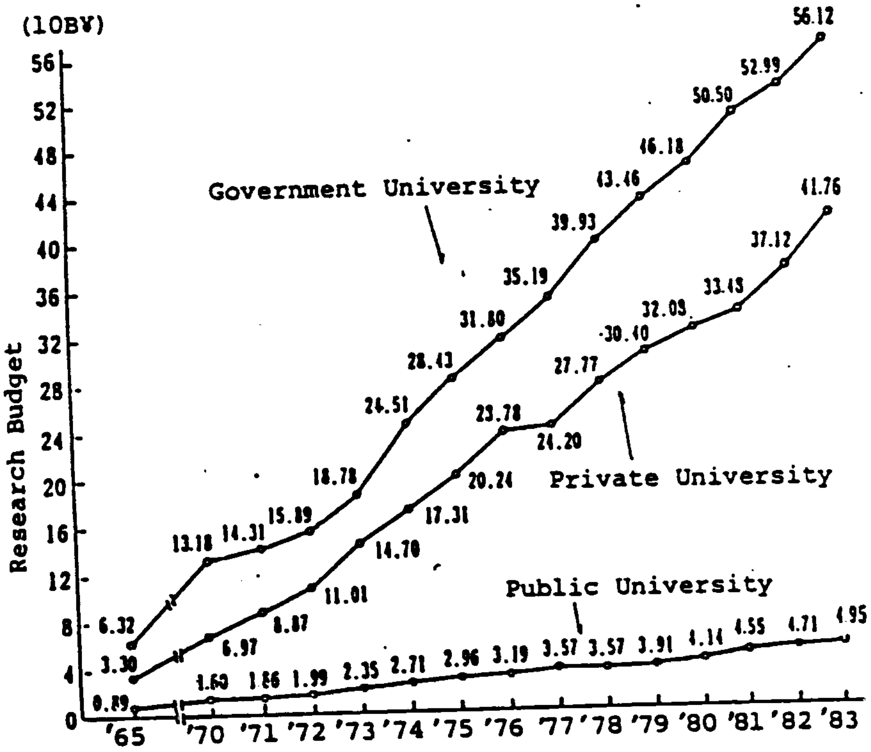
Region	1977	1978	1979	1980	1981
Total	△ 96,741	△ 70,010	△107,839	△ 79,917	△ 84,526
North America	△107,648	△108,410	△133,052	△127,361	△135,575
Europe	△ 43,319	△ 47,729	△ 58,766	△ 53,081	△ 52,276
Others	54,225	86,129	83,979	100,525	103,325



Number of Foreign Students in Tokyo Institute of Technology
Table 3

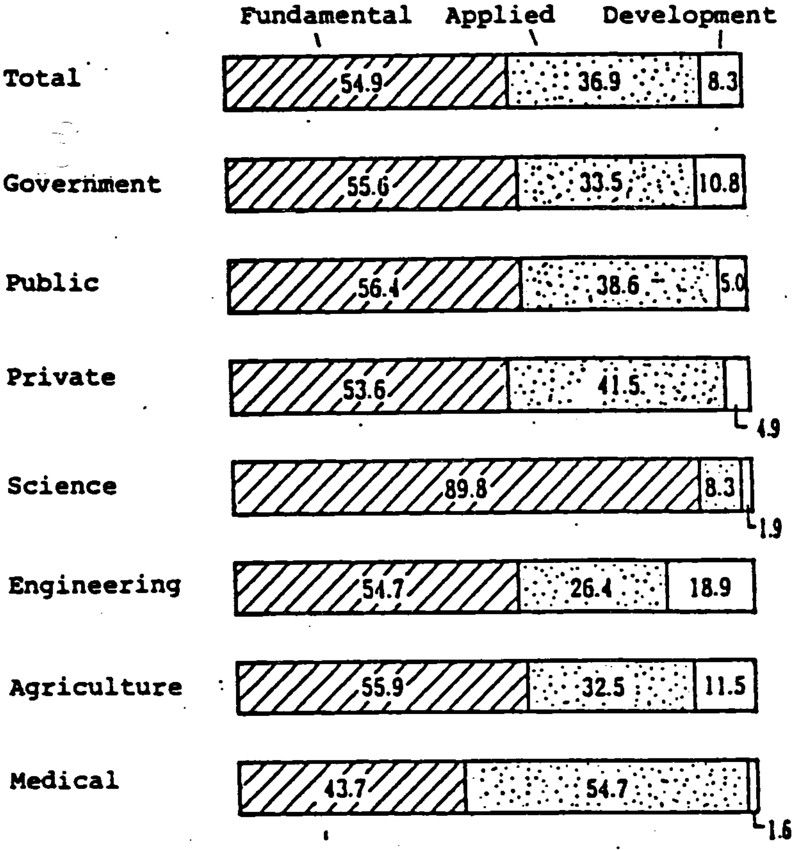


Balance of Technological Trade
Table 4



Budget for Routine Research Work(10B¥)

Table 5



Composition of Budget(%)

Table 6

CURRENT STATUS OF ENGINEERING EDUCATION IN THE UNITED STATES

W. Edward Lear
American Society for Engineering Education

The system of engineering education in the United States has been under considerable stress for more than a decade. A sharp decline in engineering enrollments at all levels followed the cutback of federal spending on the space program in the late 1960s. Students reacted to the publicity given to unemployment of engineers in some of the space-related industries, and even though engineering unemployment nationwide never exceeded 3%, many students who might otherwise have elected to study engineering decided at that time that it was an unattractive career option. By 1973, both students and employers were aware that too few engineering graduates were being produced to meet the demands of the nation, and enrollments at the bachelor's level began a spectacular climb that was to last for a decade. Much damage had already been done, however. Declining enrollments over a period of several years had resulted in static or decreased financial support for the schools of engineering -- retiring faculty members were not replaced, faculty salaries did not keep pace with the increasing cost of living, and laboratory equipment budgets were inadequate for a rapidly-changing technology resulting in a nationwide equipment obsolescence which continues to the present time.

With the increase in enrollment which began in 1973 (undergraduate enrollment was to climb 110% by 1983) came a new set of problems for the engineering colleges. The demand for new faculty members to handle the increased teaching loads could not be met. New engineering Ph.D. graduates, the principal source of engineering faculty, were simply not available in sufficient numbers to fill the vacant teaching positions. Annual production of engineering Ph.Ds. in the U.S. dropped from a high of 3700 in 1973 to 2700 in 1983, and more than 1000 of that latter number were foreign nationals. Engineering jobs were so plentiful for the B.S. graduate, and salaries so attractive, that few students opted to continue towards the Ph.D. and a teaching career. Stipends for graduate students were less than one-third the B.S. starting salary, and at the end of the 3-5 year route to the Ph.D. was a teaching job with a starting salary no better than that of the B.S. graduate. And although graduate student numbers have increased in recent years, largely because of the availability of more attractive stipends and a softer job market, moving Ph.D. output up to 3300 last year, the faculty shortage still persists in many of the engineering disciplines. An annual survey conducted by ASEE revealed that in the fall of 1985, approximately 8.5% of the budgeted engineering faculty positions were unfilled and that half of these had been vacant for more than a year.

In spite of the difficulties caused by overcrowded classrooms, insufficient numbers of qualified faculty, and aging instructional laboratory equipment, U.S. engineering education has been remarkably successful in producing graduates of very high quality. In fact, many industrial employers say that recent graduates are the best ever. This apparent contradiction can be explained in part by the fact that, in an effort to compensate for the shortage of faculty, a large number of schools have restricted engineering enrollments by raising admissions standards. The result has been an engineering student population of very high quality as measured by entrance examination scores and high school grades. However, even though the graduates from this exceptional pool may indeed be "the best ever", many engineering educators raise the question of how much better they might have been had they been exposed to an engineering education system which was not laboring under such difficulties. Meanwhile, there are signs that at least the faculty shortage problem may be solved within the next few years. Ph.D. production rose to 3400 in 1985 (although still not back to the 1973 level), and the number of students studying for the Ph.D. was more than 21,000. Students have been attracted to doctoral study by some more competitive stipends (e.g., $13,000-15,000 per year plus tuition and fees) funded by government and industry. To counter laboratory equipment obsolescence, a few states have made special appropriations to their state-supported engineering schools, but the need to bring the equipment holdings in engineering undergraduate laboratories to something near "state-of-the-art" continues to be a serious national problem.

To assure minimum quality standards in U.S. engineering programs, they are inspected periodically by the Accreditation Board for Engineering and Technology (ABET), which is a federation of the engineering professional societies. Today there are approximately 290 institutions which offer degrees in engineering, and 260 of these have one or more degree programs accredited by ABET. Most of these schools offer both the bachelors and the masters degree in the various engineering disciplines, and roughly 150 of them offer the Ph.D. degree. However, among this group of institutions there is a large imbalance in the size and activity of their Ph.D. programs. Approximately 50 engineering colleges award more than three-fourths of the nation's Ph.Ds., and most of the others graduate fewer than 10 Ph.D. candidates per year.

In addition to the accredited engineering schools, there are more than 100 institutions which have one or more ABET-accredited four-year B.S. programs in engineering technology. The engineering technology curriculum in a particular discipline covers approximately the same subject matter found in the undergraduate engineering curriculum but with less depth in the science and mathematics background, with less emphasis on theory and more on current practice, and with a heavier laboratory orientation. The four-year technology degree got its start in the 1950s following a major change in the B.S. engineering curriculum to give it a much stronger theoretical base. The number of schools offering the degree and the number of students enrolled grew rapidly for about twenty years, but both have levelled off recently and degree production is currently 11,000-12,000 per year. Although the graduates have been generally successful in finding employment, frequently with the title of 'engineer', there is a widespread lack of understanding of the differences between engineering and engineering technology among employers, prospective students and their parents, and career guidance counselors. All of this has led to what has been called an "identity crisis" in engineering technology which has persisted to the present time and which clouds the future of that part of the engineering education spectrum. This writer has suggested, and has been joined by a few others, that a solution to this dichotomy lies in recognizing what the marketplace has been telling us, which is that there is a broad range of activity which is classified as "engineering", some highly theoretical and some very hands-on and practice-oriented. Such recognition would dictate that we abandon the engineering technology degree and offer all degrees under the title of engineering, but with some schools stressing a more theoretical approach with preparation for graduate study and research while others would concentrate more on preparation for current practice. Whether or not the idea has merit, there are enough vested interests established that any change from the present uneasy alliance appears unlikely.

During the past half century the American Society for Engineering Education (ASEE) has conducted periodically a major study of engineering education to determine what changes were indicated in its content and/or structure to keep it abreast of changing technology and societal needs. The last such study, the so-called Goals Report, was completed in the late 1960s. Its major recommendation was that the masters degree be the first professional degree for engineers, with a required program length of five years. The recommendation had philosophical appeal but was never adopted by most of the engineering colleges because employers continued to express their satisfaction with the four-year B.S. graduate, leaving those few schools which had adopted the five-year recommendation at a competitive disadvantage for students.

Although they do not go into curricular details or program length as did the Goals Report and its predecessors, two major studies of other facets of engineering education were completed in 1986. The first of these, conducted under the auspices of the National Research Council with NSF and other federal funding, was a study of The Education and Utilization of the Engineer. This major effort produced a nine-volume report[1], four of them devoted to engineering education--three covering undergraduate, graduate, and continuing education of engineers and one devoted to engineering technology education. The other study, ASEE's Quality of Engineering Education Project (QEEP), was also a two-year program which was funded by thirty major corporate employers of engineers and completed in September, 1986. The final report[2] of the project contains in one volume the reports of four task forces, each with academic and industrial membership, which were charged with addressing the question of how we can assure future quality in four areas related to the engineering faculty and the working environment for that faculty.

The final reports of the NRC and QEEP efforts contain a very large number of recommendations regarding engineering and engineering technology education. The reader is referred to the individual reports for details of the specific recommendations which, in the NRC report, range over the complete spectrum of engineering education--students, faculty, facilities, equipment, curricula, research and federal support, to name some of the major areas. The two studies are completely complementary, however. QEEP addresses specifically and in detail four important issues to which the NRC report gives a broad overview or recommends for further study. Since these four areas are ones of independently shared concern in the two reports, a more detailed discussion of them is in order.

The four topics addressed in the QEEP study are Preparation for the Teaching of Engineering, Continuing Professional Development of the Faculty, the Undergraduate Instructional Laboratory and the Use of Educational Technology. The following discussion outlines some of the major conclusions and recommendations reached by the QEEP and NRC in these four areas.

The charge to the QEEP task force on Preparation for the Teaching of Engineering was to determine whether changes are indicated in the current method of preparation of an individual for an engineering teaching position. This usually consists of education through the Ph.D., and in most cases the immediate assumption of a teaching post without experience in the practice of engineering. The task force concluded that the Ph.D. is appropriate training for faculty in universities which emphasize research and graduate study but certainly not a necessity for all faculty in those schools or in schools which do not themselves offer the doctorate, where appropriate industrial experience may be a desirable alternative. But the task force looked beyond the educational background to the need for a better understanding by faculty of current engineering practice and has as its major recommendation the requirement that an engineering faculty member have a minimum of two years experience in industry or other engineering practice before senior faculty status (associate or full professor) is granted. The NRC report also expresses concern for the need of closer ties between engineering education and practice by recommending appointment of several faculty members with the title Professor of Engineering Practice. These would be people with strong backgrounds in the practice of engineering, who would not be required to hold the Ph.D. degree and who might be appointed on a part-time, temporary or permanent basis.

The task force on Continuing Professional Development of the Faculty was charged with recommending steps which will assure that engineering faculty have both the opportunity and the incentive to remain current both technically and pedagogically throughout their teaching careers. The task force concluded that the present ad hoc system of faculty development is completely inadequate in today's world of rapidly changing technology. The primary recommendation of the group is that each institution put in place a structured program of faculty development which is a regular part of the job of each faculty member and for which there is available appropriate time and institutional resources. The recommendations of all of the QEEP task forces are in most cases directed specifically to some group or entity for action, and in this case the recommendation is that ABET develop accreditation criteria which require a structured development program in each school. The report also recommends that NSF fund experiments in the development of such programs in several types of institutions which can serve as models for the other engineering schools. The NRC report reaches similar conclusions concerning the problem of faculty obsolescence and recommends that engineering schools create specific faculty development programs with shared institutional, industrial and government funding.

Emphasis on the laboratory portion of undergraduate engineering education in the United States has declined significantly over the past two or three decades. In addition to the obsolescence of equipment discussed earlier, there has been a substantial decrease in the amount of laboratory instruction required in many engineering disciplines and a widespread lack of interest by the faculty in laboratory teaching and development. The QEEP task force on the Undergraduate Instructional Laboratory was charged with recommending actions which will bring laboratory instruction back into a full partnership with the rest of the undergraduate program. The task force concluded that there are two obstacles to excellence in laboratory instruction. One is the lack of up-to-date equipment. The other, and perhaps the most important, is the lack of interest and involvement in the laboratory by the most qualified members of the faculty. Two causes are identified for the lack of faculty interest: (1) the reward system -- salary increases, promotion and tenure -- is based heavily on research and publication, and many faculty members see involvement in laboratory courses not only as an activity which will not aid them in their career advancement, but one which is counterproductive; (2) the time required for laboratory teaching is generally greater than that for a lecture course for which the same teaching credit is given.

The task force did not find any easy answers to these long-standing problems but does make some specific recommendations for action which combined could reverse the current trend. Among them is a recommendation that each engineering professional society re-examine the laboratory portion of the curriculum and establish minimum acceptable laboratory experience for students in its discipline which would be adopted by ABET as criteria for accreditation. ABET is also urged to establish criteria which would assure appropriate teaching credit for laboratory instruction, and the engineering colleges are admonished to revise their reward systems to give proper recognition to faculty who do good work in the laboratory. And to address the problem of the enormous cost of keeping equipment near state-of-the-art, it is recommended that NSF support experiments in some new and different ways of conducting laboratory instruction (e.g., combinations of simulation and hands-on instruction, use of technology to improve the efficiency and currency of laboratory instruction, etc.). The NRC report devotes a chapter in its volume on undergraduate education to the need for revitalization of the laboratory part of the curriculum. Its two recommendations call on the colleges to give priority to reestablishing emphasis on the laboratory and on industry, government and academia to develop a national program of matching grants to address the problem of outdated equipment.

The fourth area which the two reports target as one of great importance to the future of engineering education is that of the use of educational technology. The NRC report recommends that faculty weave computer use into the fabric of engineering curricula. The QEEP task force on the Use of Educational Technology, charged with aiding the engineering schools in the most efficient integration of appropriate technology into their programs over the next decade, has investigated the present state and probable future of several candidate technologies -- computers, video, communications and print. In addition to its report, the task force will publish in the December, 1986 issues of Engineering Education articles describing major experiments underway in eight universities in the integration of the computer into engineering programs. The expectation is that these will serve as models for many other universities and prevent much "reinvention of the wheel." Several recommendations found in the task force report deal with issues which must be resolved before complete integration of the technologies can be realized nationwide. These include the need for clear university policies on intellectual property rights and on the rewards for faculty engaged in the development of courseware and software, the need for portability of software among institutions and the need for standardization of hardware and operating systems.

In addition to these two recently completed studies, three other related activities should be mentioned which are either underway or in the planning stage. First is a study in progress by the Association of American Colleges (AAC) of the liberal learning component of engineering education. The current curricular requirement for accreditation of an engineering program is one-half year of humanities and social science courses. The AAC study, scheduled for completion in late 1987, seeks to determine the adequacy of that requirement. The second activity is a gathering of representatives of the various engineering professional societies for a congress to be held under the auspices of ABET in Washington, D.C., on November 20-21 of this year. At this conference, the recommendations of the QEEP and NRC reports will be examined with the objective of determining what actions regarding accreditation should be taken by ABET in response to the recommendations. The third activity is just getting underway. As mentioned earlier, ASEE has for many years conducted a periodic study aimed at charting the course of engineering education for the next decade or so. A committee of the Society has been considering during this year whether another such study is now in order. That group concluded that the time is right for the development of such a working plan to set the course of engineering education for the years ahead. However, the committee recommended, approved by the ASEE board of directors, that in view of the NRC and QEEP reports, another full-scale study of engineering education at this time is not required. Rather, the decision was that a small group of people of stature in engineering education and practice would be commissioned to draw upon the existing reports, the output of the forthcoming congress, and their own ideas about engineering education for the future to produce a "white paper" recommending a content and structure for engineering education in the years ahead. Chairing this group will be Dr. Edward David, co-chairman of this Japanese-American conference on engineering education, and it is anticipated that the task of producing this guide to the future of engineering education will be completed in less than one year.

Finally, what is the status of graduate study and research in U.S. engineering education today? In general, this important arm of engineering education is in reasonably good health. The university engineering research effort is big business in terms of numbers of people involved as well as dollars expended. Approximately 12,000 faculty members, 30,000 graduate students and 12,000 undergraduate students were engaged in separately budgeted research in the engineering colleges in 1984-85. There are some problems -- the shortage of good Ph.D. candidates mentioned earlier in connection with the faculty shortage, the faculty shortage itself with the resulting difficulty which faculty in some disciplines have in finding time to do research, and some shortfall in specialized research equipment. On the whole, though, the situation is improving with regard to all these problems, and on balance the engineering graduate study and research enterprise is doing well.

A strong movement has developed in recent years for closer ties between industry and the universities, motivated in part by the potential influence of such ties on industrial competitiveness, and many of the linkages which have been created have their focus in the college of engineering. Two very important recent programs of NSF reinforce the industry-university partnership. The Presidential Young Investigator program makes a very attractive grant to promising young faculty researchers with a requirement of matching funds from industry. And the Engineering Research Center program, a bold departure by NSF from its usual pattern of support of engineering research, is now funding eleven major university centers devoted to research of high national interest, each with substantial industrial participation as a requirement. The latest data available[3] show that business and industry in 1984-85 provided $220 million of the $1.44 billion engineering college research expenditures, while $931 million came from federal government sources. The bulk of this federal support comes from three sources: the Department of Defense; the Department of Energy; and NSF. For the 1984-85 school year, NSF had a budget of approximately $120 million for engineering research. Although the number of university-industry alliances continues to grow, with the major focus being the support of a particular area of research by industry, the federal government continues to be by far the largest source of support of research in U.S. engineering schools.

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ENGINEERING EDUCATION IN JAPAN

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Before I begin to describe the status of engineering education in Japan, I must confess that I am reluctant to do so, because describing the real situation in Japan will expose a discouraging state of affairs.

Because Japanese industry has been developing very rapidly during the past few years, I am afraid some of people from abroad will take this as being due to successful engineering education. However, this assessment is not exactly correct in my opinion. Since most of Japanese industry has been and is being run on the model of European or American engineering--in other words, as mere imitations of the developed countries--engineering education in Japan has been directed simply toward responding to this industrial situation.

Recently, though, there has emerged a general desire on the part of the Japanese people to become as competent indigenously as other developed countries in science and engineering matters, by training more truly innovative professional engineers. The objective of this effort is to create a situation in which Japan trains its own scientists and engineers, and ultimately to contribute to a more stable economic situation. Opinions are divided, however, on what strategy to employ to achieve this objective. No one strategy to date appears to provide the formula for success.

Before World War II, our educational system was a little complicated, and sometimes unreasonable. For instance no women, and no graduates of schools other than those called "koto-gakko" (a kind of special senior high school) were admitted to college level institutions chartered by the Ministry of Education. A "6-5" (that is six years of primary school followed by five years of middle school) system; or for those young people fortunate enough to be able to proceed to higher education; a "6-5-3-3" system was in effect.

After the War, the educational system was reformed, and as a result, there was much improvement. The period of compulsory education was extended from six years to nine years. Coeducation was generally adopted in the primary schools, and equal opportunity of application to any of the higher schools was given to all boys and girls, if they succeeded in the competitive examination for admission.

After nine years of compulsory education (six years of primary school and three years of junior high school), three more years of senior high school education became a prerequisite for admission to college. To be awarded a Bachelor of Arts degree, four years of undergraduate study are required. In graduate courses, students are required to study two years for a Master's degree and three more years for a doctorate. This 6-3-3-4 system was adopted following the pattern of the United States, with the enthusiastic recommendation of American occupation personnel and with the firm support of leading Japanese educators.

Many years have passed since these reforms, and at present many people state critically that the reforms have been a failure. This criticism has some validity, because many educators are dissatisfied with the present status of our country. The real failure, I believe, however is not due to the change from the prewar system to the 6-3-3-4 system. The true situation is as follows.

As a consequence of the post-war increase in the number of graduates from the junior high schools -- education through that level had become compulsory nation-wide -- the number of applicants to senior high schools and, subsequently, to colleges increased enormously. (Applicants are greatly increasing again due to the rapid growth in the birth rate during the years immediately following the War.) In order to accommodate these applicants, the government authorized not only increases in the capacity of existing schools, but also establishment of new schools, by transforming or reconstituting then existing primary and lower secondary schools. Of course, the national and local governments supported these efforts as much as possible, but even so, all schools suffered very much from the financial burdens involved in developing adequate academic infrastructure, such as land, buildings and equipment. A most serious problem, has been the recruitment of sufficient numbers of teachers, because, as is needless to say, it is very hard to train competent teachers and professors in such a short time.

This problem is not unique to engineering education. In the first place, although it is fully realized that a liberal arts education is a very important precursor to an engineering education in order to develop people of high calibre who will be indispensable to a internationally competitive society, very few professors have been successful in persuading students of the value of a liberal arts education. This is due chiefly to lack of experience and enthusiasm. The lack of enthusiasm is due to a poor understanding of the value of a liberal arts education by professors and deans, because their efforts are neither well appreciated by other faculties nor suitably rewarded by the code of administrators. Moreover, teachers in more technical fields are ever anxious to increase their own teaching hours by reducing the number of class hours allocated to liberal arts education.

In addition to these points, liberal arts and technical courses are often offered at different campuses, because of the lack of an integrated land area for the entire educational program of the university. Therefore, communication between members of the two faculties is apt to be very limited.

Recently, the administration has authorized some teaching hours which had been allotted for liberal arts courses to be given to basic courses falling within the category of professional education, for the reason that technical courses need more hours. Consequently, there is a danger that liberal arts offerings may eventually be partially replaced by purely technical study -- consciously or unconsciously.

Considering the situation mentioned above, I think that in order to promote liberal arts education in our country, first of all a much greater number of well-qualified professors should be provided. To accomplish this, faculty in both the technical and liberal arts desciplines need to cooperate and exhibit mutual interest.

On the other hand, the following measures would be desirable to enhance the capabilities of present faculty members and to increase the number of well-qualified faculty:

- To invite general education specialists from abroad to hold seminars on practical methods of teaching.
- To permit Japanese professors in charge of general education to study abroad, and to enlist the assistance of professors there in helping them to achieve their special objectives. This is particularly important, because very few Japanese who wish to study methods of college level teaching have had the opportunity to study abroad, although a good many Japanese have visited Europe and America to join in research work of their own interest.

A limited number of the education "elders" in addition to younger faculty could be awarded grants in this program. The younger men would become the main body of educators in the future, while for the established older people, it would be hoped that, by having the opportunity of studying in a distant country, they would better be able to understand their young colleagues' fresh ideas and proposals for improvement of the educational environment, and to encourage their activities. In this way the "elders" can contribute to the smooth operation of the program.

There are also several problems in the realm of professional education. It is said to be more or less difficult to recruit students in Europe and America for the science and engineering fields; however, in contrast with this phenomenon, many students in Japan strongly wish to work in industry-related fields, because these are generally accepted as being best for a stable livelihood. A majority of students with this objective apply to colleges, since in the technological fields college graduates are much better paid than in other fields. But, as the number of applicants is far beyond the capacity of the colleges to accommodate them, they are admitted only through tough competition in an entrance examination. This competition is most heated in a very limited number of prestige universities, because there is a strong tendency on the part of senior people in industry to place special confidence in the graduates of those institutions. Under these circumstances, the entrance examinations for colleges have gradually become more for the sake of competition than as an examination to determine whether the applicant is qualified to proceed to higher education. The prestige university graduates, however, are not necessarily more brilliant and competent as compared to those who come from the so-called "unknown" colleges.

College graduates are required to take an examination again when they apply to work in industry; and those who prepare the examination for each company generally are the engineers who are working for that very organization. Therefore, the content of the examination is apt to consist of material which happens to be of personal interest to the person preparing the examination; but is not necessarily important or fundamental to the subject matter.

College professors do not argue against employers on this point, but instead try to teach the students in minute detail specificities of the field to ensure that their own students score favorably on the examination as compared with those from other colleges. Consequently, class hours for technical education have increased gradually, and at present the whole day -- from morning to evening -- is filled with lectures and laboratory experiments, but no time is alloted to students for study in the library, or for mutual discussions.

It is very unfortunate that, because libraries in colleges generally are open only in the daytime, almost no students can take advantage of them because of conflicting schedules. What is worse, since examinations are given only at term-ends, students try to memorize the contents of lectures a few days before the examination. At the same time, the examinations themselves sometimes are intended merely to ascertain whether they remember particular practical facts, and not to determine whether the students have achieved a true comprehension of fundamental principles in the field. Such questions of specific fact are generally much easier for the professors to grade. I believe that this is the principal reason in my mind why the calibre of Japanese college graduates is much inferior to that of European and American graduates.

This atmosphere in professional education has a strong influence on the direction of engineering science. As a matter of fact, a particularly divided sector or sectors of engineering science is given to students according to the expected discipline requirements of their future profession. For example; in the department of mechanical engineering, the mechanics of solids and fluids and thermodynamics, etc. necessary for the proper comprehension of present practice in mechanical engineering, are considered important for the student; but electrical sciences are almost entirely neglected. On the other hand, in the department of electrical engineering almost no weight is placed on mechanics or thermodynamics. This tendency is due to the fact that engineering science is taught only to prepare the student for the comprehension of professional topics which are to be dealt with in a specific department. I am afraid that the real merit of engineering science -- in its wide and correct meaning -- is not well recognized.

Not a few professors who have made visiting tours to Europe and America have reported that the Japanese level of curricula in colleges is higher than that in other countries. This may be true, but as far as achievement is concerned, I am afraid the Japanese graduates will be much inferior to those elsewhere. This result has something to do with the fact that the most brilliant appearing graduates are not necessarily the most active in their professional fields.

As we consider the situation in Japan mentioned above, it becomes apparent that it is extremely necessary -- even essential -- for us to, communicate much more closely with industry, to in a sense, educate them, and, at the same time brush up our own educational ability.

Generally speaking, Japanese teachers at the higher levels have less enthusiasm for education than those in the lower schools. Unfortunately for college students, Japanese professors are not enthusiastic about teaching itself, but are often engaged in their own professional research work. Of course, there are reasons for this phenomenon. Although an outstanding contribution to a professional society is generally highly recognized, educational contributions are not necessarily greatly appreciated by the public. Any recognition accorded to the teachers is, in almost all cases, to acknowledge many years of service -- for longevity in the profession -- and hence teaching is not so attractive to young people. To remedy this tendency it is essential that we be able to demonstrate many worthwhile examples to convince professors that enthusiastic teaching is simultaneously fostering the progress of their research work. In other words, teaching and research work are not only compatible, but also beneficial to one another. In this respect, I hope we shall be able to carry back to Japan from Europe and America several remarkable examples which prove this mutual enrichment.

I have pointed out thus far several questions to be considered by professors, but at the same time there also are questions which the entire society must consider for the encouragement of professors. For instance, college professors of one institution generally are teaching in other colleges on a part-time basis. Although this is profitable for individual professors, it cannot be desirable for a satisfactory education or for smooth coordination within each college. It would be much better for both the college and professor if both salary and teaching loads were increased, but due to the complicated regulations of the Japanese salary system, this is not an easy task.

I would make one more point related to university-industry cooperation. Needless to say some professors cooperate with industry in research and development projects needed by industry, and industry sometimes donates large funds to colleges or to their affiliated research laboratories. But on the other hand, very few scientific developments occur as a result of this. Industry is merely trying to recruit graduates from the colleges. This may be considered highly self-interested but to improve this situation, the government might also provide incentives by offering substantial tax exemptions for contributions to educational institutions. I am sure there must be such policies in Europe and America, which we wish to study in detail.

It goes without saying that all of the problems mentioned above are our own problems, and should be solved by ourselves, but I accepted your request to describe the present status of engineering education in our country, because I hoped and expected -- perhaps a little selfishly-- that you would be so kind as to give us many suggestions and much advice toward the solution of these difficulties, and to help us expedite the improvement of our engineering education.

Before concluding my talk I must not forget to express our sincere gratitude that in 1951 fifteen American engineering professors, chaired by Dr. Haold L. Hazen, then Head of the Electrical Engineering Department of MIT, came to our country, and very kindly discussed with us the whole subject of the modernization of engineering education. That visit was very stimulating and encouraging to our people. Therefore, I wish we may have another opportunity to be with European or American friends to work for the improvement of our country, and of society in general.

Perhaps you had anticipated that my remarks would simply be words of praise for my country's education system. You will know, of course, that inasmuch as I have spent my entire life in this profession, I naturally am proud of the accomplishments in Japan. On the other hand as a scientist, I must look at things objectively, and cannot be satisfied until perfection is achieved. I truly want that perfection, and, by criticizing, hope to smooth the remaining rough spots in the engineering education system of Japan.