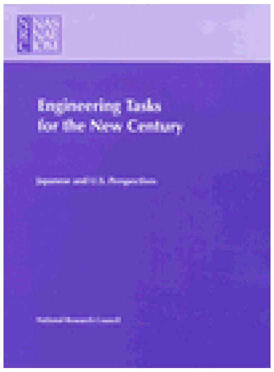

Engineering Tasks for the New Century: Japanese and U.S. Perspectives

Committee on Japan, National Research Council

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Engineering Education Tasks for the New Century:

Japanese and U.S. Perspectives

Report of a Joint Task Force of the National Research Council and the Japan Society for the Promotion of Science

Committee on Japan
Office of Japan Affairs
Office of International Affairs
National Research Council

Washington, D.C.

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making the published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their participation in the review of this report: J. Myron Atkin, Stanford University; Kent F. Hansen, Massachusetts Institute of Technology; Frank Huband, American Society for Engineering Education; Takeo Kanade, Carnegie Mellon University; Milton Levenson, Bechtel International; Roland W. Schmitt, Rensselaer Polytechnic Institute (review coordinator); William Spooner, Creative Business Solutions Group; Michiyuki Ueonohara, NEC Corp.

While the individuals listed above have provided constructive comments and suggestions, responsibility for the final content of this report rests solely with the authoring committee and the institution. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the organizations that provided support for the project.

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Since 1985 the National Academy of Sciences and the National Academy of Engineering have engaged in a series of high-level discussions on advanced technology and the international environment with a counterpart group of Japanese scientists, engineers, and industrialists. One outcome of these discussions was a deepened understanding of the importance of promoting a more balanced two-way flow of people and information between the research and development systems in the two countries. Another result was a broader recognition of the need to address the science and technology policy issues increasingly central to a changing U.S.-Japan relationship. In 1987 the National Research Council, the operating arm of both the National Academy of Sciences and the National Academy of Engineering, authorized first-year funding for a new Office of Japan Affairs (OJA). This program element of the Office of International Affairs was formally established in 1988.

The primary objectives of OJA are to provide a resource to the Academy complex and the broader U.S. science and engineering communities for information on Japanese science and technology, to promote better working relationships between the technical communities in the two countries by developing a process of deepened dialogue on issues of mutual concern, and to address policy issues surrounding a changing U.S.-Japan science and technology relationship.

Staff

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Executive Summary

The U.S.-Japan bilateral task force was tasked with addressing the following questions: (1) How do Japan and the United States educate and train engineers, and what are the major similarities, differences, and trends? (2) What are the superior practices that have been developed by each country, especially approaches that could be adopted by the other country? (3) Are there areas in which expanded U.S.-Japan cooperation could help to improve engineering education in the two countries and around the world?

The joint task force was organized by the Committee on Advanced Technology and the International Environment (Committee 149) of the Japan Society for the Promotion of Science (JSPS), and the Committee on Japan (COJ) of the National Research Council (NRC). Committee 149's work was supported by member dues, and the COJ's work was supported by the United States-Japan Foundation and the National Academy of Engineering. The joint task force was chaired by Mildred Dresselhaus of the Massachusetts Institute of Technology, and Sogo Okamura of Tokyo Denki University.

Japan and the United States are two of the leading nations in the world in engineering education and practice. Their systems for training and educating engineers display marked contrasts, resulting from the very different economic and cultural environments in which they have developed. The joint task force used a “lifelong learning” approach in examining the two countries' systems, exploring differences and similarities in K-12 education of future engineers, undergraduate and graduate education, as well as continuing education of working professionals. The panel also explored two important issues that will affect engineering education in both countries in the future: the need to educate and train “global engineers” who can work effectively in international contexts, and the potential for information technology to transform engineering education in the future.

The joint task force's findings and recommendations are divided into three sections, addressing issues relevant to Japan, the United States, and both countries.

ISSUES, FINDINGS, AND RECOMMENDATIONS FOR JAPAN

Japan's system of educating and training engineers has contributed mightily to its economic development and current status as a global leader in manufacturing and high technology. Several elements of Japan's system were highlighted by the joint task force as important assets and sources of strength for the future. Consistent excellence in K-12 mathematics and science education provides a solid foundation for future engineers, as well as the average Japanese citizen. Most large companies invest heavily in continuing education programs for employees, including engineers, allowing the Japanese engineering workforce to maintain its technical currency. Japan's education system contributes to the ability of many Japanese engineers to work well in teams, an increasingly central element of engineering work around the world.

Japanese engineers will also face significant challenges in the future, and their education and training must adapt to new realities in order to adequately prepare them. Perhaps the most important key to successful adaptation will be to reform Japan's university admissions system. This is an issue that goes beyond engineering, and is significant for Japanese society as a whole.

The university admissions system, which perpetuates a strict hierarchical ranking of schools and students, has a pervasive impact on K-12 education, the university experience itself, and subsequent hiring and career growth. While the system has helped Japan maintain high educational standards, the Japanese working group members believe that greater simplicity and flexibility would enable Japanese students to receive a richer educational experience.

In general, Japan needs to promote greater flexibility in its regulation of education to promote innovative approaches, while maintaining standards and stability in the society.

Specific action items for Japan include:

- Redoubled efforts to promote computer education for Japan's K-12 students.
- A more simple university entrance system.
- Improved quality in engineering education, including a more rigorous undergraduate curriculum, introduction of new requirements for thesis doctoral students to ensure their broad mastery of the field, and more extensive competitive funding of university research.
- Expanded industry-university cooperation in engineering education through visiting lectureships, internships, continuing education, and global engineering training.

ISSUES, FINDINGS, AND RECOMMENDATIONS FOR THE UNITED STATES

The United States has also developed an outstanding system of engineering education, which has been able to adapt to changing circumstances over the years. In particular, U.S. undergraduate and graduate engineering education attracts superior students from around the world, many of whom stay in the United States and contribute to the U.S. research and innovation enterprise.

The primary long-term challenge for the United States is to redouble efforts to improve the quality and consistency of K-12 education, particularly in mathematics and science. This has been a national focus for some years, and achieving significant progress will require substantial additional time and effort. In undertaking K-12 reforms, the United States should continue to learn from international models, including Japan. In particular, the United States has much to learn from Japan about the practice of teaching and teacher training.

The United States also needs to make special efforts to ensure that continuing education for working engineering professionals receives adequate investment. In Japan, lifetime employment at large companies creates incentives for industry to make these investments, while individuals must take greater responsibility in the United States.

Specific action items include:

- Expand efforts to learn and apply international educational best practices, such as Japanese approaches to the practice of K-12 teaching and teacher training.
- Through the National Science Foundation and other agencies and partnerships with industry, increase opportunities for U.S. engineering students and younger professionals to gain the skills and expertise needed to become effective “global engineers.”
- Renew public-private efforts to increase investments in continuing lifelong engineering education.

ISSUES, FINDINGS, AND RECOMMENDATIONS FOR BOTH COUNTRIES

The United States and Japan share several common challenges related to engineering education in the next century, such as attracting adequate numbers of young people to the field, particularly women and minority groups who are currently under represented. In a changing engineering environment characterized by intense industrial competition, rapid technological advance, and expanded international cooperation, both countries will be challenged to build on their strengths and address their weaknesses to build the right education and training systems for tomorrow's engineers. The systems must produce engineers that possess a firm grasp of fundamentals and sufficient creativity to meet unfamiliar tasks; incentives and resources to maintain and enhance their skills throughout their careers; and capabilities to operate effectively in a variety of international environments.

In the discussions of global engineering and the utilization of information technology in engineering education, the task force was only able to scratch the surface and identify issues that other groups will need to address more fully in the future. Domestic and international efforts to harmonize and rationalize educational regulatory frameworks, as well as accreditation and certification processes, will be needed so that engineering education can tap the possibilities opened by information technology advances and international cooperation. The Japanese and U.S. engineering communities, working through professional societies, government, industry, and academia, can make important contributions.

- Japan and the United States should maintain and increase their own engineering education exchanges, and lead international initiatives to improve engineering education exchanges and to develop global engineering capabilities.
- The U.S. and Japanese engineering communities should work with each other and with other countries and groups to achieve harmonized regulatory, accreditation, and certification systems that allow the timely diffusion of educational approaches utilizing information technology.

1

Introduction

This report is the product of a joint study by the Committee on Japan of the National Research Council and the Committee on High Technology and the International Environment (Committee 149) of the Japan Society for the Promotion of Science (JSPS). The project had its origins in a 1991 meeting between JSPS and the National Academies on growing U.S.-Japan interdependence in science and technology. The Joint Task Force on Engineering Education is one of three U.S.-Japan committees that were subsequently set up to explore aspects of the bilateral science and technology relationship.[1]

The U.S. and Japanese working groups interacted a number of times from the time the task forces were formed in early 1994 through 1996 (see Table 1), and exchanged draft materials. The report was completed in 1998. The work of the U.S. working group was supported by the United States-Japan Foundation and the National Academy of Engineering. The work of the Japanese working group, like other Committee 149 activities, was supported by member dues.

The members of both working groups were familiar with key aspects of both the U.S. and Japanese systems for engineering education at the outset. It took careful planning to develop an agenda of issues that would result in a rewarding, reciprocal exchange, due to the significant differences between the U.S. and Japanese systems. One of the most important differences involves the "phase shift" in where engineers in the two countries receive critical elements of their overall training. For example, the key features in the education of Japanese engineers are excellent K-12 preparatory work in mathematics and science, and the extensive on-the-job training and continuing education programs provided by large Japanese companies. In the United States, undergraduate and graduate training in universities plays a relatively more important role, while K-12 education is not as consistently thorough and in-house training by companies is generally less extensive.

In addition, it was noted that some topics of special interest to the Japanese working group were not particularly interesting to the U.S. working group, and vice versa. Furthermore, structuring a productive exchange was difficult even on issues of clear mutual interest, such as the need to attract talented young people to engineering careers, due to the breadth of those topics and the disparities between the two education systems.

In order to overcome these challenges, the joint task force adopted a "lifelong learning" approach to the issues of engineering education. Chapters 2–5 of the report deal with K-12 preparatory training of future engineers, university entrance, undergraduate and graduate education, and continuing education. In these chapters the joint task force compares the structures and functions of the U.S. and Japanese systems. Particular attention is paid to the expected competencies of engineers, the institutional mechanisms in the two countries that influence the definition and development of those competencies, and the public and private resource inputs along the continuum. Chapters 6 and 7 cover global engineering and the role of the Internet in engineering education, two issues of special interest that emerged during the study. Chapter 8 includes conclusions and recommendations, both recommendations by the respective working groups to their own countries, and joint recommendations to both countries.

The task force also recognized that examining all fields of engineering in the context of the approach described above would not be feasible. Instead the group used the knowledge and experience of the individual committee members as a basis for specific discussions in the report.

As a U.S.-Japan joint study, the project and resulting report have inevitably focused on U.S. and Japanese issues. The joint task force believes that many of the issues and challenges raised in the report are relevant to a wider international audience interested in improving engineering education and engineering cooperation worldwide. Hopefully, this report will provide a useful input to a broader discussion.

TABLE 1-1 Interactions of the Joint Task Force on Engineering Education

December 1992	Japanese working group holds planning meeting in Tokyo
May 1994	U.S. working group holds planning meeting, Washington, D.C.
June 1994	Joint task force meeting and U.S. working group study mission, Tokyo
November 1994	Joint task force meeting, Tokyo
July 1995	U.S. working group chair meets with Japanese working group, Tokyo
November 1995	Joint task force meeting in Washington, D.C.
January 1996	U.S. working group chair meets with Japanese working group, Tokyo
May 1998	U.S. working group chair meets with Japanese working group, Tokyo
July 1998	U.S. working group chair meets with Japanese working group, Tokyo
November 1998	U.S. working group chair meets with Japanese working group, Tokyo
Winter 1998	Report finalized

NOTES AND REFERENCES

[1] See National Research Council, *Global Economy, Global Technology, Global Corporations* (Washington, D.C.: National Academy Press, 1998), and *New Strategies for New Challenges: Corporate Innovation in Japan and the United States* (National Academy Press, 1998).

2

K-12 Education of Future Engineers

SUMMARY POINTS

- *There are large and persistent gaps in performance between the U.S. and Japanese K-12 education systems. Underlying these gaps are significant differences in the organization and funding of schools, the practice of teaching, and in some cases fundamental attitudes toward education and learning.*
- *Although current U.S. educational reform efforts appear to be making some headway, improving K-12 math and science education remains a serious long-term challenge. In conceiving and implementing reforms, the U.S. working group believes that there is a great deal that can be learned from Japan and implemented in the U.S. context.*
- *The U.S. working group believes that a particular focus for learning from Japan to improve U.S. science and math education should be on the practice of teaching, including approaches to teacher preparation, on-the-job training and mentoring of new teachers, and career-long enhancement of knowledge and skills. A focused U.S.-Japan exchange in this area could deliver benefits to both countries.*
- *The Japanese working group believes that developing new approaches to K-12 education that encourage students to consider and pursue engineering careers is the most serious challenge common to both Japan and the United States. For the United States, this involves ensuring that all students develop an understanding of the importance of technology and related careers in modern society. Recent efforts to make technology a subject of precollege study in addition to math and science should be pursued vigorously. Another U.S. goal is to encourage as many students as possible to retain an option to pursue engineering studies by continuing their study of math and science through grades 9–12.*

OVERVIEW

Most studies of engineering education naturally focus on undergraduate and graduate training because engineering as a specific, identifiable specialty commences at the undergraduate level. Ensuring that a sufficient number of adequately prepared students enter engineering schools is central to the long-term health of engineering education and to the larger scientific and technological enterprises of both the United States and Japan. Also, K-12 education has a profound effect on later engineering education needs and trends. U.S.-Japan differences in approach that appear at the K-12 level are linked with other features distinguishing the respective systems for training and utilizing engineers, and to the challenges for the future that each country faces.

Believing that a life-long learning approach would be the most valuable for a U.S.-Japan study, the joint task force includes this overview of K-12 education, with a focus on science, mathematics, and technology.[1] This overview includes a review of the general features of the two systems, as well as an examination of qualitative issues and challenges particularly relevant to engineering education.

GENERAL FEATURES OF K-12 EDUCATION IN JAPAN AND THE UNITED STATES

Organization, Control, and Funding

There are significant differences between Japan and the United States in the organization and control of K-12 education. The centralized, national administration of the Japanese system can be contrasted with the dispersed, local administration of the U.S. system. These differences are perceived to have significant implications for the nature of K-12 education, with the belief that Japanese strengths lie in standardization and attention to detail and corresponding U.S. advantages lie in diversity and promotion of creativity. Although there are significant differences in the general structures of Japanese and U.S. K-12 education, a closer examination shows that in some respects the conventional view is distorted and oversimplified.

Japanese K-12 education is rightly seen as very successful in fulfilling its basic mission. The Japanese population is one of the most highly educated of any country in the world. Illiteracy has been almost completely eliminated, and Japanese students consistently are among the top performers in comparative studies of academic achievement. The educational system that is responsible for these accomplishments is a post-World War II phenomenon. The drastic changes in the educational system began in 1947, when they were enunciated in the Fundamental Law of Education, a law that has guided the educational system since that time.

National curricula in Japan define what is expected of children at each grade level and textbooks are written to conform to these standards. The Ministry of Education, Science, Sports, and Culture (Monbusho) sets high standards for Japanese students, but not so high that the average student, with appropriate instruction and practice, is unable to meet them. It is assumed that standards should be set so that all children are able to understand the material if they study and if the teacher presents the information effectively. Japanese parents reinforce the effort to maintain high standards because they are aware of the competition their child faces in his or her attempts to gain entrance into a university. Because numerical grades are used in the evaluation of their child's knowledge, the parent is also aware of where their child stands in relation to these standards.

Monbusho also defines the organization of the schools and the course of study. Schools throughout Japan follow the same general schedule. Monbusho directives describe the general curriculum and individual schools are allowed to organize their curriculum in the way they wish, as long as they do not deviate from the general outline. Monbusho guidelines also specify the number of hours that should be devoted to each subject.

The organization and control of K-12 education in the United States contrasts sharply with that of Japan.[2] All children in the United States have access to a free public education, and most states require attendance until age sixteen.[3] Control of structure and curricula lies with local communities and state governments. The number of days students are expected to be enrolled each year and the number of courses required for graduation are determined at the state level, but school districts and individual schools, often working with local school boards and committees, determine the time that should be devoted to subject matter and extracurricular activities. Unlike Monbusho, the U.S. Department of Education has no role in determining curricula or standards. The U.S. federal government does have influence on pre K-12 education through its funding for supplemental programs such as Head Start aimed at equalizing educational opportunities nationwide, collection and dissemination of information about education, and in facilitating national dialogue and debate on education issues. [4]

Although both Japanese and U.S. public elementary and secondary schools rely heavily on decentralized funding support, the relative contribution by the national government is much higher in Japan (Figure 2-1 and Table 2-1). Inevitable differences exist between localities in the level at which they are willing or able to support public education. This factor, combined with the much greater heterogeneity of the U.S. population and school districts in terms of ethnicity, language and social conditions compared with Japan, results in a much wider variance between U.S. localities in the material conditions of K-12 education than is the case in Japan. Recent reforms at the state level in the United States, such as increased regulation of schools and new funding mechanisms to distribute resources more evenly, are aimed at lowering this variance.

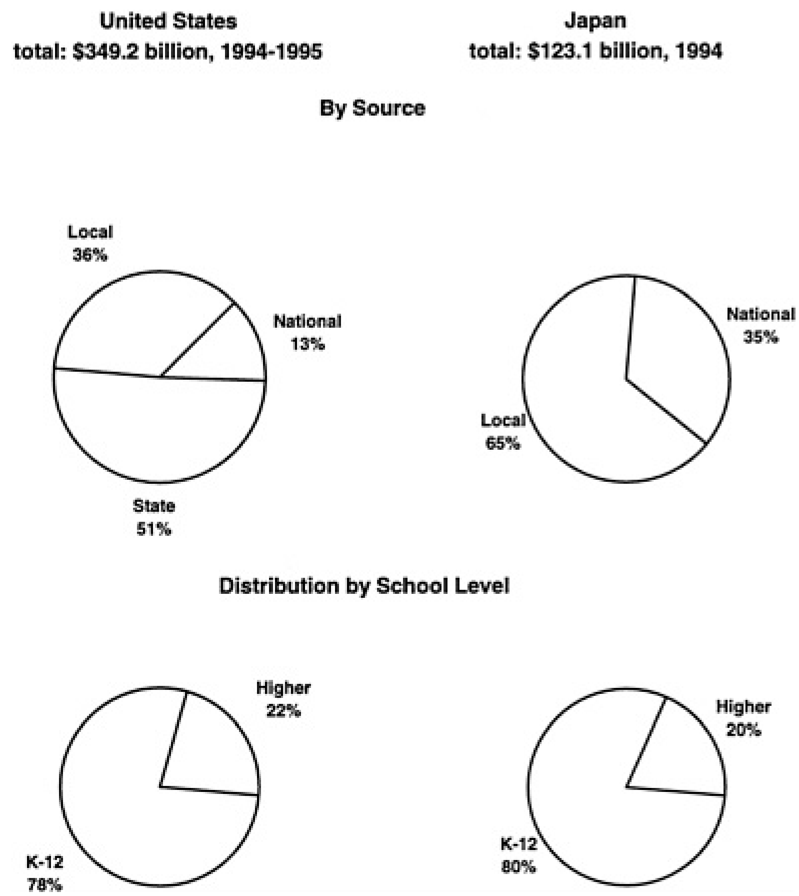

Figure 2-1 U.S. and Japanese public expenditures on education. NOTE: Exchange rates from International Monetary Fund; ¥144.79 per dollar. SOURCES: U.S. National Center for Education Statistics and Japan Ministry of Education, Science, and Culture.

U.S.-Japan differences extend to private education. Private schools tend to play a larger role in U.S. elementary education (grade and middle school) and a smaller role in secondary education (high school) compared with Japan (Table 2-2). U.S. private schools, many of which have religious affiliations, serve as an alternative to the public school system. In Japan, private high schools are often affiliated with universities, and are subject to the same national curricula and other guidelines as public schools.

TABLE 2-1 Public Education Expenditures Per Student, 1993

	Primary	Secondary
United States	$5,492	$6,541
Japan	3,960	4,356

NOTE: Constant 1993 purchasing power parity dollars. Includes public expenditure per student in public and private institutions. SOURCE: Organization for Economic Cooperation and Development, *Education at a Glance,* 1996.

TABLE 2-2 K-12 Enrollment by Grade Level and Type of School, percentage

Japan (1994)					*United States (1994)*	
	Kindergarten	Elementary	Lower Secondary (7–9)	Upper Secondary (10–12)	Pre K-8	9–12
National	0.4	0.6	0.8	0.2		
Local Public	27.1	98.5	94.1	69.2	88.0	91.0
Private	72.5	0.9	5.1	30.6	12.0	9.0

NOTE: The Japanese government provides support to schools in all categories. SOURCES: U.S. Department of Education, National Center for Education Statistics and Japan Ministry of Education, Science, and Culture, Research and Statistics Planning Division.

It is possible to make too much of these basic U.S.-Japan differences. For example, a popular image of Japan's centrally planned curriculum is that all fifth graders throughout the country learn the same lesson at the same time with the same textbook. This is not the case, for the individual school is responsible for defining its own schedule and is likely to alter the schedule from week to week.

Moreover, Monbusho guidelines are very general. For example, the description of the general objectives of sixth grade mathematics describes goals such as, “To help pupils understand the meaning of multiplication and division of fractions and develop their abilities to use them. Furthermore, to help them deepen their understanding of numbers as a totality including integers, decimals, and fractions.”[5] The whole mathematics curriculum for the elementary school years requires only 18 pages in its English translation. Although Monbusho approves textbooks, selection is controlled at the local level. Further, in the United States the national reach of textbook publishers contributes to widespread utilization of popular textbooks, a phenomenon that has a significant impact on what is taught. In short, the Japanese K-12 system may allow for more local variance and the U.S. system greater national coherence than popular images imply.[6]

Still, the different orientations of U.S. and Japanese K-12 education have important implications for science and mathematics education. In Japan, it is a given that certain prerequisite courses will be taken and that core topics will be covered. In the United States, the situation is less fixed and more chaotic. For U.S. students, taking the content of the requisite coursework necessary to enter engineering school may depend on the interest and orientation of parents, teachers and counselors. U.S. students may possess less information about career options and requirements in science and engineering compared with Japanese students, who get this information through their required courses.[7]

U.S.-Japan differences have important implications for education reform efforts as well. The publication of the seminal report *A Nation At Risk* in 1983 by the National Commission on Excellence in Education sparked increased focus on the shortcomings of U.S. elementary and secondary education. A number of reform initiatives and activities have been undertaken at the national, state and local levels, including efforts to raise standards and improve teacher training.[8] One aspect of education reform efforts in the United States is the participation of the private sector, including business involvement in adopt-a-school and other cooperative programs. The private sector is also playing a major role in developing national education standards in major subjects, including science and mathematics, although the federal government plays an important role in supporting these efforts.[9]

Learning.

Japanese educators place great importance on the belief that all children should be able to follow the regular school curriculum unless they have serious disabilities, such as blindness, deafness, or severe mental retardation or emotional disturbance. As a result, all children are automatically promoted from one grade level to the next; retaining a child in a grade for a second year is a very rare phenomenon.

Because the style of teaching in Japanese classrooms involves whole-class instruction and because there are no special classes for slow learners or fast learners, the Japanese teacher is faced with the task of constructing lessons that can be understood by the greatest number of students.

Other aspects of education in Japan serve to socialize students to work well in groups. Elementary school children serve lunch to their classmates and they all eat together with their teacher in their home room. Assisted by their teacher, children are also responsible for daily cleaning of the school. These activities as well as some academic activities are undertaken through the *han,* the subgroups into which each class is divided. Assignment to a *han* is done purposefully so that each *han* represents a wide range not only of achievement but also of other characteristics of the children in the classroom. Benefits from participating in the *han* are not only social but also academic, for slow learners undoubtedly derive important benefits from being exposed to the knowledge and skills of more rapid learners. Similarly, rapid learners are assumed to strengthen their understanding by being placed in the position of helping the slow learners. Students have an opportunity to experience both roles, since the *han* will include individuals with complementary strengths and weaknesses.

Extracurricular activities also constitute an important part of learning in Japan. After fourth grade, all children must participate in at least one extracurricular activity. Opportunities for social interaction during the recesses, lunch period, and extracurricular activities, and the fact that the children and their teacher typically remain together as a group for two or three years produce a strong group identification.

Strong efforts are made during the elementary and middle school years to create an egalitarian structure in schools whereby all children are exposed to a comparable type of schooling. High school education is, in contrast, hierarchically organized, so that the type of schooling differs, depending upon the type and quality of school in which the student is enrolled. The high school to which a student is admitted depends on the student's score on an admissions test administered by each prefecture or city. In contrast to the elementary and middle schools, which serve neighborhoods, a single high school serves students from throughout the city or metropolitan area.

Students who seek admission to the arts (humanities or social sciences) departments of universities follow a somewhat different set of courses from that of students who seek entry into science and engineering departments. There is greater emphasis for the former group on the Japanese language and social studies, and greater emphasis for the latter group on mathematics and science.[10] Other than being enrolled in high schools that place very different demands on the student in terms of academic achievement, little else is done to accommodate the differences in rate of learning among students. All students must follow the standard curriculum, but there are opportunities to enroll in elective courses. Highly capable students in mathematics may, therefore, complete the prescribed curriculum in one semester and then spend the second semester in a more advanced course in mathematics.

Efforts have been made in Japanese schools to recognize and accommodate divergent student interests and abilities. Especially during the 1970s, many local schools developed tracking systems in which students were placed in a slow, average, or fast class depending upon the students' previous performance in that subject. The system did not imply long term assignment to a particular track; if a slower student's work improved, he or she would move up to a higher level. By the early 1980s, about 40 percent of high schools practiced some degree of tracking according to level of ability. However, it seems never to have gained popular acceptance outside the urban areas of Tokyo and Osaka. The major objection was that it appeared to be a return to an “elite” form of education that characterized Japanese education earlier in this century.

Despite the remarkable success of Japan's K-12 educational system, Japanese conversations about education often lead to expression of various types of dissatisfaction. Even Monbusho suggests that “elementary and secondary education of Japan is faced with several problems, such as excessive uniformity, excessive competition to pass the entrance examination into upper level institutions, and the problem of maladjustment to school.”[11] More recently the newspapers of Japan are full of articles expressing great concern about bullying (*ijime*) and student suicides that have been linked to *ijime*.

The concern about uniformity is expressed in charges that teachers' modes of instruction and students' approaches to learning do not lead to creative, thoughtful individuals who are able to express their own opinions. A Monbusho publication suggests that “individual characteristics of each pupil ought to be developed, his/her creativity explored, and school education must be sufficiently diversified and flexible.”[12] Japanese students are pictured as being weaker in understanding a subject than in remembering facts; in being less able to think mathematically or scientifically than in recalling the content of lessons or chapters in their textbooks.

These descriptions of Japanese students—and of East Asian students in general—are based on opinions rather than upon objective research. In fact, in one recent study, fifth graders were asked to solve mathematics problems requiring the creation of word problems, explanation of mathematical operations, solution of problems involving estimation, or comprehension of number concepts and operations.[13] Japanese students were among the top performers on all of the problems. Similarly, observational studies of Japanese classrooms reveal teachers who present interesting lessons in remarkably well organized ways. Far from emphasizing rote learning and drill, the lessons encourage a conceptual, problem-solving approach to learning. The observations were made in mathematics classes, but they also characterize the teaching that occurs in other elementary school subjects.[14]

At the same time, it is important to note that Japanese elementary education has its own problems and challenges. For example, TIMSS data ranked the United States 11th and Japan

33rd in emphasis on the use of science in the real world. Monbusho has made curriculum changes to promote more active involvement of students in examining science and its role in community issues.[15]

Japanese parents and educators worry that the procedures for entrance to college place too much stress on high school students and deprive them of experiences that are appropriate for their level of development. [16] Thus far, the most common response to this problem has been the adoption of the recommendation method for gaining entrance to colleges and universities.[17]

More recently there has been a great deal of interest in *kosei kyoiku,* which is often translated as "individualized education." It is an attempt to encourage high schools to make their curricula more flexible so that the schools can do a better job of meeting the individual interests, abilities, and needs of the students. What is meant by *kosei kyoiku* remains vague and educators are unclear about what individualized education would encompass. Discussions of *kosei kyoiku* are important, however, for they signal an awareness among Japanese educators of a need for greater flexibility in the structure of education in Japan. This movement is supplemented by a recent interest in life-long learning, whereby education is considered to be a process continuing throughout life, rather than terminating upon graduation from high school or college.

Due to the stronger local orientation of U.S. education, there are no national guidelines "for grouping students, or for determining the level of instruction or kind of course work in which students should be enrolled."[18] Generally, there is no segregation of students into different schools by ability level, although the popularity of magnet and other specialty schools has increased in recent years. U.S. schools appear to be much more inclined than Japanese schools to group students by ability within schools and to utilize other related practices such as retention of a child in a grade and organizing special programs for gifted and talented students. In elementary schools, ability grouping is more likely to be within the same class, especially in reading, while junior and senior high schools use other approaches. In senior high school, where Japanese students tend to be grouped according to their school, U.S. students are likely to be grouped within a school according to tracks or separate programs of instruction (such as general course and college preparation). Some U.S. ability grouping approaches are designed to minimize social class distinctions.

The widespread use of ability grouping in the United States reflects a common belief that student abilities are relatively fixed, and that students learn best when grouped with students of similar abilities. [19] The belief that exceptional learners should be allowed to proceed at an accelerated pace and that contact with brighter peers might be a detriment to less capable students contrasts sharply with the Japanese beliefs and practices outlined above. Research into the actual impacts of ability grouping on enhancing or hindering student performance are inconclusive.[20] Despite the common utilization of ability grouping in the United States, the high percentage of students from lower ability groups who go on to community and four-year colleges illustrates a significant degree of overall flexibility in the U.S. system.

The role of school in the lives of young people also appears to be quite different in the two countries. American elementary and secondary students generally spend less time in school than students in other countries, including Japan, and much of the time spent in school is not spent in class.[21] U.S. high school students also spend much more time socializing with peers and in paid employment than they do studying outside of class.

Extracurricular activities also play a role in student life in the two countries. *Kurabu* and *bu* (clubs or circles), for example, two types of extracurricular activities, amplify opportunities for learning in Japan.[22] Participation in *kurabu* is required of all elementary school students in grades four to six and of all middle school and high school students. Participation in *bu* is generally optional.

Kurabu serve many purposes. The overall goals are to foster

students' creativity, cooperative behavior, and self-direction. From

kurabu activities students are expected to acquire attitudes of being self-directed and spontaneous, to interact more easily with adults including their teacher, to cultivate interest in subject matters other than those taught in regular classes, and to integrate intellectual, moral, and physical aspects of development. The most common types of *kurabu* are calligraphy, photography, music, sports, art, tea ceremony, Japanese chess, handicrafts, and flower arranging. Other less popular, but important topics for potential engineers and scientists are *kurabu* that allow students to conduct experiments in various areas of science. Extracurricular activities play an important role in counterbalancing the more rigid national curricula. Most extracurricular activities deal with topics not included in the national curricula.[23]

Extracurricular activities are important for American students, as they are for Japanese students, although there are differences in the role that they play. In contrast to the requirement in Japan that fifth grade students participate in at least one activity, participation in extracurricular activities in the United States is not widespread until junior high school.[24] For U.S. students of junior high school age, there appears to be a wide variation in the opportunities available according to where they live.[25] Overall, sports appear to be the most common extracurricular activities for junior and senior high school students, with participation rates of over fifty percent.

Although U.S. schools do not teach teamwork as explicitly as Japanese schools, participation in sports is a mechanism for teaching students to work together. An important trend in recent years is the growing involvement in athletics by young women in the United States. This may have future implications for greater utilization of women in various aspects of American life, including engineering.

Teaching

Two steps are required in order to become a qualified teacher in Japan. The candidate must first enroll in an institution of higher education accredited by Monbusho and must take the necessary courses for teacher certification. Meeting this requirement provides eligibility for taking the qualifying test administered by each prefecture or city.[26] The test includes an evaluation of the candidate's knowledge, a test for suitability as a teacher, essay tests, interviews, tests of practical skills, and a health examination. Those who pass these requirements are qualified to teach in that prefecture. However, this does not necessarily mean that a position will be available for each qualified candidate. In fact, among college graduates in 1996 who received teachers' certificates, only 7 percent were actually hired as teachers. This is roughly the same percentage that has existed for the past several years.

It is not assumed that graduation from a university and the brief period of practice teaching during the undergraduate years provide adequate training for teachers. Rather, teaching is believed to be a matter of continuous learning, characterized by teachers sharing information and techniques with their colleagues and by participating in workshops and seminars in subject areas and in teaching techniques conducted by experts.

New teachers are assigned a light teaching load during the first year of teaching so they can benefit from attendance at teacher training programs held outside the school and from the mentoring by a skilled teacher assigned to them within the school. Thus, even though the new teacher may lack knowledge in certain aspects of science or mathematics, efforts are made to enhance the teacher's ability to meet the requirements for being a good teacher. This model is much like that of other professions, such as medicine or law, where a good deal of the practical information necessary for the professional occurs in the professional setting of the hospital or court, rather than in classrooms in schools of medicine or law.

In their emphasis on continued investments in teacher training, Japanese schools are similar to corporations and other Japanese organizations. Another familiar feature of Japanese management also found in education is regular job rotation. It is unusual for teachers or administrators to spend more than four or five years at any one public school, and teachers often move with their pupils to the next grade, sometimes for two years and sometimes for three. Administrators are taken from the ranks of teachers. Although class size is generally much higher in Japan than in the United States, Japanese teachers have much more time than their U.S.

colleagues to spend on planning, course development and professional development.[27] Further, the ratio of teachers to non-teaching staff in Japan is much higher than in the United States.[28]

As indicated by the relatively low placement rate for certified teachers, teaching is a high status occupation in Japan. It is difficult to determine average levels of compensation, for the regular salary is supplemented in many different ways, depending upon the status and needs of the individual. All teachers receive a 12-month salary and two additional bonuses which total about five months' salary. Further, allowances are made if the teacher must serve in a remote area, if the teacher provides special services, if the teacher is involved in vocational training, and if the teacher meets numerous other qualifications. Medical insurance, a retirement plan, low interest loans, and investment of savings are provided by the school system. These liberal financial rewards account in part for a high level of the individuals who are attracted to the teaching profession.

The status of teachers is enhanced by the prestige and respect that are accorded to teachers in Japan. Japanese parents consider education to be the major means of access to a good life, and thereby entrust their children's futures to their teachers. As a result of this important role in Japanese society, the term *sensei* carries with it a strong sense of admiration and esteem. This role is granted, not only because of the importance placed on being a teacher, but also because Japanese teachers are known for their hard work and ability, devotion to children, and their concern for doing a good job.

In the United States, standards and requirements for the preparation of teachers vary by state and school district, with no national consensus on the knowledge or skills necessary for teaching.[29] Schools of education play an important role in preparing U.S. teachers. These evolved from the “normal schools” which originated in the mid-1800s to train prospective teachers at public elementary schools, who at that time were predominantly female and generally entered training having completed elementary school. Normal schools evolved into teachers' colleges and state colleges early in this century and many have since attained university status.[30] At the same time that normal schools were developing, universities began establishing departments of education, aimed at training high school teachers and school administrators.

The nearly 1,300 teacher education programs that exist today in the United States are highly diverse in terms of size, targeted student base, and other factors. A common route to teaching is the baccalaureate in education, in which two years of a general liberal arts curriculum are followed by a specialized education program of course work and student teaching. There are also extended programs, many offering masters degrees, which allow students to pursue majors in non-education fields. Most states have also adopted alternative certification programs, which provide on-the-job training and supplemental classes to college graduates in order to expand the number of potential teachers.

Although one thrust of the education reform movement beginning in the 1980s has been to promote the professionalization of teaching through the expansion of graduate teacher training programs, the undergraduate education degree remains the most common route to entering the profession. A high proportion of secondary school math and science teachers did not major in their teaching specialties.[31] It appears, however, that efforts to raise the standards for entering undergraduate education programs, through establishing minimum grade point averages and other requirements, have made some headway. The gap in SAT (Scholastic Aptitude Test) scores between education majors and the national average narrowed significantly during the 1980s.[32]

Certification requirements and procedures also vary by state. Although the standard method of teacher certification had been through school accreditation—graduates of programs accredited by the state were automatically certified—there has been a growing movement in recent years toward increased use of competency testing, including testing for certification at the state level.

A number of education researchers and others have pointed out that isolation of teachers in the classroom is one of the prominent aspects of teaching in the United States. This is due to the large number of hours that U.S. teachers are required to teach and the general lack of opportunities for informal collegiality and mentoring.[33] Particularly when compared with the

Japanese system, where support for the professionalization of teaching appears to be central to the management of K-12 education, it is clear that the United States faces special challenges in creating teaching and educational environments that adequately prepare students both for the initial stages of engineering training and for active and productive participation as citizens in a society where technology increasingly impacts on everyday life.

Despite an increased focus in recent years on improving standards and training for teachers, the adequacy of teacher preparation and skills is still a serious issue in the United States. This is particularly true in fields that have experienced shortages of teachers, math and science among them.[34]

ISSUES AND CHALLENGES RELATED TO ENGINEERING EDUCATION

In this section, we will review some of the prominent issues and challenges facing K-12 education in both the United States and Japan, with emphasis on their implications for engineering education more broadly.

Overall Performance of the K-12 System in Mathematics and Science

Overall performance, or the effectiveness of the educational system in helping students develop the skills and capabilities necessary for educational and career advancement, has been a major concern of the United States for more than a decade. Standardized tests taken by students have been used to measure performance, but have a number of drawbacks, particularly in cases where the utilization of test results for policy decisions encourages a focus on rote memorization, or where the establishment of minimum standards ensures that more students reach the standard but fewer go beyond it. However, activities such as the National Assessment of Educational Progress (NAEP), which has many items that go beyond multiple choice and short answer exams, and international comparative studies do provide measurements of student achievement that serve as rough gauges to assess overall performance and allow for the tracking of trends over time. Over the years, international comparative studies have documented the poor performance of the U.S. K-12 education system relative to other nations with similar economic development levels in mathematics and science education, and have also highlighted the superior performance of Japan (Figure 2-2).[35]

NAEP results over time are shown in Tables 2-3 and 2-4. Tables 2-5 and 2-6 indicate that more U.S. students are persisting in math and science through their high school years. Still, a continuation of the general pattern in which a large percentage of U.S. students only achieves basic math and science skills, and where the achievement of top U.S. students matches only the average level of students in Japan and other high achieving countries has clear negative implications for the future ability of the United States to maintain its leadership in research and high technology.[36]

Some of the performance gap is probably connected with how math and science are taught in the United States and elsewhere. In Japan, the mathematics curriculum continues a linear approach throughout all years of school; that is, a new topic is not introduced until the prior topic has been mastered. This is in contrast with a spiral curriculum generally used in the United States, where topics are revisited year after year, presumably at a higher level of development. During the 1960s and 1970s, significant resources were devoted to developing new curricula in the United States, with the “new math” being particularly prominent. These efforts were followed by severe drops in student performance as measured by standardized tests. Although other factors and trends were also implicated in this drop, curriculum reform efforts did lose some credibility, and lessons from this experience are being incorporated into ongoing efforts to

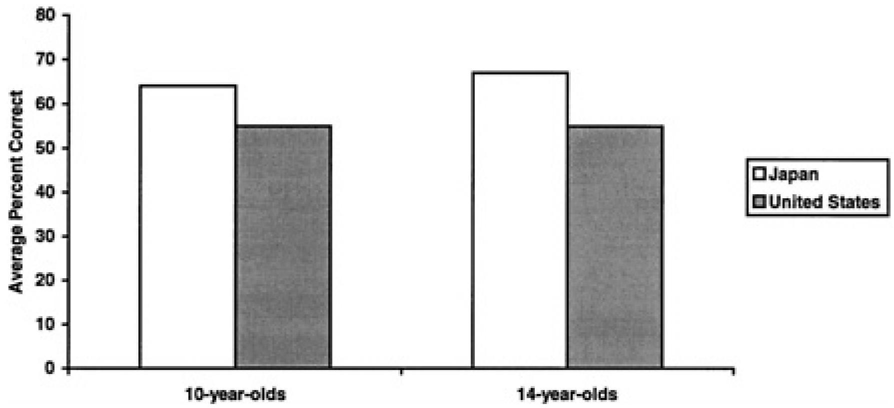

Figure 2-2 Average percent correct on TIMSS science general knowledge achievement, 1994–1995. NOTE: The final year of secondary school comparison is not made since there are no Japan data posted in TIMSS for this level of students. SOURCE: Third International Mathematics and Science Study.

TABLE 2-3 Trends in Average Mathematics Proficiency, U.S. Students

	9-year-olds	13-year-olds	17-year-olds
1973	219	266	304
1978	219	264	300
1982	219	269	299
1986	222	269	302
1990	230	270	305
1992	230	273	307
1994	231	274	306
1996	231	274	307

NOTE: These test scores, ranging from 0 to 500, are from the National Assessment of Educational Progress. The breakdown of scores and level of performance are:

150-knowledge of basic addition and subtraction.

200-understanding of two-digit numbers and knowledge of basic multiplication and division facts.

250-initial understanding of the four basic operations and ability to compare information from graphs and charts.

300-ability to compute decimals, simple fractions, and percents; knowledge of geometric figures; and development of skills to operate with signed numbers, exponents, and square roots.

350-ability to apply a range of reasoning skills to solve multistep problems and solve routine problems involving fractions and percents; recognition of properties of basic geometric figures; and ability to work with exponents and square roots.

SOURCE: U.S. Department of Education, National Center for Education Statistics.

TABLE 2-4 Percentage of U.S. Students At or Above Selected Science Proficiency Levels

	9-Year-Olds				*13-Year-Olds*				*17-Year-Olds*			
	Knows every day science facts	Understands simple scientific principles	Applies general scientific information	Analyzes scientific procedures and data	Understands simple scientific principles	Applies general scientific information	Analyzes scientific procedures and data	Integrates specialized scientific information	Understands simple scientific principles	Applies general scientific information	Analyzes scientific procedures and data	Integrates specialized scientific information
1977	93.5	68.0	25.7	3.2	86.0	48.8	11.1	0.7	97.1	81.6	41.7	8.5
1982	95.2	70.7	24.3	2.3	89.8	50.9	9.6	0.4	95.7	76.6	37.3	7.1
1986	96.2	72.0	27.5	3.0	91.6	52.5	9.1	0.2	97.1	80.7	41.3	7.9
1990	97.0	76.4	31.1	3.1	92.3	56.5	11.2	0.4	96.7	81.2	43.3	9.2
1992	97.4	78.0	32.8	3.4	93.1	61.3	12.0	0.2	97.8	83.3	46.6	10.1
1994	97.2	77.4	33.7	3.8	92.4	59.5	11.8	0.2	97.1	83.1	47.5	10.0
1996	96.8	76.0	32.4	4.4	92.2	57.7	12.3	0.4	97.8	83.6	48.5	10.8

SOURCE: U.S. Department of Education, National Center for Education Statistics.

improve K-12 math and science education.[37] Rather than a centralized, top-down approach, many current U.S. education efforts focus on collaboration between various national private sector organizations and local educators and officials.[38]

There is some cause to be optimistic about the prospects for U.S. education reform efforts, since there appears to be widespread recognition of the problem and long-term focus on problem-solving.[39] However, some education researchers believe that a number of the factors underlying the international gaps in student achievement between the United States and other countries are closely linked to attitudes and beliefs among the American public at large, implying that more fundamental changes will be necessary.[40]

TABLE 2-5 Percentage of U.S. High School Graduates Taking Selected Mathematics and Science Courses in High School

	1982	1987	1990	1994
Algebra	53.9	64.0	64.2	66.4
Geometry	45.5	59.7	63.4	70.4
Calculus	4.6	6.0	6.5	9.2
Biology	76.4	87.8	91.3	93.5
Chemistry	30.9	43.7	49.0	56.0
Physics	14.2	19.2	21.5	24.4
Earth Sciences	13.2	14.5	24.8	23.0

SOURCE: U.S. Department of Education, National Center for Education Statistics.

TABLE 2-6 Percentage of U.S. High School Graduates Earning Minimum Credits in Selected Combinations of Academic Courses

	1982	1987	1990	1994
4 English/3 social science/3 science/3 math/0.5 computer science/2 foreign language	2.0	12.1	18.3	25.3
4 English/3 social science/3 science/3 math/0.5 computer science	2.9	16.6	23.3	32.0
4 English/3 social science/3 science/3 math/2 foreign language	9.2	20.6	30.3	39.1
4 English/3 social science/3 science/3 math	14.0	27.9	38.8	49.8
4 English/3 social science/2 science/2 math	31.5	54.0	66.5	74.6

SOURCE: U.S. Department of Education, National Center for Education Statistics.

Developing New Approaches to Improved Performance

What positive impact can this U.S.-Japan joint task force study have on addressing the serious challenges that will continue to face U.S. math and science education? Although this study is concerned with engineering education in a broad sense, the U.S. working group believes that Japanese practices and experiences are quite relevant to current U.S. conditions, and that there is greater scope for learning from Japan to improve U.S. K-12 education in math and science than is commonly believed. The U.S. working group believes that several points are worth emphasizing.

First, in the area of basic orientation and philosophy, the Japanese experience shows that U.S. beliefs about education put too much weight on the innate ability of students in determining the area of study. As other groups have pointed out, a fundamental reorientation of the U.S. approach to math and science education is required—one that results in the majority of students acquiring what are currently considered "advanced" skills.

Second, as current U.S. education reform efforts illustrate, significant change in a system as large and basic to society as education can be undertaken only through long-term broadly based efforts. In the area of learning from Japan, however, the U.S. working group believes that particular focus should be placed on the preparation of teachers and the practice of teaching, an area in which Japan excels and where improvements in the United States could have a major impact. A U.S.-Japan exchange on the practice of science and mathematics teaching, focused on exploring new approaches to the initial preparation of teachers, on-the-job training and mentoring of beginning teachers, and career-long enhancement of knowledge and skills, could help leverage and inform ongoing efforts in both countries.

Promoting Interest in Engineering and Technical Careers

Concerns have been raised in both Japan and the United States over whether primary and secondary education adequately encourages students to enter careers in science and engineering. Japan's attention to this question has been more focused in recent years.[41] Japanese observers have pointed to several trends, including a drop-off in the number of student applicants to enroll in engineering faculties in recent years, survey data which shows that young adults in their twenties may be less interested in scientific and technological issues and a decrease in the number of Japanese engineering graduates finding employment in manufacturing industries. Combined with larger social and demographic trends that are frequently the subject of discussion in Japan, such as the aging of the population and the low birthrate, indications that younger people might be losing interest in science and technology appear to have fed concerns about whether Japan's scientific and engineering human resources will be adequate to sustain the nation's status as a leader in research and high technology. Figures 2-3 and 2-4 show K-12 enrollment trends in the United States and Japan.

The Japanese working group believes that the issue of younger people losing interest in science and technology is undoubtedly the most serious problem common to both the United States and Japan. Another issue of concern for both countries is attracting female students to engineering.

"Technology in Education" and "Education About Technology"

Another important issue in K-12 education for future engineers is teaching about and applying advances in technology. This encompasses two aspects. The first is the use of technology as an aid for teaching and learning. The second aspect is engineering and technology as subjects of K-12 education.

In recent years, a number of advanced technologies, particularly personal computers, have become widely available in U.S. and Japanese schools. Although the diffusion of computers in

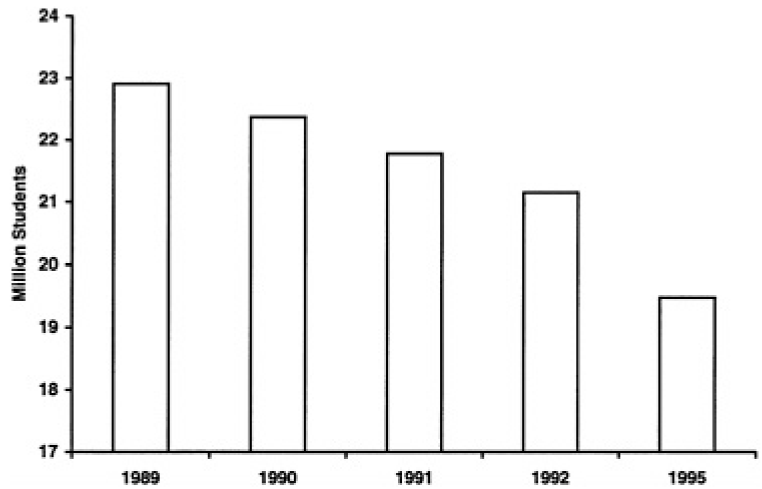

FIGURE 2-3 Total K-12 enrollment in Japan. SOURCE: Japan Ministry of Education, Science and Culture.

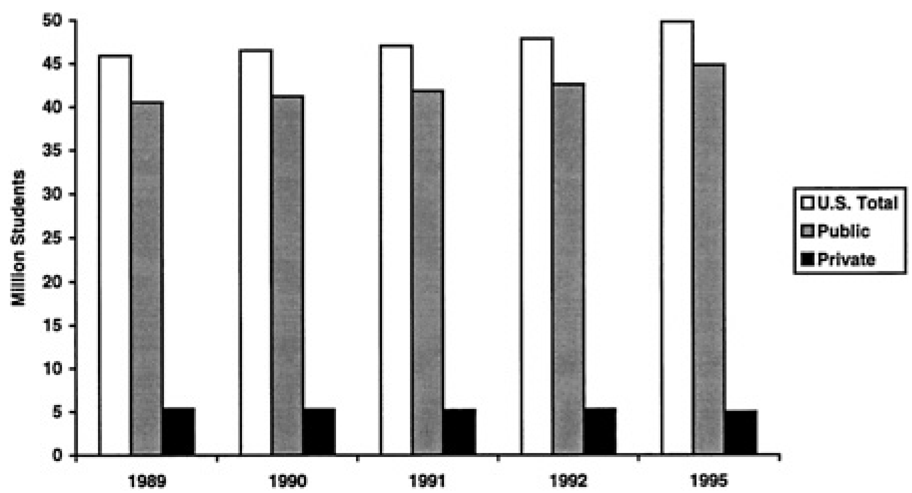

FIGURE 2-4 K-12 enrollment in the United States. SOURCE: U.S. Department of Education, National Center for Education Statistics.

schools occurred sooner in the United States, Japan is currently making large investments. According to a recent annual survey conducted by Monbusho, as of March 1994, for example, 66 percent of Japanese elementary schools, 98 percent of junior high schools and 100 percent of high schools were equipped with computers.[42] Monbusho reportedly planned to spend $2.6 billion on installing more computers in elementary and junior high schools over the 1994–2000 period.[43] Although members of the U.S. working group observed computers being used in science class demonstrations during a visit to a Japanese high school in June 1994, it appears that the main goal of large Japanese investments in this area is to raise computer and keyboard literacy among young people by making computers available for use outside of class, rather than aggressive integration of advanced technologies into actual classroom instruction.

In the United States, there is growing interest in how new technologies can be utilized to full advantage in K-12 education.[44] Although this issue is not a particular focus of the joint task force study, how new technologies are applied in the classroom will undoubtedly have an important impact on K-12 education for future engineers. [45] Information technology could also be utilized to improve U.S.-Japan interaction and learning among students and educators.

Technology as a subject of learning in K-12 education is more central to the concerns of the joint task force, even though a detailed examination of this fast-moving subject was not possible to undertake.[46] In both countries technology is rarely mentioned in K-12 curricula, and when it does appear it is as an incidental part of science education. In both the United States and Japan, there is increasing interest in technology education. For example, U.S. science education standards feature technology content.[47] As part of efforts to increase interest among Japanese young people in pursuing scientific and engineering careers, Japanese universities and research institutions are developing a number of new programs in collaboration with primary and secondary schools to increase student exposure to science and technology. This is an issue where continued U.S.-Japan dialogue and exchange can have a positive influence on the individual efforts of the two countries.

NOTES AND REFERENCES

[1] Harold W. Stevenson and James W. Stigler, *The Learning Gap* (New York: Touchstone, 1992) provides the basic background. The Third International Mathematics and Science Study (TIMSS), which was recently completed, involved collection of data on half a million students from 41 countries, and is the largest, most comprehensive, and most rigorous international study of schools and students ever. The National Center for Education Statistics website is a useful starting point for finding out about TIMSS (http://nces.ed.gov/TIMSS/).

[2] Roberta Nerison-Low, "The Educational Structure of the U.S. School System," in U.S. Department of Education, *The Educational System of the United States: Case Study Findings* (Washington, D.C.: U.S. Government Printing Office, forthcoming).

[3] Japan requires attendance until age fifteen.

[4] Nerison-Low, op. cit.

[5] Monbusho, *Development of Education in Japan.* (Tokyo: Monbusho, 1992).

[6] Efforts to develop national education standards in the United States are described below.

[7] Japanese working group members believe that Japanese high school students have sufficient information, but their primary focus in using this information is on the university entrance examinations, covered in Chapter 3.

[8] Nerison-Low, op. cit.

[9] National Research Council, *National Science Education Standards* (Washington, D.C.: National Academy Press, 1996).

[10] In theory, it is possible for Japanese students pursuing an arts curriculum to decide late in their high school careers to gain admittance to an engineering school, but in practice this occurs very rarely due to the difficulty of the university entrance examination.
[11] Ministry of Education, Science and Culture, *Government Policies in Education, Science and Culture* (Tokyo: Ministry of Finance Printing Bureau, 1989), p. 25.
[12] Ibid., p. 26.
[13] James W. Stigler, S.Y. Lee and Harold W. Stevenson, *Mathematical Knowledge of Japanese, Chinese and American Children* (Reston, Va.: National Council of Teachers of Mathematics, 1990).
[14] S.Y. Lee, T.A. Graham and Harold W. Stevenson, "Teachers and Teaching: Elementary Schools in Japan and the United States" in Thomas Rohlen and G. LeTendre, eds., *Teaching and Learning in Japan* (New York: Cambridge University Press, forthcoming).
[15] Japan Ministry of Education, Science and Culture, *Japanese Government Policies in Education, Science and Culture 1994,* (Tokyo: Printing Bureau, Ministry of Finance, 1995).
[16] Hidetaka Shimizu, "Individual Differences and the Japanese Education System," in U.S. Department of Education, *The Educational System in Japan: Case Study Findings* (Washington, D.C.: U.S. Government Printing Office, 1998).
[17] A more detailed examination of issues related to university entrance is given in Chapter 3.
[18] Heidi Schweingruber, "The Perception of Ability Differences in U.S. Education," in U.S. Department of Education, *The Educational System of the United States: Case Study Findings* (Washington, D.C.: U.S. Government Printing Office, forthcoming).
[19] Schweingruber, op. cit.
[20] Ibid.
[21] Andrew Fuligni, "Secondary Education in the Life of American Adolescents," unpublished manuscript.
[22] A discussion of *juku, yobiko* and other education outside of school is included in Chapter 3.
[23] A more detailed discussion of the utilization of technology in schools appears later in this chapter.
[24] In addition, participation by U.S. students in organized activities not related to school, such as scouting and youth sports, is fairly common.
[25] Fuligni, op. cit.
[26] This requirement is only for public school and does not apply to private schools.
[27] It is estimated that Japanese teachers spend about 40 percent of their time at school in non-instructional pursuits.
[28] For 1991, the Japanese ratio was calculated as 2.19, while the U.S. ratio for 1990 was 1.22. Considering the larger class sizes in Japan, this seemingly small administrative overhead is even more impressive.
[29] Barbara K. Hofer, "Teachers' Training and Teachers' Lives in the United States," in U.S. Department of Education, *The Educational System of the United States: Case Study Findings* (Washington, D.C.: U.S. Government Printing Office, forthcoming).
[30] Ibid.
[31] As of 1993, 41 percent of U.S. mathematics teachers in grades 9–12 nationwide had majored in mathematics or science, while 63 percent of science teachers in the same grade levels had majored in science or mathematics. See National Science Board, *Science and Engineering Indicators, 1998* (Washington, D.C.: U.S. Government Printing Office, 1998), p. 1–24.
[32] Hofer, op. cit.
[33] Ibid.
[34] A 1989 report estimated that over half of the 200,000 secondary school teachers of mathematics in the United States did not meet current professional standards for teaching mathematics, and that only 10 percent of elementary school teachers met contemporary standards for teaching mathematics. See National Research Council, *Everybody Counts: A Report to the Nation on the Future of Mathematics Education* (Washington, D.C.: National Academy Press, 1989), p. 28.
[35] See TIMSS web site, op. cit.

[36] Leaders of U.S. industry, academia, and government cited K-12 education as the most serious problem affecting U.S. competitiveness, (MIT Forum on Competitiveness, 1997).
[37] National Research Council, *Everybody Counts,* op. cit., pp. 78–79.
[38] National Research Council, *National Science Education Standards,* op. cit.
[39] Although the federal government is not the primary source of support for primary and secondary education in the United States, federal investments in efforts to improve pre K-12 science, mathematics, engineering, and technology education totaled $770 million in 1993. See Committee on Education and Human Resources, Federal Coordinating Council for Science, Engineering and Technology, *The Federal Investment in Science, Mathematics, Engineering and Technology Education: Where Now? What Next?* (Arlington, Va.: National Science Foundation, 1993).
[40] National Science Board., op. cit.
[41] The issue was featured in Kagaku Gijutsu-cho (Science and Technology Agency), *Heisei Go Nenban Kagaku Gijutsu Hakusho, Wakamono to Kagaku Gijutsu* (Science and Technology White Paper 1993: The Relationship Between Young People and Science and Technology), (Tokyo: Okurasho Insatsukyoku, 1993).
[42] The Monbusho survey is summarized in U.S. National Science Foundation Tokyo Office, “Computers at Japanese Public Primary and Secondary Schools,” *Report Memorandum 95-12,* May 15, 1995.
[43] Neil Gross, “A Game of Catch-Up,” *Business Week,* Annual special issue, 1994, p. 38.
[44] For example, President's Committee of Advisors on Science and Technology, *Report to the President on the Use of Technology to Strengthen K-12 Education in the United States,* March 1997 and U.S. Congress, Office of Technology Assessment, *Teachers and Technology: Making the Connection* (Washington, D.C.: U.S. Government Printing Office, 1995). In addition to exploring the issues related to using technology in the classroom setting and adequate training for teachers, one of the latter report's main areas of focus is how teachers can utilize technology to enhance professional growth and exchange.
[45] A recent report calls for increased investment in technology for K-12 education in the United States. See President's Committee of Advisors on Science and Technology, op. cit. However some experts are skeptical that such investments would make a significant contribution, even if resources were available. See comments by Bruce Alberts and Wm. A. Wulf in National Research Council, *Harnessing Science and Technology for America's Economic Future* (Washington, D.C.: National Academy Press, 1999).
[46] See http://www.nae.edu for an overview of some of the issues and related initiatives of the National Academy of Engineering.
[47] National Research Council, *National Science Education Standards,* op. cit.

3

University Entrance Issues

SUMMARY POINTS

- *U.S. and Japanese practices concerning university entrance are quite different, with major implications for other aspects of engineering education.*
- *For a number of historical and institutional reasons, university entrance and the entrance examination play a major role in determining the future employment and career prospects of Japanese young people. Therefore, the entrance exam is a major focus of effort and competition. Conditions in the United States are different. Although university entrance is a major event for young people, competition and effort are less intense than they are in Japan..*
- *Although the Japanese entrance exam system has a number of advantages for all concerned (students, universities and companies), the disadvantages of the system are increasingly apparent. The major disadvantages identified by the Japanese working group are: (1) The focus on entrance examination scores in Japan encourages students to find the quickest and easiest way to answer examination questions, often to the detriment of deeper understanding, (2) This emphasis on finding the "right answer" tends to stay with Japanese students even after they enter university and embark on their engineering careers, and (3) Since Japanese students who enter prestigious universities are assured of being hired for a lifetime position at a top company, they tend to be less diligent as university students.*
- *A number of very worthwhile technical reforms have been undertaken over the years, such as establishing the National Center Test for University Admissions. However, the underlying problems of the Japanese entrance exam system are more fundamental, and have not yet been adequately addressed.*

EDUCATIONAL AND SOCIAL CONTEXT

The main reason for devoting an entire chapter to the process and consequences of university entrance is that some of the most important contrasts between the U.S. and Japanese systems appear in this area. The importance of university entrance examinations in Japan, and the "examination hell" undergone by students preparing for the exam, are fairly well known in the United States and elsewhere. However, the tight linkage between the entrance examination system and other institutions and practices in Japanese education are less widely appreciated. Debates in Japan on reforming aspects of engineering education, and education in general, often center on the impacts of the examination system.

In view of the importance of this topic for the Japanese engineering education system, most of the discussion in this chapter will concern Japan, with information and data on the United States introduced for the purpose of comparison.

As pointed out in Chapter 2, an engineer's education in Japan begins before university, with an emphasis on group work and a good grounding in fundamentals of math and science. Between high school and job, the universities are officially supposed to teach fundamentals. In fact, the universities also perform the vital function of "quality screening" for employers, through their entrance examinations.

As explored more fully in Chapter 5, Japanese companies play a more active role than U.S. companies in imparting an understanding of actual engineering methods and practice through in-house classes and institutes, and apprenticeship-like on-the-job training. “Examination hell,” while often a subject of humor (and much tension) for its own sake, is also responsible, in large degree, for the style with which Japanese engineers pursue their profession. The “best” students in Japan will want to attend the most prestigious university, and work for the “best” companies (or government agencies). In turn, the best companies prefer to hire graduates of the most prestigious university. The quality strata in both universities and companies roughly match up. The class stratification of jobs and universities makes it relatively simple to match the best students and the most prestigious companies.

Several historical and institutional factors have contributed to the development of Japan's university entrance system and its far-reaching impact on future opportunities available to Japanese students. In the late 19th century, Japan built its secondary and higher education systems at the same time, in order to support rapid economic development. At first, the new universities generally accepted any student who could certify completion of secondary school and afford to attend, but soon secondary schools produced more graduates than universities were able to accept. The most prestigious universities, particularly the national universities, established their own exam systems as a result.[1]

The basic structure of the current Japanese system, in which companies and government agencies hire new graduates based on the selectivity of the universities they attended, predates World War II. With the much wider availability of secondary and higher education in Japan in recent decades, a much higher proportion of the high school population has become subject to the incentives and pressures of the university entrance exam system. Attempted reforms undertaken during the U.S. Occupation aimed to lower the emphasis on entrance exams, but these did not take hold.[2]

Table 3-1 provides an overview of the higher education systems of Japan and the United States. At the top of the hierarchy of prestige in Japan are the national universities, with several selective private universities also seen as highly desirable by students and employers. [3] Farther down on the hierarchy are less selective private and public universities. With a few exceptions, this informal but very stable prestige and desirability ranking holds across all fields.

TABLE 3-1 Four-Year Institutions

	Japan	United States
Total institutions[a]	565	1,809
Institutions awarding engineering degrees	187	390
Public	72	211
National	61	
Local	11	
Private	115	179

[a] Japanese institutions as of 1995; U.S. institutions as of 1992.
SOURCES: U.S. Department of Education, National Center for Education Statistics; Japan Ministry of Education, Science, and Culture.

The Japanese context differs from that of the United States in several significant respects. First, the United States does not have national universities, but does possess a wide range of public and private institutions. Because cost, quality, and selectivity of institutions vary widely by state, the choice available to students in different locations, especially those who cannot afford more expensive private or public out-of-state tuition, varies as well. The historical development of these institutions and the lower regional concentration of universities and economic development in the United States compared with Japan has mitigated against the emergence of a rigid national rank ordering of prestige and selectivity. Although selectivity clearly varies among U.S. universities, because lifetime employment is not institutionalized, the importance of the employment decisions of new graduates is less far-reaching for both the graduates and the employers. In the United States, there appears to be a lower correlation between attending a specific university and later success in life. The costs of a “wrong” decision being relatively lower for U.S. graduates and employers than it is for their Japanese counterparts, the importance of a screening device like the university entrance exam is correspondingly less. Further, there is considerable variation in the perceived quality of U.S. universities according to the particular field of study, as well as a significant amount of subjectivity involved in student preferences, depending not only on the expected field of study but on the learning environment and other factors. Finally, as discussed in more detail below, U.S. universities do not have entrance examinations, and standardized tests are among several criteria evaluated by U.S. universities to determine who should be admitted.

In some respects, there is a weak parallel between the Japanese undergraduate education admissions process and that of U.S. professional schools, such as business and law schools, where there is a fairly high correlation between getting into a top school and the desirability of initial job offers. The U.S. test preparation industry, to be discussed further below, focuses a great deal on the LSAT and GMAT, standardized tests used by law and business schools, respectively, as a result. Still, even among the most selective U.S. professional schools, standardized tests are just one of a number of factors evaluated in admissions decisions. It is also interesting to note that institutional structures similar to that surrounding the Japanese entrance exams have appeared in other rapidly developing Asian countries in which the initial hiring decision after graduation secures lifetime employment at a prestigious government agency or private company.

UNIVERSITY ENTRANCE PROCESSES AND CRITERIA

Although our discussion will mainly deal with university entrance, it is important to note that parental concern in Japan about the high school entrance examination process has increased dramatically over the past several decades as entrance to universities has become more competitive, and as admittance to a highly selective high school appears to be closely linked to the prospects for entering a prestigious university. In fact, a number of the most prestigious private universities also run high schools, and graduates of these affiliated high schools do not have to take the entrance exam in order to be admitted to that particular university. Although there are no national statistics on utilization of these “escalator” schools, this route appears to be increasing in popularity. Admission from affiliated high schools accounts for about 10 percent of the total admissions at Keio University and Waseda University, two of the most selective private universities. [4] At some universities, admissions from affiliated high schools may be close to 20 percent.

Graduating from high school qualifies a Japanese student to take the college-entrance examinations, although it is possible for non-graduates to apply to a college if they pass a special qualifying examination. Data for 1998 indicate that if only four-year universities and colleges are considered, approximately 55 percent of the high school graduates applied and 30 percent were enrolled. Before students are allowed to apply to a university they are expected to have completed at least the equivalent of a high school education and are expected to be at least 18 years of age by the time they enter the university. To meet the first requirement, individuals need to graduate from a high school or an equivalent educational institution or to pass an annually held University Entrance Qualification Test. This test covers the material taught at high school. Some students who are applying for admission to the nation's top universities may stay at home during part of their senior year or earlier in order to have the free time they believe is necessary to prepare adequately for the entrance examinations.[5]

In the pre-1979 system, each of Japan's national universities gave its exam on one of two dates, and the exam was generally used by all of its departments. Private universities, by contrast, were free to set the date for their own exams, and various departments within the university often gave separate tests. Students were therefore limited to applying to two national universities, but were free to prepare for and take the examinations of as many private universities as they wished, so long as the examination dates did not overlap.

As the burden on students and families to prepare for examinations grew, Monbusho and the universities sought to make reforms in the system. The National Center for University Entrance Examination was established in 1977 to develop and administer common scholastic aptitude and scholastic achievement exams that could be utilized by all national and public universities. In 1979, the first common examination for university entrance was given. In 1990, the National Center Test for University Admissions (NCT) was established, in which private as well as national and public universities could participate. Table 3-2 shows the basic outline of the National Center Test.

At the present time, all 95 national universities and 61 public universities use the National Center Test to supplement their own entrance exams, and the number of private universities utilizing it has gradually increased to 217 in 1998. The advantage for students is that utilization of the National Center Test reduces the number of specific subject tests that need to be taken for each university to which they are applying. From the standpoint of the universities, the National Center Test has the additional merit of establishing the fundamental competence of the students, which allows universities more scope to utilize essay exams, interviews and other means to evaluate advanced achievement and other capabilities of applicants.

In addition to reform of the entrance examination system itself, there has been movement in Japan in recent years away from an exclusive focus on entrance examinations and toward diversifying the criteria utilized in admissions decisions. One example is the utilization of

TABLE 3-2 University Entrance Examination System in Japan Since 1990

	Exam	Number of Subjects/Type of Exam
National, public, and some private universities	National test of the “National Center of University Entrance Examinations”	Tests in 1–5 subject areas
	Individual university entrance examinations (additional exams)	Tests in 2–3 subject areas, essay, interview, skill test, single test consisting of several subjects
Private university	Individual university entrance examinations	Tests in 1–3 subject areas

SOURCE: Japanese working group.

affiliated high schools, discussed above. In addition, students may be accepted by a university through the recommendation system, in which teachers may recommend an especially outstanding student for admission. The recommendation system currently accounts for nearly 30 percent of admissions in four year institutions nationwide.[6] The recommendation system is especially beneficial for students who do not perform up to their capacity in highly competitive examination settings. The fact that admissions are announced in the late fall rather than in the spring after the examinations are given is also helpful to students because students who are not accepted at their top choice through the recommendation system have the option of sitting for examinations. The recommendation system is not utilized by the most highly selective national universities such as the University of Tokyo. In general, the higher prestige universities rely most on their own entrance examinations in evaluating applicants, and less selective universities rely more on the NCT or other criteria.

Japanese experts have raised several issues about the recommendation system. For example, middle tier universities are able to attract better quality students through the recommendation system than they could through entrance exams, since there is an incentive for students to apply by recommendation at a somewhat less prestigious university in the autumn and avoid the risk of failing to gain admittance later to a more prestigious university through the entrance examination. In order to prevent universities from utilizing the recommendation system exclusively, Monbusho has reportedly issued guidance that no more than 30 percent of students should be admitted in this manner. In some cases, the recommendation system also involves complex social obligations. For example, a student accepted through the recommendation system to a given university who later decides to attend a more prestigious university will discredit his or her high school. The university that accepted the student through the recommendation system would be less likely to accept students from that high school in the future.

Table 3-3 shows statistics on the 1995 entrance quotas, number of total applicants and successful applicants at a range of leading Japanese national and private universities. While the top universities shown in Table 3-3 have a very high "yield," only about half of the accepted applicants of lower prestige universities finally enroll, since Japanese applicants are generally accepted at two or more universities.

Due to a number of factors, including differences in the social and historical context surrounding the development of universities, entrance procedures for U.S. universities are much different from those of Japan. As is the case in Japan, U.S. universities encompass a range of types, with varying levels of selectivity. In contrast to Japan, the most selective U.S. universities are generally private. Table 3-4 shows admissions and other data for several representative U.S. universities with leading engineering programs.

Each U.S. college or university determines its own admissions criteria. Most selective schools utilize a number of criteria, which are weighted and evaluated by admissions office staff and faculty admissions committees. Since the process is more complex, U.S. universities have larger admissions office staffs than Japanese universities.[7]

Taking a standardized test, either the American College Testing exam (ACT) or the Scholastic Aptitude Test I (SAT I) of the College Board is generally a requirement.[8] The ACT is more widely utilized in the Midwest. The SAT I consists of seven sections, three Math, three Verbal and one experimental section that does not count toward the student's score. The SAT I Math and Verbal sections are each scored on a 200–800 scale, and the test takes three hours to complete. In 1995 the College Board "recentered" the SAT I scores, which means that the average score will be higher than it was prior to the recentering. The SAT I and ACT are given several times a year. Students can take the tests multiple times, and have the scores sent to the schools they intend to apply to. In addition to the SAT I verbal and mathematics tests, the College Board also gives a series of specific subject tests in mathematics, English and various areas of science, collectively known as the SAT II.

In addition to standardized tests, U.S. universities examine high school grades, taking the quality of the high school and level of coursework into account, the personal statements that are submitted with the application and other aspects of the student's high school achievements, such as participation in sports or other activities. Some universities require a personal interview. Besides ensuring the overall quality of the incoming freshman class by evaluating the academic and personal achievement and potential of individual applicants, U.S. universities pursue other goals through their admissions policies, such as increasing the number of students from traditionally underrepresented groups.[9]

TABLE 3-3 Admissions for Selected Japanese Universities, 1995

	Quota	Applicants	Acceptances
Public/National			
Hitotsubashi University	1,140	3,755	1,189
Hokkaido University	2,487	8,966	2,634
Kyoto University	2,921	11,360	2,980
Kyushu University	2,521	7,165	2,693
Nagoya University	2,213	6,918	2,386
Osaka University	2,825	8,098	3,001
Tohoku University	2,549	8,033	2,757
Tokyo Institute of Technology	1,277	5,688	1,419
Tokyo University	3,526	10,885	3,587
Total	21,459	70,868	22,646
Private (Tokyo area)			
Hosei University	4,890	60,022	10,409
Keio University	4,010	48,362	10,697
Meiji University	4,548	65,262	11,889
Nihon University	7,735	109,719	22,065
Rikkyo University	2,150	33,187	5,986
Sophia University	2,045	25,820	4,145
Tokyo Denki University	1,510	16,626	4,070
Waseda University	6,820	102,049	14,405
Private (Kyoto/Osaka area)			
Doshinsha University	3,083	34,461	10,434
Kansai Gakuin University	2,470	35,355	9,497
Kansai University	5,190	79,974	15,652
Kinki University	3,708	70,184	13,973
Konan University	2,050	14,273	3,289
Kyoto Sangyo University	2,760	25,274	6,728
Ritsumeikan University	5,430	92,620	17,610
Ryukoku University	2,015	40,943	9,851
Total	60,414	854,131	170,682

NOTE: The discrepancy between quotas and acceptances for private universities results from the practice of accepting a larger number of students than are expected to actually enroll.
SOURCE: Japan Ministry of Education, Science, and Culture.

TABLE 3-4 Overview of Admissions and Other Information for Selected U.S. Universities and Engineering Schools

	Status	Engineering Majors	1997–1998 Admissions	1997–1998 Entering SAT Scores	Class Rank in Top Quarter	1998–1999 Expenses
The Cooper Union for the Advancement of Science and Art	private	63%	2,173 applied 290 accepted	25th percentile: 1320 75th percentile: 1500	100%	$500 tuition 8,000 room/board
Massachusetts Institute of Technology	private	47%	7,836 applied 1,938 accepted	25th percentile: 1390 75th percentile: 1560	99%	$24,050 tuition 6,750 room/board
University of Maryland, College Park	public	11%	16,182 applied 10,458 accepted	25th percentile: 1100 75th percentile: 1320	77%	$4,699 tuition in state 11,221 out of state 5,848 room/board
University of Michigan	public	18%	19,114 applied 13,099 accepted	25th percentile: 1160 75th percentile: 1360	89%	$6,063 tuition in state 18,629 out of state 5,486 room/board
Purdue University	public	22%	17,256 applied 15,394 accepted	25th percentile: 980 75th percentile: 1220	60%	$3,500 tuition in state 11,720 out of state 5,032 room/board
Georgia Institute of Technology	public	69%	7,676 applied 4,702 accepted	25th percentile: 1230 75th percentile: 1410	N/A	$2,991 tuition in state 9,921 out of state 5,700 room/board
University of Texas, Austin	public	11%	14,974 applied 11,708 accepted	25th percentile: 1080 75th percentile: 1300	74%	$3,004 tuition in state 9,394 out of state 4,537 room/board
California Institute of Technology	private	39%	2,389 applied 540 accepted	25th percentile: 1420 75th percentile: 1570	100%	$19,166 tuition 5,881 room/board

SOURCE: *U.S. News & World Report*, “America's Best Colleges,” August 31, 1998.

For many major U.S. universities, the various constituent schools or colleges may have different admissions criteria, although they will typically use the same application process and forms. Engineering schools are often more competitive and difficult to enter than liberal arts colleges of the same university. In evaluating engineering applicants, U.S. universities often pay particular attention to the SAT I math score, to ensure the minimum capability necessary to perform up to standards.

THE EXAM PREPARATION PROCESS AND INFRASTRUCTURE

Any discussion of the Japanese educational system requires that attention be paid to *juku* and *yobiko,* two out-of-school academic institutions. Both of these institutions have gained great popularity in recent years and represent a multi-billion yen industry that provides supplementary education for Japanese students.[10]

Juku offer special tutoring lessons in a wide variety of subjects. Children attend *juku* during elementary school to learn such things as calligraphy, use of the abacus, and music. By the time they are in high school, most of the students who attend *juku* do so to prepare for the college entrance examinations. Many parents do not believe that the high school curriculum prepares students for the rigorous university entrance examinations. This is especially true of parents of students at public high schools, where Monbusho sets the number of hours required for each subject more strictly than at private high schools. As a result, it is difficult for teachers to find adequate time to prepare students for the college entrance examinations.

Attendance at *juku* during high school varies with the grade level of the student, the size of the city in which the student lives, and the family's income. In some locations only a small percentage of high school students attend *juku;* in other locations, more than half of the students in the second and third years of high school study academic subjects at *juku. Juku* offer a wide variety of subjects, and attendance at academic classes accounts for only a moderate percentage of the total percentage attending *juku.* Figure 3-1 shows national trends for *juku* attendance at various grade levels.

The increase in *juku* attendance is a relatively recent phenomenon, but even more recent is the upsurge of interest in studying at *yobiko.* The original purpose of *yobiko* was to prepare students who wished to re-take the college entrance examinations after an initial failure. These students are popularly known as *ronin,* or masterless samurai. Currently, students are more likely to attend *yobiko* for a year or two to enable them to be more adequately prepared for their first effort at taking the college entrance examinations.[11] The sole purpose of *yobiko* is to prepare students for the college entrance examinations. An increasing number of high schools are even providing *juku* or *yobiko* classes to their students by satellite, as Figure 3-2 shows. Although this mostly reflects the fact that the leading *yobiko* are located in the middle of cities and are not accessible to students in outlying areas, in some cases high schools and individual teachers are introducing the classes in order to increase the rate at which their students are accepted at leading universities.

In conjunction with the *juku* and *yobiko* industries, publishers put out guidebooks for individual universities that contain general information about the university, the examinations given in recent years, strategies and "countermeasures" for the exam, and rankings of how selective the university is compared with peer institutions.

The United States also has growing supplementary education and test preparation industries, but these are much smaller and have somewhat different roles than their Japanese counterparts. For example, while for-profit educational companies have traditionally provided remedial training for students who have fallen behind their peers, there is a strong shift toward academically successful children being enrolled in summer and other enrichment programs provided by single-storefront schools or regional and national chains. In addition to providing additional opportunities to learn math, computer skills and grammar, these schools also serve a

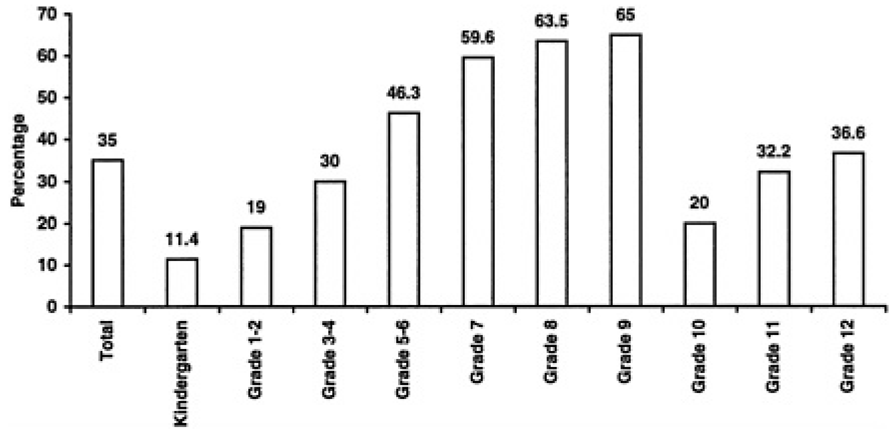

Figure 3-1 Percentage of children attending juku for supplementary lessons, 1995. SOURCE: Japan Ministry of Education, Science, and Culture.

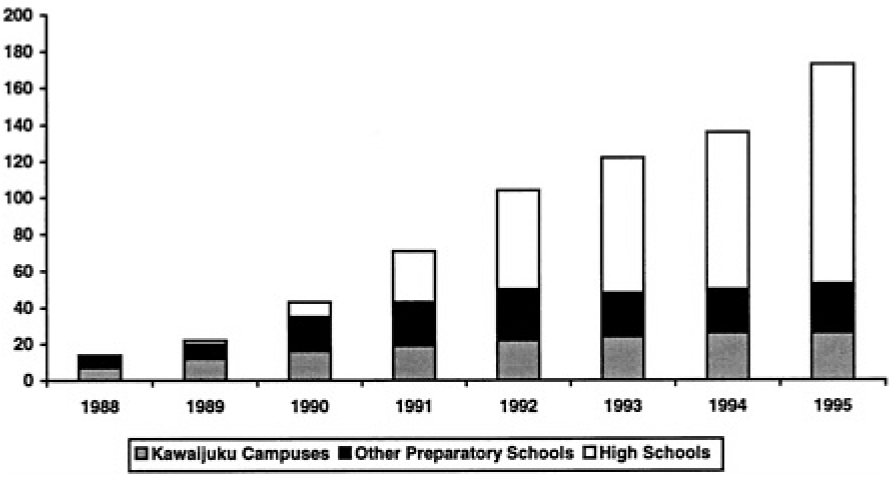

Figure 3-2 Number of schools that have introduced satellite Kawaijuku classes. SOURCE: Japan Ministry of Education, Science, and Culture.

social function of occupying the children of families in which both parents work during the long summer vacation. One for-profit educational chain that is expanding rapidly in the United States is Kumon USA, an affiliate of a large Japanese operator of *juku.*[12]

Several U.S. companies have also grown considerably over the past decade by providing classes and published materials aimed at helping students to prepare for the SAT and other standardized tests. Classes are generally provided in a series, taking place during the evenings or on weekends. While there is no U.S. equivalent to the Japanese *ronin* or *gen-eki,* students who are spending an extra year or two after high school studying for the entrance exam, the U.S. test preparation industry also provides students with information about various universities, so that they can more accurately assess their chances of being admitted and find attractive alternatives to their first choices. Increasingly, test preparation and other university admissions-related materials are provided on-line, through CD-ROM and other computer-ready formats. In Japan, the National Center for University Entrance Examinations provides information on universities and their examinations on-line through its HEART system, while universities, *juku* and *yobiko* are rapidly increasing the amount of information provided on the internet and through CD-ROM.

ISSUES

Notwithstanding the positive reforms made in the Japanese university entrance examination system in recent years and the numerous positive impacts, the disadvantages of the system are becoming increasingly apparent. The Japanese working group took the lead in articulating a number of these disadvantages from the standpoint of engineering education, and in identifying areas to develop reforms in the future. The institutional context surrounding the university entrance exam has deep roots and has developed over many years. Still, Japan's national government has significantly greater responsibility in education, including areas related to university entrance, than does the U.S. federal government. This implies at least the possibility of implementing significant nationwide reform.

Declining Interest in Math and Science.

As noted in Chapter 2, Japanese agencies and experts have noted a declining interest in mathematics, science and engineering among young people. There is good reason to think that the current university entrance exam system is at least partly responsible for this trend. In particular, Japanese task force members point out that because the entrance examination does not test knowledge and skills related to experiments, problem solving and other hands-on learning techniques, there has been a tendency to deemphasize these techniques in high school education and at *juku.* This lowered emphasis on hands-on learning and problem solving may in turn be partly responsible for declining interest among young people in science and engineering.

The Japanese task force members believe that this negative impact can be at least partly addressed through the development of entrance examination questions and problems that explicitly test experimental and hands-on learning. Problems that test knowledge across several areas of science and technology in an integrated way and better measure student creativity and problem solving ability could be developed by the National Center for University Entrance Examinations and individual universities. However, the nature of the large entrance examination industry that exists in Japan is an obstacle to this. The Japanese group believes that *juku* and *yobiko* will continue to respond by teaching students refined methods of passing particular examinations.

A related issue is the role of the entrance examination in maintaining standards. Overall, the system has the positive effect of contributing to high standards among Japanese high school students and teachers. However, Japanese working group members believe that it is necessary to expand the pool of young people who are able to enter the engineering discipline. For example, graduates of technical high schools often have significant hands-on experience in engineering-related fields, but would not be able to do well enough on the entrance examination to enter one of the elite engineering schools. Japanese universities, particularly the second and third tier engineering schools, could perhaps do more to attract these students. Currently, technical high school graduates tend to be hired by companies, which provide them with extensive training.

Opportunity Costs of Time and Resources

As pointed out above, preparation for university and high school entrance examinations in Japan involves a large expenditure of time and financial resources for a large proportion of the school-age population. Although this effort should perhaps not be judged too harshly, particularly when compared with what many U.S. students spend time and resources on, in many cases it appears that the future development of Japanese students is sacrificed in the all-consuming focus on entrance examinations. To some extent, this problem can be addressed through further technical changes in the system, but for the most part progress will appear as the result of larger, more evolutionary systemic changes, including changes in the attitudes and behavior of employers, students and parents.

The Entrance Examination System and the Academic Environment in Universities

Another issue that has been raised with Japan's university entrance examination system is the emphasis of Japanese employers on which university students attend and the exclusion of other possible hiring criteria such as grades or performance during internships. This often results in students not having an incentive to study hard during their university years. The Japanese working group believes that this is a serious issue, and the situation will only be changed if companies and government agencies in Japan move toward diversifying their human resource needs.

There have been indications in recent years that this is occurring to some extent, and that Japanese companies are placing some value on factors such as international experience gained through overseas study. However, as long as the lifetime employment system continues for a significant percentage of the Japanese working population, it will be difficult to change the incentives of Japanese employers. Because of the high level of commitment to the employment contract by employers and employees implied by lifetime employment, employers prefer to hire highly capable but inexperienced young people who have been screened by the entrance examination or similar system.

There is a further impact of the entrance examination system on university education that should be raised in this context, that is especially relevant to science and engineering. Because it is necessary to take a limited number of subject tests on the NCT and individual university exams, high school students tend not to take subjects that will not be tested. As the high school curriculum has become more flexible in recent years, this means that some university students studying medicine might not have taken biology in high school. Private universities, however, are decreasing the number of subjects because many students now simply do not apply to schools requiring many different subject areas on entrance examinations. The Japanese working group believes that universities should respond to this trend by offering remedial science courses that cover some high school material.

Other New Approaches

In addition to intensified efforts to develop examination questions that better test student creativity and problem solving ability, and long-term actions by universities, companies and government to alleviate the negative impacts of the entrance examination system, the Japanese working group believes that Japanese universities should utilize information technologies more aggressively to benefit potential applicants. Ensuring that all universities have a home page on the world wide web that provides information on the university, admissions procedure and the entrance examination is an important task for the next several years.

PRIORITIES FOR THE FUTURE

Based on this discussion of the Japanese university entrance examination system, the Japanese working group has identified a number of tasks that might be tackled by Japan in order to improve the system by alleviating the negative impacts. These tasks include:

- *Alleviating the negative impact of the examination system on the high school curriculum and learning environment by developing testing methods and questions that allow scope for students to exercise creativity and enable universities to assess problem-solving capabilities of applicants.*
- *Alleviating the negative impact of industry hiring practices on the university learning environment by encouraging universities to further diversify their criteria for admissions, and by encouraging industry to diversify and raise the expectation level of skill and experience profiles of new hires.*
- *Encouraging universities to aggressively utilize information technologies to disseminate admissions and other information to potential applicants and parents.*

NOTES AND REFERENCES

[1] Ikuo Amano, *Proceedings of the International Conference on University Admissions for the 21st Century,* The National Center for University Entrance Examinations, July 1995, p. 5.

[2] Ibid., p. 8.

[3] Although the context includes the role of two-year institutions, the discussion here and in Chapter 4 is limited to four-year institutions.

[4] Amano, op. cit., p. 11.

[5] Although no statistics are available, members of the Japanese working group believe that the number of such students is very small.

[6] In two-year institutions, the recommendation system accounts for about half of all admissions.

[7] Japanese universities do have small admissions office staffs, but the main admissions-related work in Japanese universities is compiling and grading the exam, which is done by faculty on a part-time basis. The impression of U.S. and Japanese Joint Task Force members is that Japanese faculty members spend much more time on admissions-related work than do U.S. faculty members.

[8] The College Board is a nonprofit organization comprised of member institutions of higher and secondary education. The College Board sponsors a range of standardized tests used in university admissions that are developed and administered by Educational Testing Service (ETS). ETS is also a nonprofit organization, with a budget of $350 million per year, and is headquartered in Princeton, New Jersey.

[9] Japanese universities often give special consideration to working adult applicants and applicants who have lived much of their secondary school years outside of Japan.

[10] Although *juku* and *yobiko* could be clearly distinguished in the past, Japanese task force members report that companies that have traditionally run one or the other type of school are increasingly expanding

into other markets. Kawaijuku, which despite the name, has traditionally focused on operating *yobiko,* is one example.

[11] According to Japanese working group members, it is difficult to find hard data on this trend, but their impression is that the percentage of students taking this route, known as *gen-eki,* or active duty soldiers, is rising, but that the total number of such students has been stable recently because of the decline in Japan's 18-year-old population.

[12] Sarah Lubman, "Summer school is no longer just for kids who fell behind," *The Wall Street Journal,* August 8, 1995, p. B1.

4

Undergraduate and Graduate Education

SUMMARY POINTS

- *Engineering education at the university level has been a very important factor in building the technological capability of both Japan and the United States. A comparison of statistics and basic information shows important similarities and differences. Similarities include education costs and the general content of undergraduate education. Differences include more generous financial aid for students at the undergraduate and graduate levels in the United States, the larger relative size of Japan's undergraduate engineering enterprise, and Japan's dissertation (or "paper"*[1] *) doctorate system, which has no U.S. equivalent.*
- *One important difference is in accreditation, financing, and control. Japan's Ministry of Education, Science, Sports, and Culture performs all of these functions in Japan, although there has been movement in recent years to diversify funding for university research and advanced education with industry and foundations providing some support to Japanese researchers. In the United States, engineering education and research at universities is funded by a variety of federal agencies, states, and industry, while a private group, the Accreditation Board for Engineering and Technology, is responsible for accreditation.*
- *Undergraduate and graduate engineering education have been the subject of much discussion and a number of reform efforts in both countries. A common theme is ensuring that university training prepares students for the diverse challenges and opportunities that will face engineers in the twenty-first century.*

STATISTICS AND BACKGROUND INFORMATION

Undergraduate Engineering Education

Discussion and tables in Chapter 3 covered the range of institutions granting four-year degrees in each country. Almost three times as many U.S. institutions award general four-year degrees as Japanese institutions. There is a sharp contrast between Japan's fairly rigid hierarchy of national and private universities with the United States, which has a wider variety of institutions and only a rough hierarchy.

Table 4-1 shows total enrollment and enrollment in engineering and natural science for the most recent years available in Japan and the United States. Figure 4-1 shows the trend in engineering and natural science degrees. In 1994, Japan awarded about a third more engineering degrees than the United States. It is necessary to consider both engineering and natural science degrees in U.S.-Japan comparisons, because several fields of applied science that are found in Japanese engineering schools, such as computer science, applied chemistry, and applied physics, are considered natural science fields in the United States. Still, combined engineering and computer science degrees were slightly higher in Japan than the United States in 1994, meaning that Japan is awarding about twice as many degrees per capita in these fields.

TABLE 4-1 Undergraduate Enrollment

	Japan (1996)	United States (1995–1996)
Total undergraduate enrollment	2,263,512 (100%)	7,791,000 (100%)
Engineering and computer science	516,244 (23%)	696,000 (9%)

SOURCES: Japan Ministry of Education, Science, and Culture, and National Center for Education Statistics, *Digest of Education Statistics 1997,* 1998.

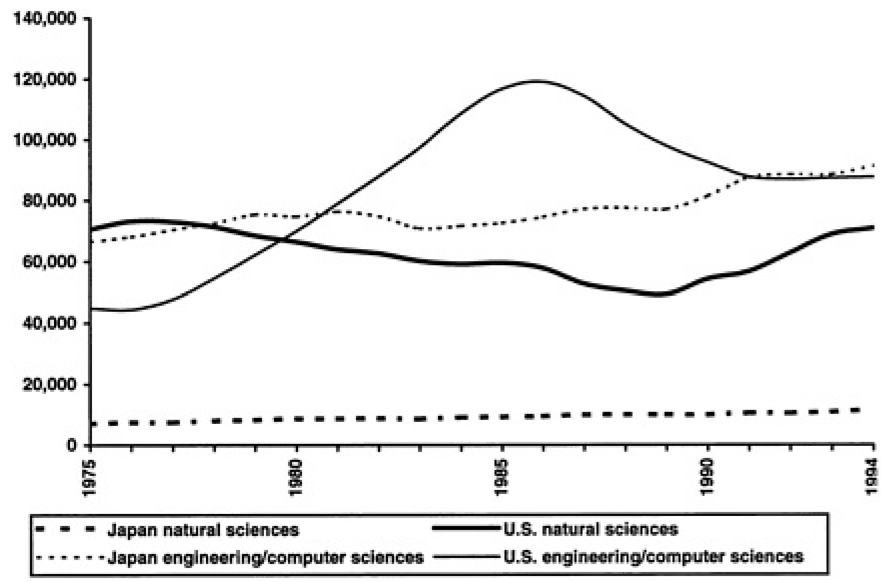

Figure 4-1 Bachelor's degrees in natural sciences and engineering and computer sciences, 1975–1994. NOTE: Natural sciences include physical, biological, earth, atmospheric, and oceanographic sciences.
SOURCE: National Science Foundation, The Science and Technology Resources of Japan: A Comparison with the United States, 1997.

Figure 4-2 illustrates an issue that the Japanese system will be facing in the coming years. Because of a decline in the birthrate since the 1970s, Japan's college-age population is shrinking. Entrance to engineering schools is very competitive, so the number of engineering degrees granted in Japan is unlikely to decline in the foreseeable future. Still, the Japanese working group and other experts have raised concerns about maintaining a high quality applicant pool for engineering schools.

Table 4-2 shows the breakdown in disciplinary concentrations for first engineering degrees awarded in the United States and Japan in 1994. In most engineering fields, the percentages are roughly similar within a few percentage points.

In the area of costs and financial aid for students, the two countries display some differences. According to statistics from the Ministry of Education, Science, Sports, and Culture (Monbusho), the tuition for national universities in 1995 was 447,600 yen, or $3,443 at 130 yen per dollar. During the freshman year, the student is charged an admission fee as well, which was 260,000 yen ($2,000) in 1995, bringing total tuition and fees, which is uniform for all national universities, to $5,443 for freshmen and $3,443 for the remaining years. The corresponding average figures for private universities in 1995 were 728,365 yen for tuition ($5,603), a freshman admission fee of 282,574 yen ($2,174), and a total cost to freshman of $7,777. Two decades ago, private school costs in Japan were much higher relative to national universities than they are today. Most of the costs of college education are borne by students and their families, with only about 11 percent of Japanese undergraduates receiving financial aid.

In the United States data for the 1995–96 academic year shows that tuition and required fees averaged $2,179 for in-state students at public institutions.[2] For private institutions, the average for tuition and required fees was $11,864.[3] As for financial aid, during the 1995–96 school year 62.8 percent of full-time students at public institutions received aid, while 80.3 percent of full

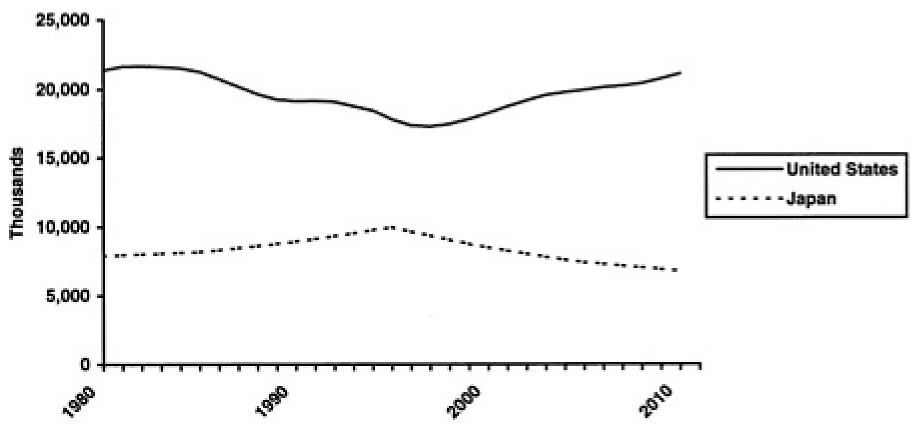

Figure 4-2 Population of 20-to 24-year-olds in Japan and the United States, 1980–2010. SOURCES: National Science Foundation, *Human Resources for Science and Technology: The Asian Region,* 1993 and U.S. Census Bureau.

time undergraduate students at private institutions received aid. Financial aid in the United States is provided in the form of loans, grants, work-study or some combination. The average amount of financial aid received by all full-time U.S. students was $6,832 per year.

A further contrast between the two systems is in retention. Table 4-3 shows that a very high proportion of Japanese students graduate in four years, including engineering students. In the United States, for students entering public four-year institutions in the fall of 1989, only 42 percent had received a degree by 1994, while 58 percent of the 1989 entrants to private universities had done so.[4] The reasons for leaving school before receiving a degree in the United States are complex. Failure is only one contributing factor. Offers of attractive and high paying jobs is another, especially in computer-related areas.

TABLE 4-2 First University Engineering Degrees

Field of Study	Japan[a]		United States	
Total	91,184	100 %	63,012	100 %
Aeronautical/astronautical	776	0.9	2,330	3.7
Chemical	10,335	11.3	5,636	8.9
Civil	18,015	19.8	10,603	16.8
Electrical and computer	27,346	30.0	18,241	28.9
Industrial	4,757	5.2	3,453	5.6
Mechanical	18,664	20.5	15,297	24.3
Materials/metallurgy	1,125	1.2	1,106	1.8
Other	10,166	11.1	6,346	10.1

[a] Computer science is included within engineering departments in Japan. SOURCE: National Science Foundation, *Science and Engineering Degrees 1966–1994* and Japan Ministry of Education, Science, and Culture, Basic Education Survey, 1995, as compiled in National Science Foundation, *The Science and Technology Resources of Japan: A Comparison with the United States,* 1997.

TABLE 4-3 University Retention in Japan

	All Fields	Engineering
Entrants to four-year institutions in 1990	492,340	97,317
Graduates in 1994	390,451	75,685
Percentage graduating in four years	79%	78%

SOURCE: Japan Ministry of Education, Science, and Culture.

The enrollment of women in undergraduate engineering also shows a disparity between the two countries. Women and minorities are still underrepresented in U.S. undergraduate engineering enrollment, but steady increase is occurring. Female engineering enrollment was about 12 percent in 1979, and grew to 18 percent in 1994.[5] Enrollment of underrepresented minorities in U.S. undergraduate engineering grew from about 8 percent in 1979 to 14 percent in 1994. In Japan, female enrollment in engineering was a little under 8,000 in 1996, about 12 percent of the total.[6]

Graduate Engineering Education

Table 4-4 shows graduate education enrollment, enrollment in engineering, and enrollment in science and engineering for Japan and the United States. One obvious difference between the two countries is that graduate education is a much larger enterprise in the United States than it is in Japan. However, engineering constitutes a higher proportion of graduate enrollments in Japan than it does in the United States, so that per capita graduate engineering enrollments are roughly equal.

Table 4-5 shows the number of foreign students enrolled in science and engineering graduate programs in the two countries. Although the collection methods are different and the data on foreign students are not directly comparable to the overall enrollment data, a rough comparison (Tables 4-4 and 4-5) shows that the United States has a much higher proportion of foreign students among those studying engineering.

TABLE 4-4 Graduate Enrollment, 1994

	Japan	United States
Total graduate enrollment	138,752 (100%)	1,734,371 (100%)
Engineering	52,540 (38%)	113,865 (7%)
Total science and engineering	91,181 (66%)	433,152 (25%)

NOTE: Japanese engineering enrollment includes computer science. SOURCE: National Science Foundation, *The Science and Technology Resources of Japan: A Comparison with the United States,* 1997.

TABLE 4-5 Foreign Students Enrolled in Science and Engineering Graduate Programs, 1994

	Japan	United States
Foreign students in science and engineering	10,127	96,475
Foreign students in engineering	4,749	44,114

SOURCE: National Science Foundation, *The Science and Technology Resources of Japan: A Comparison with the United States,* 1997.

TABLE 4-6 Graduate Degrees, 1994

	Japan	United States
Total Master's degrees	36,581 (100%)	389,008 (100%)
Engineering Master's degrees	18,096 (49%)	28,717 (7%)
Total Doctoral degrees	11,367 (100%)	41,011 (100%)
Engineering doctoral degrees	2,501 (22%)	5,822 (14%)
University-based engineering doctoral degrees	1,323	
“Thesis” engineering doctoral degrees	1,178	

NOTE: Japanese figures include computer science. SOURCE: National Science Foundation, *The Science and Technology Resources of Japan: A Comparison with the United States,* 1997.

Table 4-6 shows the number of masters and doctoral degrees in engineering granted in the two countries in 1994. Engineering accounted for a large proportion of the masters degrees awarded in Japan. The table also shows the breakout in Japanese engineering degrees between university-based “course” doctorates and “thesis” doctorates earned for a dissertation prepared outside the university. The proportion of university-based doctorates had been lower than that of thesis doctorates until the early 1990s. On a per capita basis, the Japanese system grants the same number of doctoral degrees in engineering as the United States.

In the financing of graduate engineering education, there have been fairly wide disparities between the United States and Japan. Although directly comparable data do not exist, support for graduate students has traditionally been much lower in Japan. About 26 percent of master's students and 59 percent of Japanese doctoral students receive “scholarships,” which are interest-free loans that need to be repaid after graduation.[7] About 70 percent of U.S. science and engineering graduate students receive support through research and teaching assistantships, fellowships and traineeships. In 1993, 45,000 graduate students were supported primarily through fellowships and traineeships, and about 155,000 through research and teaching assistantships. The only form of support that must be repaid in the United States is loans. In recent years Japan has been increasing support for science and engineering graduate students through fellowships from the Japan Society for the Promotion of Science (JSPS) and other agencies. The announced goal is to increase the number of fellowships from 6,000 in 1996 to 10,000 by 2000.

CONTENT

Undergraduate Education

It has been noted in Chapter 2 that Japanese engineering students enter universities with a more consistently thorough and advanced grasp of mathematics and science than their American counterparts. During the undergraduate years, it appears that a certain amount of catching up takes place on the part of U.S. students. Although Japanese engineering students have a heavier work load than Japanese undergraduates in other disciplines, it is said that they do not work as hard as U.S. engineering students.[8] Japanese courses tend to be more general and theoretical than U.S. courses, and are oriented toward lectures and supervised laboratories. Grading in U.S. engineering courses depends a great deal on take-home problem sets, which are virtually absent in Japan.[9] Japanese grading relies heavily on written final examinations, which are also widely used in the United States.

The content of the undergraduate curriculum does not differ a great deal between the two countries, with the first two years mainly focused on generalized coursework and the last two on more specialized subjects. One difference is the foreign language component for Japanese engineering students. Many public universities require study of English and a second foreign language, while most private universities require only one. U.S. engineering schools do not generally require language study, and indeed because of time constraints, it is very difficult in most U.S. universities for engineering students to study a foreign language while fulfilling other requirements.

Graduate Education

It is useful to distinguish between master's and doctoral training in engineering. For engineers not planning a career in research or university teaching, the master's degree is an appropriate terminal degree in both the United States and Japan. In both countries, the engineering master's course generally lasts for two years. In Japan, the engineering master's program consists mainly of coursework and seminars, with a thesis required to graduate. Most U.S. programs include research or laboratory work, and many require a thesis. Dual degree and interdisciplinary master's programs are common in the United States, as are programs that require or facilitate internships. These sorts of programs are rare in Japan.

In Japan, university-based doctoral training consists of three years of research, presentations on the student's research results, and preparation of the dissertation, following completion of the master's course.[10] Alternately, the dissertation (or “paper”) doctorate is earned by a working professional based on work completed outside the university. The candidate does not have university coursework requirements and is not registered as a formal doctoral student, but does have a dissertation advisor on the university faculty and his/her work is evaluated and approved by the academic department.

In the United States, the typical Ph.D. program also focuses on a doctoral dissertation based on original research that may take two or more years to complete. The dissertation is expected to describe the student's research results, relevance of research to previous work, and significance in advancing understanding.[11] The value of the dissertation is that it demonstrates the student's ability to conduct independent research. One common practice in science and engineering fields is for a doctoral candidate to work as a research assistant on the project of a faculty member, and to take one aspect of this work as a dissertation topic which is mainly independent work.

ACCREDITATION AND CONTROL

In the United States, undergraduate engineering education programs are accredited by the Accreditation Board for Engineering and Technology (ABET).[12] ABET is a coalition of engineering societies, which has been granted exclusive jurisdiction by the U.S. Department of Education to accredit engineering education programs. Accreditation is a voluntary process aimed at ensuring that educational programs meet high quality standards and serve the long term needs of the engineering profession. ABET has developed criteria for accreditation, which are revised periodically. Engineering Criteria 2000, which will be phased in over the 1998–2001 timeframe, is intended to allow for more diversity of approach. Accreditation is implemented through the evaluation of programs by expert committees.

In Japan, general as well as engineering curricula and certification of public and private universities is controlled by Monbusho. Monbusho also regulates student enrollments, department by department, for each university. One effect of the regulatory environment for education in Japan is that it is very difficult to start a new university. In addition to certifying universities, Monbusho makes periodic checks to see if quality is being maintained. Monbusho introduced changes in its certification practices in the early 1990s in order to allow for more flexibility in curriculum.

ISSUES, CONCERNS, AND REFORM EFFORTS

United States

A number of groups and prominent individuals have examined U.S. undergraduate and graduate engineering education in recent years.[13] The general sense of these reports is that although the current system and practices have performed well, undergraduate and graduate education will need to undertake major reforms in order to prepare engineers for a rapidly changing environment. The most important trend forcing change is the growing diversification of engineering career paths. Engineers are increasingly finding employment in nontraditional sectors. Even traditional employers of engineers are demanding capabilities and knowledge beyond technical skills, in areas such as communications ability, teamwork, capability for lifelong learning, and understanding of the business context of engineering work. These are also among the characteristics desirable for an engineering workforce that increasingly will be involved in international collaborations. The “global engineer” is discussed in more detail in Chapter 6.

There is general agreement that engineering education needs to attract and retain greater numbers of students, increase the numbers of women and underrepresented minorities in the engineering workforce, facilitate acquisition by students of a broader range of skills, and forge deeper connections between universities, K-12 education, industry, professional societies, and other groups. Unlike the U.S. engineering education reforms of the 1950s, which were extensive and had the clear focus of strengthening the science base of engineering education, experts who are proposing change today do not propose an extensive set of reforms implemented from the top down.[14] Instead, the stakeholders in the engineering education system are being urged to make evolutionary changes, many involving partnerships among various institutions.

This general emphasis of reform efforts on creating new partnerships and coalitions reflects changes in engineering education that have occurred over the past 10–15 years. Significant program initiatives with this orientation include the Engineering Research Centers, launched in 1985, and the Engineering Education Coalitions, launched in 1990 and sponsored by the National Science Foundation.

Finally, some have expressed concerns about trends in U.S. doctoral education in both science and engineering.[15] First, the length of time from bachelor's to doctorate has increased in science and engineering fields, moving from 7.6 years in 1979–1980 to 9.1 years in 1994–1995. One view holds that the extra time results from students having to do more research on their professors' projects, reflecting a shift in student funding over the past two decades from fellowships to research assistantships. Some have questioned whether the extra time delivers sufficient educational benefit to the student. In response, a renewed effort to increase fellowship support has been recommended. [16]

Second, the proportion of engineering doctorates awarded to U.S. citizens hovered at about 40 percent during the early 1990s, with the proportion of foreign citizens around 60 percent. Although the reasons for this are complex, and most experts recognize that foreign science and engineering talent has long made a significant contribution to U.S. capabilities, some would advocate efforts to raise the number and proportion of U.S. citizens among doctoral recipients.

Third, employment of doctoral graduates in academia and industrial research declined in the early 1990s, although this has been a larger problem for some scientific fields than in engineering. Efforts to better educate students about non-academic and non-research career options are being pursued.[17]

Japan

Japan also faces significant challenges in undergraduate and graduate engineering education, and a number of policy changes aimed at reform have been undertaken in recent years. In general, concerns expressed by Japanese experts about whether the education system can change quickly enough to meet the needs of a rapidly changing employment environment are similar to those expressed about the U.S. system.

One recent study by the Engineering Academy of Japan (EAJ) identified three emerging mismatches: (1) a mismatch between the education demanded by employers and the education provided by engineering schools, (2) the mismatch between university curricula and high school curricula, and (3) the mismatch between academic and industrial value judgements. [18] The concern expressed in the EAJ report and the Japanese Working Group that increasing numbers of Japanese high school graduates are not well prepared for undergraduate engineering study was surprising to the U.S. Working Group.

Much of the focus on educational reform in both science and engineering in Japan has been on graduate education.[19] This focus is related to Japan's overall effort to improve its capability in fundamental research. Specific initiatives have included increased funding for university-based research as well as for graduate fellowships, as described above. Funding for university and other research facilities has also increased in recent years. The goals are to significantly increase the overall level of research and number of graduates, to facilitate more creative university-based research, and to link research more closely with education.

Japan's reform efforts and policy changes are aimed at addressing several perceived problems in the system besides the simple lack of resources for university research and graduate education. Traditionally, research funding has been channeled from Monbusho to the universities through senior professors to their research groups, known as *koza.* This system has come under criticism because funding is not granted competitively, and because heavy reliance by junior faculty and graduate students on senior professors is seen as discouraging original approaches. The general Japanese practice, particularly at the national universities, of not hiring many faculty who have graduated from other universities is also believed to contribute to a lack of communication and cross-fertilization among academic researchers in Japan.

New programs have attempted to address these issues. For example, new policies are aimed at increasing the flow of industry funds to universities. Since 1995 agencies other than Monbusho, including the Ministry of International Trade and Industry (MITI) and the Science and Technology Agency (STA) have been allowed to support university research. Monbusho, MITI, and STA have all established new funding programs that are awarded competitively. Finally, the number of post-doctoral fellowships have been increased to allow more young Japanese scientists and engineers to gain research experiences outside their home institutions, including abroad.

NOTES AND REFERENCES

[1] See Graduate Education section later in the chapter for a description of this system.

[2] National Center for Education Statistics, *Digest of Education Statistics, 1997* (Washington, D.C.: U.S. Government Printing Office, 1997). If only four-year public institutions are included, the average rises to $2,848. The average total cost of four-year public institutions including room and board was $7,014.

[3] Ibid. If only four-year institutions are included, the average rises to $12,243. The average total cost of four-year private institutions including room and board was $17,612.

[4] National Center for Education Statistics, *Digest of Education Statistics 1997,* 1997.

[5] National Science Board, *Science and Engineering Indicators 1996* (Washington, D.C.: U.S. Government Printing Office, 1996).

[6] From Monbusho.

[7] National Science Foundation, *The Science and Technology Resources of Japan: A Comparison with the United States,* 1997.

[8] William F. Finan and Jeffrey Frey, *The Effectiveness of the Japanese Research-Development Commercialization Cycle: Engineering and Technology Transfer in Japan's Semiconductor Industry,* Semiconductor Research Corporation, August 1989.

[9] D. Eleanor Westney and Kiyonori Sakakibara, *Comparative Study of the Training, Careers, and Organization of Engineers in the Computer Industry in Japan and the United States,* MIT Japan Program, 1985.

[10] Tanya Sienko, *A Comparison of Japanese and U.S. Graduate Programs in Science and Engineering* (Tokyo: National Institute of Science and Technology Policy, 1997).

[11] Committee on Science, Engineering, and Public Policy, *Reshaping the Graduate Education of Scientists and Engineers* (Washington, D.C.: National Academy Press, 1995).

[12] Detailed information on ABET is available on the World Wide Web at http://www.abet.org.

[13] For example, COSEPUP, op. cit.; National Research Council, *Engineering Education: Designing an Adaptive System* (Washington, D.C.: National Academy Press, 1995); American Society for Engineering Education, *Engineering Education for a Changing World,* 1994; and Joseph Bordogna, “Making Connections: The Role of Engineers and Engineering Education,” *The Bridge,* Spring 1997.

[14] Edward W. Ernst, "Reform Efforts in the United States: Where have we been? Where are we going?" Paper delivered at the International Symposium on Engineering Education Reform and Evaluation, Osaka, November 1995.
[15] COSEPUP, op. cit.
[16] Ibid.
[17] See the on-line Career Planning Center for Beginning Scientists and Engineers of the National Academies, at www2.nas.edu/cpc.
[18] Engineering Academy of Japan, "Study on Engineering Education at EAJ," English summary, May 24, 1997.
[19] See Sienko, op. cit.

5

Life Long Learning for Engineers

SUMMARY POINTS

- *Continuing education practices in U.S. and Japanese companies reflect differences in employment patterns and in earlier stages of education. For large Japanese companies, lifelong employment is still the expectation. Engineers are typically rotated through a number of functions during their careers, and large companies maintain extensive in-house capabilities for continuing education. Japanese universities are seeking to play a more active role in continuing education, in areas such as developing distance learning programs.*
- *There appears to be more variance among U.S. companies in their continuing education practices for engineers. Because of the high level of job mobility in the United States, U.S. companies are not willing to invest as much as Japanese companies in continuing education. With intensified competition and tight staffing practices, it has become even more difficult to maintain these investments.*
- *At many large, high-technology U.S. companies, there are defined career paths for engineers who wish to stay in technical positions rather than go into management. Some large U.S. companies maintain extensive in-house programs, but short courses at graduate schools, new institutions such as the National Technological University, and other mechanisms are also used.*
- *In both Japan and the United States, it appears that small and medium-sized companies may face challenges in providing sufficient continuing education opportunities to engineering staff.*

U.S. AND JAPANESE CONTEXT FOR ENGINEERING CAREERS

This section provides an overview of the basic environment for engineering careers and continuing education in the United States and Japan. [1] Table 5-1 shows some differences in the experiences and attitudes of U.S. and Japanese engineers who graduated from top schools: MIT and University of Tokyo. Although the subjects of this survey may not be typical of U.S. and Japanese working engineers, the survey does quantify some general differences between the two countries.

U.S. Context

Economic Context

Several factors have influenced the rise and fall in demand for U.S. engineers in various industries over the past decade and a half. For example, the significant expansion of high technology nonmanufacturing industries such as software and related services, telecommunications and others has resulted in an increase in the demand for engineers in these industries.[2] In the mid 1990s, the gains in competitiveness made by U.S. companies in industries such as automobiles led to a renewed demand for engineers. At the same time, defense budget cuts have led to layoffs of engineers at defense companies. This has led to growing interest in alternative careers for engineers from defense industries.[3]

TABLE 5-1 Comparison of Career Experiences of Massachusetts Institute of Technology and University of Tokyo Engineering Graduates, 1993

	MIT	Tokyo
Have never changed companies in career	29.8%	83.8%
Most desired career path	have own company (25.7%)	climb the organizational ladder (40.2%)
Defense-related job	14.9%	0.9%
Technology-related job	54.8%	67.8%
Manufacturing-related job	5.0%	12.1%

NOTE: The survey was sent to engineering graduates from both schools for years 1960, 1970, 1980, and 1985.
SOURCES: Compiled from Masamichi Ishii, Yoshiko Yokoo, and Yukihiro Hirano, "Comparative Study on Career Distribution and Job Consciousness of Engineering Graduates in Japan and the U.S.," NISTEP Study Material, No. 28, March 1993.

Corporate Context for Continuing Engineering Education in Industry

Since job mobility is high among U.S. engineers, companies are reluctant to invest large amounts of resources in training and continuing education. Education is considered a benefit rather than an investment in essential capabilities. In tough times, education budgets are among the first to be cut. Also, there is a wide variety of engineering education practices among U.S. companies. Some large companies have extensive in-house programs and provide educational benefits such as time off and support to pursue outside training, while others do not.[4] Smaller companies and consulting firms are generally unable to provide in-house training, and are financially constrained from offering educational benefits.

Competitive Context for the Content of Continuing Engineering Training

Particularly in U.S. manufacturing companies that have had to cope with competition from rivals in Japan and elsewhere, a significant focus of attention and resources for training has been in the adaptation of methodologies associated with the Toyota production system and other "pull-based" manufacturing systems, such as just-in-time inventory management, total quality management, concurrent engineering and others. Within manufacturing companies, the demand for engineers with advanced degrees to engage in engineering development linked with manufacturing has increased significantly.[5]

Expected Competencies of Engineers Entering the Company

U.S. engineers entering companies are expected to have acquired from their university training: "an understanding of fundamental scientific principles…command of basic knowledge…an understanding of engineering methods…experience in applying these methods…an understanding of social and economic forces and their relationship with engineering systems…a sense of professional responsibility…mastery of the ability to organize and express ideas (and)…socialization in the thought patterns and conduct appropriate to the profession."[6] Clearly, this list implies a facility to solve problems, which is a major expectation of employers. At a concrete level, engineers are expected to have a considerable amount of experience and competence with computers.

Institutions and Trends

There is widespread recognition of the growing need for engineers and the organizations that employ them to create a new engineering culture that encourages lifelong learning.[7] As noted above, U.S. companies vary widely in their approaches, and the overall patterns of investment in continuing education of U.S. engineers cannot be accurately tracked. Other institutions are seeking to fill the demand for continuing education for engineers, including the engineering societies.

The National Technological University (NTU) is an important example. NTU delivers classes from major engineering schools by satellite to working professionals in industry. NTU and Motorola University, Motorola's extensive in-house program, have been cited as U.S. "best practices" in this field.[8] In the future, it is likely that new technologies such as the Internet and interactive video will have a significant impact on continuing education for engineers.

DeVry Inc. is another interesting example of an institution that has grown to fill the educational needs of U.S. engineers and would-be engineers who must rely on their own resources and initiative. DeVry was founded in 1931 as a mail-order, electronics repair school, and now operates a network of 27 for-profit business and technical schools with a faculty of 850 nationwide.[9]

Other Characteristics of U.S. Engineers

Although the proportion of female engineers in the United States doubled during the 1980s, the profession is still 92 percent male. Except for Asians, who are overrepresented in U.S. engineering, ethnic and racial minorities are underrepresented, although numbers have been rising. For example, among U.S. educated engineering Ph.D. holders in the labor force in 1993, less than 2 percent were African American and less than 2 percent were Hispanic, but over 25 percent were Asian. [10]

Japanese Context

Economic Context

In recent years, a number of Japanese government and private sector reports have expressed concern about falling levels of interest in engineering careers among young people. Although, on the whole, Japanese university engineering departments continue to attract many more applicants every year than they are able to accept, there is a continuing trend of a decrease in the ratio of applicants to acceptances. The increasing number of engineering graduates who chose careers in financial services rather than manufacturing was also raised by some as a concern in the early 1990s. However, this trend seems to have been halted by the continuing tough times in Japan's financial services sector.

Corporate Context for Continuing Education in Industry

Although job mobility in Japan has increased in recent years and is expected to continue rising moderately in the future, in large manufacturing companies, lifetime employment is still the expectation of both companies and engineers. This provides a context in which investments in training and education can be recovered by the company. Most large companies have extensive in-house continuing education programs. The Japanese Working Group reports that these are largely being maintained despite the long recession in Japan.

Another traditional element of Japanese engineering is the emphasis on teamwork. Much of the in-house training that occurs early in the careers of engineers and other new hires is designed to build group consciousness and the effectiveness of teamwork. Teamwork training in Japan begins in K-12 and continues in the university.

Expected Competencies of Engineers Entering the Company

Japanese students entering one of the more prestigious engineering schools typically possess knowledge equivalent to a U.S. college sophomore in math, physical science and written language.[11] Despite this head start, young engineers entering Japanese companies are not expected by their employers to have acquired understanding of engineering methods.

Institutions and Trends

A number of Japanese universities are developing new programs for continuing education and are experimenting with distance learning. [12] Japanese universities are seeking to play a greater role in continuing education for engineers, but task force discussions indicate that Japanese companies are skeptical about whether universities can be as effective as in-house programs. Although several national and private universities have launched night graduate schools in recent years, the focus has been on professional master's programs in areas such as public policy studies, management information systems and counseling.[13]

Japanese task force members also raised concerns about engineers employed by smaller companies, whose continuing education needs appear to be underserved. A 1990 survey by the Japan Federation of Employers Association, or *Nikkeiren,* found that 35.4 percent of firms reported that they were too busy to find time for continuing education for employees.[14] The survey also shows that Japanese companies spend about the same amount on professional development per employee for engineers as they do for marketing staff.

Another U.S.-Japan contrast lies in the role of professional certification for engineers.[15] As in the United States, certification is more important in construction, architecture and building engineering. In contrast to the United States, where professional certification is regulated by the states, several of Japan's central government ministries regulate the process. In 1995 only 32,000 engineers, including 69 foreigners, held a Gijutsushi license, which is useful when opening a consulting office.[16]

Other Characteristics of Japanese Engineers

Japan's largely homogenous population means that there is even less diversity among Japanese engineers than is the case in the United States. Therefore, Japanese engineers may have less opportunity to work with other engineers with significantly different backgrounds and perspectives.

U.S.-JAPAN COMPARISON OF ENGINEERING CAREERS AND CONTINUING EDUCATION EXPERIENCES.

This section compares typical engineering careers and continuing education experiences in U.S. and Japanese companies. To supplement the broad general discussion, the task force was fortunate to be able to examine the approaches of Xerox Corporation and Fuji Xerox. [17] Although the two companies design, develop, and manufacture similar hardware and technology, engineering careers and continuing education experiences can differ significantly. This specific comparison reveals a number of general differences in continuing education for engineers between the two countries. Figure 5-1 shows the expected career paths of engineers at Xerox and Fuji Xerox.

The differences start with the attitudes and expectations of employer and employee as new engineers enter the company. The primary goal of new engineering graduates entering Xerox is to obtain skills and experience, which are critical for enhancing their market value both inside and outside the company. By contrast, the Japanese engineering graduate views entering Fuji Xerox as the beginning of a life-long relationship.

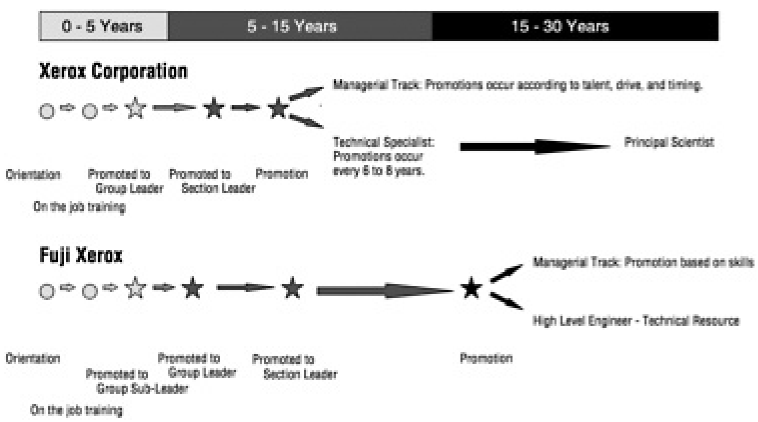

Figure 5-1 Typical Xerox and Fuji Xerox engineering career paths. SOURCE: Xerox and Fuji Xerox.

Early Career Training

General Issues

Most U.S. engineers hired out of college and employed by U.S. companies spend their first few years working under the supervision of a senior engineer and performing specific tasks in areas like product development or process design. Skills needed to meet deadlines, work in teams and manage projects are learned on the job without much formal in-house training. Many engineers begin taking post-graduate courses after work if their employer provides support. Particularly valuable in learning are mentoring relationships with senior engineers. U.S. companies are very diverse in the approaches that they use.

Compared to U.S. companies, the training approaches of large Japanese companies for early career engineers are extensive, systematic and quite similar across companies and industries. Training for new hires typically begins with several months of general training on the various operations of the company. Once Japanese engineers are assigned to a specific product development, research or manufacturing section, they sometimes go through a process of one-to-one training in which they are assigned to various engineers in the section for a period of one or two weeks each. On-the-job training is supplemented by course work in in-house educational programs and “small group activities” aimed at improving group performance and productivity. Box 5-1 describes NEC's in-house programs. Much of the in-house training that occurs early in the careers of engineers and other new hires is designed to build group consciousness and the effectiveness of teamwork.

Xerox Early Career Training

Xerox Corporation hires engineers into one of three major career areas: Research, Product Development or Manufacturing. Training of new graduates varies for each of these areas as business needs change. The general orientation at Xerox consists of a day long session where representatives from various departments explain their role in the engineer's future. Much of the orientation consists of fulfilling various administrative tasks, such as filling in forms and learning about company benefits. In addition, all Xerox engineers are required to take a one week course in Xerox quality principles and processes, known as Leadership through Quality.

In the 1980s Xerox recognized the need to build stronger links between product development engineers and end customers, as well as to heighten awareness of the manufacturing environment where their product designs would be realized. The goals of “design for manufacturability and serviceability” were to reduce service and manufacturing costs and to increase quality while reducing time to market. Engineers from various disciplines were trained in a one-year Engineering Development Program (EDP). The EDP began with a full week of instruction on Xerox Corporation, Xerography technology, and Xerox quality principles with emphasis on customer satisfaction. This was followed by a three month field service assignment that pairs each engineer with a service district. Engineers were provided with hands-on experience in product service and customer interface. The service assignment was followed by a nine month assignment in a manufacturing facility.

EDP graduates participated in a job fair for the open entry level engineering positions, since job assignments under this recruitment structure were not identified at the time of hire. Although all new hire engineers did not go through the entire EDP process, the majority participated in one or more phases.

BOX 5-1 CONTINUING EDUCATION PROGRAMS AT NEC CORPORATION

NEC Corporation maintains extensive continuing education programs, particularly for engineers. The NEC Institute of Technology Education was established in 1979, has a full-time staff of less than 20 and an additional 20 on concurrent assignments as steering committee members. Since 1979, there have been three principal study programs:

Integrated Technology Study Program (ITSP)

ITSP is a one-year general program aimed at broadening the knowledge of engineers in their chosen field who have been in the company for at least two years. Students dedicate one day a week to the program. Courses include communication technology, information processing (hardware, software), systems engineering, semiconductor device technology, and mechatronics.

Principal Technology Study Program (PTSP)

PTSP is designed to strengthen the ability of engineers who have been in the company for at least five years to develop new products. It is a year-long program, with students spending one half day every two weeks in class for the first six months and preparing a thesis during the second six months. Courses offered during a recent session included micro-fabrication technology, pattern recognition technology, object-oriented software, and information network technology.

Relevant Technology Study Program (RTSP)

RTSP consists of a variety of technology-specific courses ranging from three days to one year and is targeted at a broad range of engineers, from new hires to section chiefs. Recent study themes included LSI designs, artificial intelligence (AI) systems, and space navigation systems.

Recently, NEC Institute of Technology Education was reorganized to become NEC University, integrated together with other in-house educational institutions. The University will deliver and support continuing education programs, including synchronous and asynchronous distance learning for various domestic and overseas subsidiaries.

SOURCE: NEC Corporation.

Xerox revamped its training approach in the early 1990's, as it restructured into smaller, more autonomous business divisions focused on specific markets. For example, the EDP program was dropped. Engineering teams and supporting human resource development organizations were split to support the business division structure. As a result, orientation and early career training have become more varied between divisions.

More recently, Xerox is reevaluating this decentralized approach, which has produced engineers with 5 to 10 years of tenure with diverse skills and training experiences. There is a growing recognition that some degree of centralized engineering training activity and common core skill requirements across divisions is valuable. However, continuing organizational change—the only constant in today's U.S. industry environment—makes defining and implementing such a “core skills” approach increasingly difficult.

When an engineer is first assigned to a work group or team at Xerox, training is loosely structured and may include the assignment of one or more senior engineers to mentor and assist the new team member. The first few weeks are spent learning the relevant designs and processes, visiting the various management forums and labs, and simply observing. The engineer is assigned to assist a more senior engineer on a current project or may be assigned a small project. Although the assignments in the three career areas mentioned above vary dramatically, team dynamics are crucial in all. It is here that the engineer will develop the necessary scientific skills and day-to-day administrative skills that will be crucial for future success. Many of the lessons learned during the first year or so will be taught by the work group. Each member of the group will be a role model and resource for the new employee. It is through this interaction with established members of the community that the new engineer gains confidence and experience.

Relevant training and continuing education during this time period are specific to the career area chosen. For example, manufacturing engineers are given courses in safety, quality control, and parts/supplies management, while product development engineers are given courses in product development processes and design methodology. Priority is given to training directly relevant to the job and product area to which the engineer has been assigned. Training is not generic across Xerox and varies at the discretion of the product manager and the engineer. Although all Xerox employees are encouraged to take a minimum of two courses per year in career development (this is tracked and managed via the annual objective management processes) it is not atypical for engineers to double or triple this objective in the first three to five years of their careers.

As their skills and experience increase, young engineers begin to emerge as individual contributors to the group. After three to four years, they are prepared to take on additional responsibilities such as leadership of small tasks. As a project or task leader the engineer has greater autonomy and a strong role in the group's viability. This role usually includes directing or mentoring junior engineers, technicians and designers.

Fuji Xerox Early Career Training

At Fuji Xerox the idea of orientation encompasses a much broader introduction to the company than does the typical U.S. company orientation. The process takes three months to complete and involves exposure to many areas of the company. In the first month, all new corporate hires, including engineers, reside at the training center and study the company. They learn about Fuji Xerox's history, organizational structure, products in production, and marketing strategies. They also take part in problem solving and teamwork exercises and training.

After this overview, new employees are deployed to specific manufacturing areas for one month. They may work on an assembly line, in distribution, or perhaps in a warehouse. This experience allows each new hire to gain valuable exposure to the products.

The final month of orientation brings the new employee face to face with the customer. A sales representative will act as a mentor for a small number of new employees. The mentor takes the group to meet customers and helps them understand the customer's requirements and concerns. At the end of the orientation period, each engineer is assigned to an organization by the Human Resources Department and begins on-the-job training (OJT). It is important to note that this is not a job assignment, the engineer has simply been named to a certain organization.

At Fuji Xerox, OJT is formalized as a one year assignment. Every entering engineer is matched with a trainer or mentor. This mentor is usually a mid-level engineer with five to ten years of experience. During their year together the new employee helps the mentor do their job, while the mentor teaches the new employee the tools necessary to do the job. Along with the technical exchange, a large component of learning involves interaction with other members of the organization. This contact will help the new employee when a tentative job is assigned at the end of OJT.

After three years on the job, the Fuji Xerox engineer will usually become a small group sub-leader. As a part of this transition the employee takes part in two weeks of mandatory non-technical training. This training will concentrate on essential leadership qualities. The position of group sub-leader will afford the employee the chance to develop leadership skills slowly, while continuing to enhance his technical expertise.

The Five to Fifteen Year Professional

General Issues

Even after they have achieved the status of established members of the technical community of their respective companies, Japanese and U.S. engineers still differ with regard to their responsibilities and roles. At Xerox Corp., for example, engineers are typically responsible for concept, analysis, and the necessary administrative steps for getting a component from the designer's drawings into the manufacturing process. By contrast, engineers at Fuji Xerox have a broader range of responsibilities. A typical engineer will do his or her own design and testing. Engineers are responsible for the concept, analysis, and ultimately manufacturing. For the Fuji Xerox engineer, a solid knowledge of technology, cost management, and manufacturing technology is a must.

After five years, about half the entering cohort of engineers at a typical large U.S. company has moved on to a different company or left to pursue graduate training. At this point engineers still with their original companies are typically assessing whether they want to stay in a technical track or move to a management track. Apart from tuition reimbursement, it does not appear that corporate investments in continuing education are large during the first five years. Engineers themselves are largely responsible for planning their own careers and acquiring necessary skills.

As time passes, it becomes increasingly difficult to maintain current engineering skills, which gives companies a high incentive to move experienced engineers into management rather than retrain them for purely technical responsibilities. Many companies have created parallel ladders to allow engineers to receive substantial promotions and raises without entering management. While engineers can receive good starting salaries, salary growth tends to slow after ten years if they stay in engineering. In 1992, for example, median salary for an engineer with a master's degree and ten years of experience was $53,400, but only $64,850 for 25 years of experience.[18]

In contrast to the United States, where the tendency is for individuals to bear the greatest responsibility for career planning and determining training needs, Japanese companies take on more responsibility for career development.

After five years the Japanese engineer has mastered the specific engineering tasks and issues in the section and is looking forward to his first promotion and job rotation. In some industries, such as computers and semiconductors, promising new hires are typically assigned to product development. After they have mastered the relevant technology and are experienced with the product, they are often rotated to the manufacturing plant that produces the product that they have designed. After several years in manufacturing, engineers are often assigned to work in marketing and service functions, with their performance in these areas enhanced by their knowledge of the product.

Most Japanese engineers are expected to move into some form of management as they advance through the company. Typically, after 7–8 years, an engineer will be promoted to *kakaricho,* responsible for supervising 5–10 others. In the mid to late thirties engineers are promoted to *kacho,* or section chief. Promotion to *bucho,* or division chief, typically occurs in one's late forties.

Japanese companies also use study leaves as a professional development tool.[19] This involves selection of key personnel between the ages of about 25 to 35 for dispatch to a university, research institute, or another company as a visiting scholar or researcher for periods of up to several years. This mechanism is rarely utilized by U.S. companies.

Xerox Practices and Experience.

In the United States, the question of whether to pursue a managerial career or stay in a technical path arises early. Most U.S. companies maintain “dual ladder” systems. Still, in Xerox as in many other U.S. companies, there are a number of pressures on engineers to pursue a managerial path. Long-term career opportunities for the generalist far exceed those available for technical specialists. Although ascendancy as a technical expert is possible, there are fewer opportunities as promotional grades climb, and compensation lags for technical specialists with equivalent years of employment. Given the low number of opportunities for technical specialists, the qualifications, in terms of experience and education, are significant.

In the six to eight year range, a Xerox engineer may be given responsibility for an entire sub-system. As a sub-system leader, the engineer will lead a team and oversee all aspects of the sub-system. At about ten years the engineer faces the decision of whether to remain a technical contributor or to proceed on the managerial track, an issue discussed further below. Although job rotation is not formalized within Xerox, most projects have a life cycle of 3–5 years. Engineers have the opportunity to move to new areas of development, design or manufacturing at the conclusion of the project or after some mutually agreed milestone.

Outstanding Xerox engineers may be promoted to management after about ten years. Several years prior to this, the engineer begins preparatory coursework. It is during this time frame that engineers begin to select the path of management or technical specialist. One concrete issue is whether the engineer should pursue an MBA degree to complement his or her technical skills. Skills and technical courses are widely available at Xerox through video courses, on-site courses at local universities, as well as in-house training programs. Prior to the advent of a focused re-engineering effort at Xerox, however, the technical training, averaged over the whole population, was probably only in the range of 2–3 days per employee annually.

The engineer desiring management experience will seek to gain experience managing small projects and giving direction to a group of engineers. Course study varies from formal in-house management development courses, to pursuit of graduate degrees (MBA, MS, Technical Management). Those focusing on becoming technical experts seek more challenging and complex systems and designs with more opportunity for innovation and invention. Course study focuses on specialized technical areas of interest, conference attendance and seminars. Graduate and/or doctoral degrees may be pursued to complete their technical portfolio and further establish their expertise. Those engineers who fail to plan may maintain skills relevant for their current jobs, but may be unprepared to ascend as technical specialists or technical managers.

There are two specific branches of technical management. One can achieve up to middle management levels as an area or discipline manager. The opportunities are more lucrative, however, for those broadening their experience set to comprehend product and system integration. The Chief Engineer and Technical Program Manager are required to possess a practitioner level of knowledge in the key process areas of systems engineering, system design or architecture, design or module integration, system or product assurance, and operability. Systems engineering is a learned discipline requiring a foundation in a core engineering discipline supplemented by experience in each of the key process areas (manufacturing, marketing) through rotational assignments.

Fuji Xerox

Fuji Xerox has approximately 15,000 employees, of whom about 5,600 are engineers. About 4,000 of these engineers are considered to be specialists. Fuji Xerox invests 330 million yen per year in continuing education on this group of 4,000 (about 82,000 yen per engineer).

There are ten full-time staff members devoted to engineering education with responsibility for planning, preparation, management, and supervision. Fuji Xerox also maintains an in-house training facility. Engineers enrolled in classes reside at the facility. In 1994, Fuji Xerox engineers spent a total of 11,000 days on engineering training. Across Fuji Xerox, all employees spent a total of 76,000 days receiving training.

Fuji Xerox offers two types of continuing education courses for engineers. The first type includes “common” or general courses that are offered to all salaried employees by the Fuji Xerox Learning Institute (FXLI). Topics for these general courses include management skills, approach to quality circles (small group activities aimed at improving quality), financial management and personnel regulations. In addition, technology-oriented courses are offered by the Technical Human Resources Department. These include management engineering (encompasses industrial engineering, quality circles, “value engineering,” and cost management), computer skills (including new software packages, firmware, and computer-aided design), chromatics, and Xerography engineering. Over 2,000 Fuji Xerox engineers per year take a technology specific course. Employees stay at the in-house training facility for classroom sessions and experimental work.

Each division in Fuji Xerox has an education promotion committee which announces and promotes education programs. Course guides provided by the Technical Human Resources Department are available to all employees in electronic form. Course selection is based on the engineer's interest and guidance from his manager, taking experience and career plans into account. Lecturers and trainers are mainly drawn from the Fuji Xerox engineering staff, although the engineering education department also has a few full-time lecturers.

Engineers at Fuji Xerox are generally given greater responsibility after roughly five years. At this point, engineers are given two weeks of mandatory training to prepare them for their responsibilities as group leader.

Every two years the Fuji Xerox engineer generates a report for his manager and the Human Resources division that indicates the desired next job. Although rotation is ultimately decided by management, the engineer's request is given weight, and reflects previous informal consultation among the engineer, supervisor and others. In Fuji Xerox approximately 4 percent of engineers per year are rotated to another department to experience development of a different product, manufacturing process or quality control.

Later Career Trends

After 10 or 15 years of experience, it appears that investments in continuing engineering education drop off for most companies and most engineers, in both the United States and Japan.

For the experienced Xerox engineer still remaining on the technical career path the last remaining step would be to be named a principal engineer. A minority of the best and most senior engineers will earn this promotion. For engineers who have chosen the managerial path promotions are no longer a matter of seniority alone. The rate of promotion and final level attained are based on a mixture of talent, drive and proven performance. Engineers who have reached the Chief Engineer or Technical Program Management levels may aspire to business management positions, and will seek rotational assignments in marketing, sales or other areas to gain the needed experience.

Approximately 30 percent of engineers at Fuji Xerox are officially recognized as experts in a specific area of technology, compared with less than 5 percent at Xerox. Over half of Fuji Xerox engineers move into some form of management such as technical manager, product manager or a staff position. For engineers who have moved into line management or staff positions, management education is more important than engineering education.

Although the percentage of engineers entering management is not as high at Xerox as it is at Fuji Xerox, the opportunity set is similar. Management training is a priority at this stage. Although technical currency is also important, knowledge requirements typically fall short of a practitioner level. Those who have moved into technical management require some knowledge and currency on tool sets and processes relevant to their discipline to ensure peak productivity and quality levels from their teams. Those engineering professionals moving into middle management rarely do so without some cross-functional experience.

The typical timelines described here for Xerox and Fuji Xerox are for “normal” entry level engineers. Both companies have rather similar advancement paths. The timing of promotions is more defined, however, at Fuji Xerox. An additional similarity exists in the “final” job choice. For both companies moving into management is much more lucrative than remaining on an engineering track.

ISSUES

Maintaining Technical Currency and Vitality

Since engineers in the United States have traditionally been accountable for their own continuing education, they have also recognized ownership of their own technical currency. However, until recently, technical currency has been defined narrowly by many engineers in the context of their current job. In the view of the U.S. working group, the trend toward downsizing by large U.S. companies is forcing many engineers to broaden the context of technical currency to technology that is state of the art across their industry.

Engineers are facing the same challenge at a micro level that corporations are facing. Within corporations it is often cheaper to hire new employees with needed skills than retrain the existing workforce. Faced with this dilemma, engineers seeking to maintain technical currency must place equal importance on skills needed for their current job and those in demand on the open market. Rather than expecting to climb the corporate ladder, engineers must maintain a portfolio of skills that they can sell to a series of customers or employers.[20]

The cost individually of maintaining technical currency is great. Graduate course study can exceed $3,000 per course. Courses by independent training companies are equally expensive and often require time off during the work day. Given these costs, educational benefits such as tuition reimbursement is one of the most important portions of a company's overall benefit package.

Despite changes in the Japanese business environment, this issue of maintaining technical currency is not as urgent for the Japanese engineer. Japanese engineers still expect lifetime employment and assume that the company is largely responsible for continuing education. Japanese engineers rarely leave their companies for graduate school or go to night school at their own expense.

Just as individual engineers face the challenge of maintaining their technical currency, U.S. and Japanese companies are faced with maintaining technical vitality. Paul Gehrmann defines the notion of technical vitality as "…acquiring, applying, communicating and creating technical knowledge."[21] Maintaining technical vitality in organizations is becoming more difficult and expensive as technological change accelerates and organizations become flatter and leaner. For Xerox, Fuji Xerox and many other U.S. and Japanese companies, training aimed at allowing engineers to take maximum advantage of information technologies is a major focus of efforts to maintain technical vitality.

A related issue faced by established companies is to balance the imperative to incorporate new technologies with the requirement of maintaining and further developing old technologies. In many cases these technologies are core to the business, such as Xerography in the copying business. Engineers are required to become experts in old technologies to assure the maintenance and support of key products. Managing and balancing these needs is difficult, particularly for U.S. companies where engineers need to be prepared to move to a different company. Engineers will be increasingly reluctant to develop skills in older technical areas that may not be valued outside the company.

Maintaining technical currency (for individual engineers) and technical vitality (for companies) involves considerable expense. Estimates range from 15 percent of available business time per person to the equivalent of one college course per semester. At this point, it is easier for Japanese companies to make these investments because the long-term interests of the company and individual engineers coincide fairly well. It is more difficult in the United States, since companies are more reluctant to invest in employee training due to greater job mobility than in Japan.

The Importance of Diversified Experience

Excellent U.S. and Japanese companies agree that diversified experiences are very beneficial for engineers, particularly for those wishing to move into management. Through extensive on-the-job training and rotational assignments, Japanese companies have long focused on exposing engineers to customer interaction and the manufacturing environment. U.S. companies are increasingly aware of the benefits of engineers gaining experience in dealing with customers and with manufacturing. In many businesses, such as information systems, the involvement of engineers in working with clients to specify needs and develop solutions is increasingly essential to a successful project.

Lifetime Employment and the Need for Different Perspectives

Fuji Xerox and other large companies in Japan have an advantage in being able to design and undertake in-house continuing education programs that strengthen the skills of engineers in support of company goals. The lifetime employment system that makes this possible does have a downside, however. There is a danger that the engineering culture of a company may become inbred, stagnant and resistant to change. In recent years, Japanese companies have expressed concern that the Japanese education system and social tradition do not sufficiently promote risk taking and originality among engineers. [22] U.S. and Japanese members agree that younger American engineers generally have more input into decision-making than engineers at a similar age do in Japan.

NOTES AND REFERENCES

[1] This section relies heavily on Pamela Atkinson, “Continuing Engineering Education in the U.S. and Japan: Exploring Best Practices,” May 1, 1994.

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[3] See Committee on Science, Engineering, and Public Policy, *Reshaping the Graduate Education of Scientists and Engineers,* (Washington, D.C.: National Academy Press, 1995).

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[5] Arden Bement, “An Industrial Perspective on Engineering Training and Education,” Remarks at the Academies-JSPS Meeting on Scientific and Technological Interdependence: New Challenges for the United States and Japan, 1991.

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[13] Monbusho Koto Kyoiku Kyoku (Ministry of Education, Science, and Culture Higher Education Bureau), “Rifuresshu kyoiku kanren data shu” (Data related to continuing education), March 1995.

[14] Reported in Lola Okazaki-Ward, *Management Education and Training in Japan* (London: Graham & Trotman, 1993).

[15] Kaneichiro Imai, “Recent Changes in Engineering Education in Japan,” Paper presented at the American Society for Engineering Education International Conference on Engineering Education and Practice, June 1996.

[16] Ibid. By contrast, over 250,000 were Registered Architect and Building Engineers, and 350,000 were Registered Civil Construction and Management Engineers.

[17] The Joint Task Force appreciates the work of Task Force member Mark Myers and Xerox engineer Kim Smith in developing this comparative material.

[18] Mark Alpert, “The Care and Feeding of Engineers,” *Fortune,* September 21, 1992.

[19] Sam Stern, “Education and Work in Japan: Implications for Policy,” *Educational Policy,* Vol. IX, No. 2, June 1995, p. 205.

[20] Valery Law, “Graduating Engineer: Current Trends in the Entry Level Engineering Job Market,” Speech at the Annual Convocation of Professional Engineering Societies, May 16, 1994.

[21] Paul Gehrmann, "Technical Vitality of Computer Professionals: A Competitive Advantage of the 90s," *American Programmer,* January 1996, Vol. IX, No. 1.

[22] Companies are taking a variety of approaches to address this problem. Some have reported success with utilizing foreign engineers as "project leaders" to introduce Japanese employees to new perspectives. See Nihon Seisansei Honbu (Japan Productivity Center), *Minkan Kigyo ni okeru Kenkyusha/Gijutsusha no Ikusei oyobi Katsuyo ni kan suru Jitsujo Chosa (Survey on Actual Experience of Private Companies in Training and Utilizing Researchers and Engineers),* report commissioned by the Agency for Industrial Science and Technology, March 1994.

6

Meeting the Challenge of Global Engineering

SUMMARY POINTS

- *A "global engineer" is defined as one who has the personal qualities, international knowledge, and technical skills required to work effectively in a range of international settings and work environments.*
- *The United States and Japan are among the leading countries in global engineering activities and capability. However, the two countries have different strengths and environments for global engineering training and education.*
- *The global engineering skill set includes (1) language and cultural skills, (2) teamwork and group dynamics skills, (3) knowledge of the business and engineering cultures of counterpart countries, and (4) knowledge of international variations in engineering education and practice.*
- *This U.S.-Japan joint study naturally focuses on the experiences and capabilities of Japan and the United States. Still, the Joint Task Force believes that much of this experience has wider applicability, and that an expanded examination of global engineering issues to include other developed and developing countries would be useful.*
- *The U.S. group believes that the United States has been making progress in developing awareness of the importance of international capabilities in engineering, but believes that new efforts by government, universities and industry are needed.*

WHY ENGINEERS WITH GLOBAL CAPABILITIES?

With the explosive growth in recent years of foreign direct investment and international corporate alliances involving technology transfer and engineering cooperation, the development of products and manufacturing processes increasingly requires cooperation among technical personnel based in two or more countries. Speed to market, efficiency in product development and even the technical success and failure of a given project often depend on the performance of engineers working in international settings with teams spanning diverse cultures. Japanese and U.S.-based companies are very often at the forefront of these global engineering activities.[1] Even in academic research, collaboration between researchers in different countries is becoming more frequent and more important to the advancement of engineering science.

Recognizing the growing necessity for American and Japanese engineers to work effectively in international collaborative activities, the Joint Task Force on Engineering Education decided to focus a major part of its effort on identifying the required capabilities of "global engineers," the skills and approaches that engineers from the United States and Japan bring to international collaboration, and future tasks for companies, educational institutions and engineers to meet emerging challenges of the global engineering environment.[2]

A U.S.-Japan Definition and Vision of the "Global Engineer"

At a basic level, a "global engineer" can be defined as one who possesses the cultural and personal skills to work effectively anywhere in the world, displays outstanding technical competence, and contributes to advancing the objectives of his or her individual organization and its partners. Below, we will discuss in greater detail the skills and capabilities required of global engineers, and the contributions that global engineers can be expected to make in the future.

U.S. AND JAPANESE CONTEXT FOR DEVELOPING AND UTILIZING ENGINEERS WITH INTERNATIONAL SKILLS

The preceding chapters provide most of the context for understanding the skills, styles of work and engineering cultures that prevail in the United States and Japan today, and how they affect the skills and capabilities that U.S. and Japanese engineers bring to international collaborative activities. Some of the material for the following discussion is drawn from surveys and interviews conducted by the Japanese and U.S. working groups (see Box 6-1).

The Place of Engineers in Society

U.S. and Japanese engineers both play prominent roles in their respective societies, but there are interesting differences. It is widely perceived that managers with engineering backgrounds are more likely to rise to the top management level in Japanese companies, particularly in manufacturing, than is the case in U.S. companies. Figure 6-1 shows that a high percentage of Japan's corporate top management are engineers. Rigorous U.S.-Japan comparative surveys are difficult to come by.

The situation in public service appears to be somewhat different. It appears that U.S. engineers and scientists are more likely to hold key policymaking positions as cabinet level officials and heads of major scientific and regulatory agencies than are Japanese scientists and engineers. This is partly due to the fact that under Japan's parliamentary system elected legislators are generally chosen to head the major agencies, in contrast to the U.S. system in which the president appoints cabinet members from a variety of backgrounds. In addition, the U.S. system allows for presidential appointments to a much lower level of the bureaucracy than is the case in Japan, where only the minister and a parliamentary vice minister for each agency are appointed by the prime minister. Career officials, many of whom graduated from the law or economics faculties of their universities, possess correspondingly greater influence in Japan.

Therefore, while it appears that Japanese engineers enjoy a higher level of status and responsibility in the corporate sector than their U.S. counterparts, greater job mobility and other factors may allow U.S. engineers the flexibility to wield leadership in a wider range of institutions, including universities, private foundations and other nonprofit organizations, as well as public service in federal, state and local agencies.

BOX 6-1 INFORMAL U.S. AND JAPANESE SURVEYS ON GLOBAL ENGINEERING

Discussion in this chapter incorporates insights from informal surveys conducted separately by the U.S. and Japanese Working Groups on issues related to global engineering.

U.S. Survey

The U.S. group asked two types of experts for their perspectives on global engineering. One type consisted of two senior managers with engineering backgrounds, one the senior vice president for technology at a supplier of high performance computing systems and the other the chief executive officer of an engineering consulting firm specializing in risk-based assessment of engineered systems. This group gave “corporate level” assessments of the motivations and context for international cooperation in engineering and technology development. These managers gave their perspectives on the following issues:

- What has been the experience of upper management involved in international engineering projects?
- What role has global engineering cooperation played in strategic decisions? What factors have prompted your firm's decision to pursue global engineering cooperation?
- What criteria are used to select and evaluate opportunities for global engineering cooperation? How have these criteria been affected by your experience with past opportunities?
- What have been the significant problems and successes related to global engineering cooperation?

In addition to these two senior managers, the U.S. group also heard from two engineering managers with hands-on experience in U.S.-Japan and other international engineering and product development projects. One of these “project level” engineers had worked with a small software developer, and the other for a large office equipment manufacturer. They gave their perspectives on the following issues:

- What has been the experience of the “front line” engineers involved in international engineering efforts?
- What special capabilities are provided by global engineering project teams? What obstacles arise from global engineering interaction?
- What human relations issues have emerged on such projects?
- What special training requirements have been identified from the need to integrate global engineering staffs? What skills or special competencies are expected from the global engineer?
- What incentives are there for individuals to develop global engineering skills? What are the avenues for obtaining these skills?
- What have been the significant problems and successes related to the interaction of multinational staffs?

Japanese Survey

The Japanese Working Group sent questionnaires to managers at nine large manufacturing companies, mainly in the electronics and heavy equipment sectors. Of the nine respondents, most were directors of their respective firm's technical training institute, although a few managed other activities.

The Japanese survey included the following questions:

- What are the skills and capabilities required for a global engineer?
- Through what methods of training can acquisition of these skills and capabilities be ensured?
- What are the necessary university curriculum and ancillary training programs for nurturing global engineers?
- How should the nurturing and development of various global engineering capabilities such as applying international standards, adapting to diverse cultures, and effective project management be handled?
- Can it be said that group problem-solving capability is high among Japanese engineers? How do Japanese and U.S. engineers compare in this area?
- What is your future vision of a global engineer?
- Describe a concrete example of a person who has succeeded in fulfilling the requirements of a global engineer (including nationality, product specialty, operational specialty, key factors in their success).

Incentives for Organizations.

One of the engineers interviewed by the U.S. working group was a senior executive at Alpha Corp., a medium-sized U.S. company in the field of high performance computing (not the real name of the company). This company's experience reflects a number of the traditional motivations for international engineering collaboration on the part of U.S. companies. Alpha has utilized collaboration in order to develop market opportunities in a variety of countries, and most of the international projects involve some form of technology transfer from the United States to the other country or vice versa. Although at times international collaboration can be difficult to manage, Alpha reports that the benefits of greater exposure in international markets are well worth it.

Alpha makes extensive use of foreign nationals in its overseas operations and alliances. Most collaboration is company-to-company. In one case, Alpha worked with a large Japanese steel company as it sought to diversify into computing and information systems. Alpha received funding for the development of several specific products. The Japanese partner became more familiar with the American management style in computing, and gained licensing revenues and limited distribution rights within the Japanese market. Most of Alpha's successful collaborative projects with non-U.S. companies have been with Japanese partners. Market exposure and access, rather than technology acquisition, has typically been the most important motivation for Alpha.

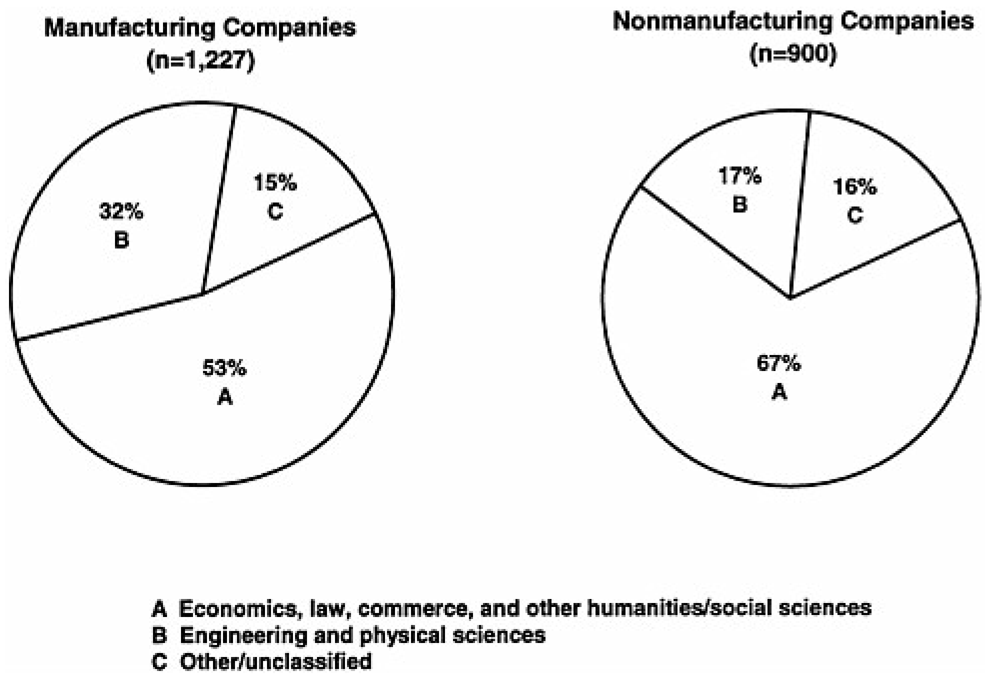

Figure 6-1 Academic backgrounds of Japanese corporate presidents, 1993. SOURCE: Toyo Keizai Shimpo Company.

In other cases, Alpha has had success in working jointly with universities in Taiwan and Spain. This has worked well in terms of accessing technology. Since universities are often able to tap government funding, this approach can also help to leverage resources. In Alpha's experience, a non-U.S. university will generally not demand technology transfer as a condition for collaboration, as non-U.S. companies often do. Indeed, collaboration with Taiwan has been expanding in recent years. One factor contributing to the ease of collaboration is that the vast majority of Taiwanese engineers with graduate degrees received advanced training in the United States. Thus, Taiwanese engineers often have a better understanding of American culture than do engineers from other countries.

Incentives for Individuals

The U.S. respondents point out that there are few immediate incentives for individual engineers to develop international skills and experience. Often, these skills and experience are gained as a by-product of being selected to work on a given international project because of specific technical skills. Japanese companies are seen by U.S. respondents as generally providing more structured career tracks and support for employees to gain international skills. However, Japanese respondents did not think that the approaches of Japanese companies are adequate at this point.

Both Japanese and U.S. respondents pointed out several strengths of the U.S. system. For example, several Japanese responses pointed out that although Japanese companies do send talented engineers for training in leading U.S. universities, the U.S. system provides greater flexibility for individuals to pursue their own interests and gain necessary skills by returning to graduate school or seeking other outside training.

Another difference between the U.S. and Japanese systems springs from differences in approaches to managing international operations. According to several U.S. respondents, U.S. companies are more likely to rely on non-U.S. engineers and other professionals in managing overseas facilities and engaging in collaborative product development than Japanese companies are to rely on non-Japanese. Many of these foreign engineers with experience in U.S. multinational companies have moved to the United States to take on key responsibilities with headquarters. As their numbers grow, and it becomes more obvious that the best U.S. companies do not limit the opportunities of capable foreigners, these U.S. companies are better able to attract highly skilled foreign engineers.

Accreditation and Certification Standards

Two kinds of standards can affect global engineering. The first consists of the standards used to accredit or certify engineering education programs and professional engineers. Chapter 4 contains some discussion of differences between the United States and Japan in accrediting undergraduate and graduate engineering education programs. The Accreditation Board for Engineering and Technology (ABET), the U.S. accreditation body, is a participant in the Washington Accord, where a number of countries grant mutual recognition to their engineering accreditation processes.

The Japanese working group believes that the development of international standards for certifying professional engineers is an important task. [3] In practice, certification is most important in civil engineering and related areas involving large projects. Some members of the U.S. working group believe that the engineering community as a whole needs to pay more attention to certification as a means of enhancing the status of engineering as a profession. The present study was not able to address certification issues in great detail, but the task force members agree that international harmonization in accreditation and certification will be increasingly important.

The second area in which standards affect global engineering is that related to information technology and other systems standards. The U.S. and Japanese surveys indicate that familiarity with these standards usually needs to be acquired on the job.

U.S. AND JAPANESE PERSPECTIVES ON GLOBAL ENGINEERING TASKS AND NECESSARY SKILLS

The Challenge of Organizing and Managing Multinational Product Teams

One of the experts interviewed by the U.S. Working Group worked as a “front line” engineer who managed and participated in a variety of international engineering projects for Advanced Office, Inc. (AOI), a major supplier of office equipment (not the real name of the company). Multinational teams utilizing staff from the United States, Japan and Europe have developed a number of products collaboratively.

These global engineering project teams have provided AOI with world wide engineering development capability, allowing it to capitalize on the strengths of each site and to implement development and manufacturing world wide. This global engineering capability gives AOI the flexibility to locate development or manufacturing activities at the most desirable site.

AOI has encountered a variety of obstacles to smooth global engineering interactions. There are often differing agendas among the regions involved in a project. Ultimate customer requirements are sometimes different for each market area. Different views of contracts or specifications exist. There are differences between the short-term and long-term focus or vision. Personnel issues, such as differences in merit systems, promotions, rewards and recognition, vacation entitlement and practices, bonus systems, expense accounting and local customs governing relationships with vendors and customers, are frequent obstacles. Ordinary “red-tape” or paper work problems and relationships with government agencies can be a source of frustration.

Communications problems arise between team members due to differences in language, culture, value systems, process and protocol. Differences in style and perspective among team members can also cause friction in areas such as the value placed on the ability to act quickly as opposed to a desire for advanced preparation. Outside the United States there is a greater focus on the importance of establishing interpersonal relationships as part of the business relationships among team members. Foreign team members often place a much greater emphasis than Americans upon their view of total consistency in a person's behavior. They expect to see an integration of the business, social and personal behaviors of an individual. This emphasis may have important implications for the training of U.S. engineers. Finally, hardships arise due to long-term business travel and expatriate family adjustments.

Human relations issues have caused barriers to international collaboration for AOI as well. As in purely domestic projects there have been personality clashes. Specifically, there are sometimes clashes due to different reporting relationships arising from hierarchy differences among companies. There are often differences in expectations for professional roles, especially with respect to the technical contributions of managers. Responsiveness to requests can vary among sub-teams. Distrust can emerge among team members due to mistrust at higher levels in the partner organization.

AOI provides cross-cultural training for engineers who will be joining international project teams, using both inside and outside consultants. This is supplemented by on-the-job training and ad hoc sessions. Expatriates can elect to receive language instruction. First-time visitors to a foreign country are usually briefed in sessions that explain the basics of expected behavior and available resources. They can also elect to receive consultations from “veterans.”

International work sessions require an investment in planning and organization in order to achieve maximum output. This includes: a clear, advanced definition of session objectives and definition and discussion of issues plus expected outcomes. Work sessions are preceded by an exchange of presentation materials one to two weeks prior to the session to provide an opportunity for questions to be submitted in advance. Meetings of each site team are held before the session in order to align opinions and positions so misunderstandings are avoided and time is not wasted at the session. Proper meeting management and facilitation are required to keep to the agenda topics, and to document agreements and action items. Issues are discussed and efforts are made to validate agreement on wording in real-time while the topic is fresh in participants' minds. A wrap-up session is held to brief upper management of both sites on accomplishments, agreements, issues and next steps. Entire work session materials are compiled before the session breaks up so that everyone leaves with the identical package and common understanding.

In forming international teams, AOI requires at least one individual with fluency in the appropriate language (s), at least one team member with mediation skills, and at least one with negotiation skills. Team members are expected to be flexible and to have a positive attitude toward interactions with others. Global engineers should be open-minded and be willing to accept different ideas, ways of thinking and ways of doing things. An enthusiasm toward the country being dealt with is also required of global engineers.

While AOI expatriates upon their return to their “home” division are guaranteed a job assignment equivalent to the position held prior to going abroad, there are currently no specific incentives provided for individuals to develop overseas experiences and skills and little actual value is placed on overseas experience by the domestic division. All incentives for developing such skills are currently based upon the individual's own initiative and interest in a particular country, travel, or international involvement.

The primary avenue for obtaining global engineering skills is on-the-job training through continuous improvement and nurturing by peers and management (mentoring). Language skills can be gained through schooling and immersion in the foreign environment. A systems-oriented college curriculum that balances the “generalist” perspective and the “specialist” perspective, is appropriate for the global engineer. Such a curriculum should broaden the global engineer's focus while at the same time allow him or her to integrate the “deep” perspectives of a variety of specialists across several disciplines. Finally, global engineers should seek out jobs that entail international interactions for self-training.

The significant problems encountered by global engineering project teams at AOI have included major slips in schedule (some of which have led to program cancellations), successive production line stoppages and start-ups, and major distrust between managers at different sites.

Significant successes have included the ability to launch a variant product produced by another site months ahead of schedule, the ability to take full advantage of learning and complementary strengths across the AOI group companies in development and manufacturing, and the ability to balance resources and capacity to produce a better product line for AOI's world wide customer base. Furthermore, AOI subsidiaries and partners have learned processes and technologies from each other, have shared competitive benchmarking information, have developed technologies and products for use on a world wide basis, and have agreed upon missions at each site to reduce redundancy of efforts and to maximize productivity.

Teamwork

The ability to work effectively in groups or teams is an increasingly critical skill for engineers, as products become more sophisticated and complex, and companies devise new organizational systems to improve product development and manufacturing performance. The informal surveys conducted by the U.S. and Japanese working groups indicate that there are some interesting differences in perspective on the context for teaching these teamwork skills.

Most of the U.S. respondents and members of the U.S. working group familiar with Japanese and U.S. education practices and organizations believe that the Japanese system (both in formal education and corporate management) develops teamwork skills much more systematically and effectively than does the U.S. system. As noted in Chapter 2, primary and secondary school students in Japan do much of the cleaning up and other work tasks at school in teams. On the job, it is the impression of U.S. group members that Japanese engineers (and other employees) are evaluated and rewarded more on the basis of group performance than is the case in U.S. organizations, where more emphasis is placed on documenting and evaluating individual contributions.

Although one Japanese expert polled by the Japanese Working Group did not believe that there is a great disparity in teamwork skills between U.S. and Japanese engineers, most respondents confirmed the impression that Japanese organizations place a higher emphasis on training engineers and others to work in teams. The implications are not clear-cut, however. One of the Japanese respondents remarked that in some situations U.S. teams whose members perform well individually may perform as well as Japanese teams. There was also a concern that Japanese engineers may not perform as well outside of the group context.

Language and Cultural Skills

Respondents to the U.S. and Japanese working group surveys responded that language and cultural knowledge are very important in enabling engineers to work effectively in international settings. Several Japanese respondents stated that knowledge of two languages in addition to Japanese is necessary. There appears to be asymmetry between U.S. and Japanese needs in this area. International business is conducted largely in English, so language skills are more important for non-U.S. engineers working with Americans. However, respondents agreed that even limited capability in foreign languages is useful for U.S. engineers working with international partners. In addition, a growing number of engineers in Asian countries such as China and Korea are learning Japanese.

In the area of cultural skills, Japanese respondents tended to emphasize the importance of understanding foreign cultures and what was unique or different about Japan. The American respondents tended to emphasize the importance of basic adaptability and openness to foreign cultures. Several of the U.S. survey respondents believed that the most important personality factors, such as openness to different viewpoints, tolerance for different ways of doing things, and patience, perhaps cannot be taught.

Box 6-2 contains more discussion of language and cultural issues arising in a specific U.S.-Japan partnership.

BOX 6-2 SUPERIOR SOFTWARE-MOMIJI ELECTRIC[1]

One of the respondents to the U.S. survey worked for Superior Software, a small U.S. company that developed several products in collaboration with Momiji Electric, a large Japanese manufacturer of office equipment. The experiences of these companies illustrate several differences between U.S. and Japanese engineering styles, and the skills necessary to overcome resulting obstacles to collaboration. Superior engineers participating in the collaboration were given opportunities to pursue Japanese language training, and presumably Momiji provided English language training as well. However, the U.S. engineers did not receive any other specialized training.

Balancing Language, Cultural, and Technical Skills in Selecting Engineers for "Interface" Roles

The Superior-Momiji experience illustrates that one obvious, but still very important, issue is language and culture. In U.S.-Japan technology and engineering alliances, key people on both sides in the relationship are often chosen because their language skills and cultural adaptability allow them to operate effectively. This selection is mostly independent of whether the people have the best technical skills or have the correct degree of influence in their organizations. For example, one of the engineers assigned to the project at the outset by Momiji could barely speak English and had difficulties in dealing with Americans. He was taken off the project, but later reemerged and was able to contribute several years later when the relationship between the two companies had become more established.

However, selecting engineers to manage the relationship with the best language and cultural skills usually meant that Superior's engineers were not interacting with the "right" Momiji person for the problem at hand, and vice versa. Engineers playing interface roles may not have a great deal of clout in the organization, particularly on the U.S. side. Their insights or the information they glean from counterparts may fall on deaf ears back home.

One practical lesson a Superior engineer learned in effective communication in English with Japanese counterparts is that written materials should be favored over or used in conjunction with verbal presentations wherever possible. Most Japanese engineers have greater facility in reading and writing English than in speaking.

Mutual Benefits From Collaboration

In the Superior-Momiji relationship, both sides benefited, but some of the benefits were not what was expected at the outset. The Japanese company learned a great deal about modularity in software development, top down design, utilizing modern software development tools, software project management tools, and how to develop multiple products simultaneously from the same software base. The U.S. firm learned the importance of the factory in the development process, that a good application of less advanced technology in a good team is generally superior to a spotty application of cutting edge technology, the special factors involved in developing a product that will go out in thousands of units rather than tens or hundreds, and structuring a question-answer setup for testing a major application.

[1] Not the actual names of the companies.

Differences in Business and Engineering Management Culture: "Effort" vs. "Results"

The Superior-Momiji collaboration also illustrates differences in business and engineering culture between the two countries. Besides those differences that have been extensively discussed, such as greater Japanese emphasis on group effort and performance vs. American emphasis on individual effort and performance, Superior engineers also learned that different values placed by U.S. and Japanese organizations on "effort" vs. "results" has an impact on the management of projects which can result in frictions between U.S. and Japanese partners.

For many Japanese organizations, a "good effort" builds character and is very important to morale. For many American organizations, however, an effort without a result is essentially a waste of time and energy, while a result without an effort is welcomed as a bonanza. In a case where management decides to end an unsuccessful project, an American organization will end all effort and work on a project the instant the decision is made. After all, further work would only be wasted effort, in the American view.

In Japan, the approach is often different. If employees are to be denied the benefits of successful completion, they should not be denied the benefit of a good effort. Therefore, management may keep secret the impending demise of the project until the next major milestone, doing nothing to alleviate the hard work and late nights that people put in to meet that deadline. When the milestone is reached, management congratulates everyone on their good effort and explains that the company has no further need for the project. Everyone has saved face, everyone has benefited, and life goes on.

These different attitudes may cause problems in U.S.-Japan collaborative endeavors. In the second year of the Superior-Momiji collaboration, the U.S. partner scrambled to complete a drastically under-bid schedule for a December 31 release. Engineers worked weekends, evenings and holidays. When the product was delivered, there was no response for several weeks. Then, a manager from Japan visited to announce that the project had been cancelled. Suspicious that the software had never been tested and that the decision to cancel had been made well before Christmas, the U.S. team members were frustrated and demoralized.

Later, when one of the Superior engineers was in Japan acting as a liaison for another project, a Momiji colleague came by quietly to let him know that this project had also been cancelled. As the Momiji engineer tried to explain why he did not want his U.S. counterpart to tell anyone, the cultural difference was recognized, and a solution was worked out. At Momiji, the management and the U.S. liaison were the only ones to know, and the American agreed to work to maintain the illusion as the Japanese engineers assigned to the project continued to work on it. At Superior, however, everyone (including the Japanese liaisons positioned there) would know, all work would stop immediately, and planning would start on the next project.

Better mutual understanding of these sorts of differences among Japanese, American and other engineering cultures on the part of participating engineers could promote smoother interactions.

Note: The intent of this description is to illustrate several issues that can become barriers in cooperative activities, rather than to portray a typical interaction between U.S. and Japanese engineers.

Knowledge of Business and Engineering Culture.

The example described in Box 6-2 illustrates how lack of knowledge of differences in business and engineering culture can act as a barrier to cooperation. These differences can make it difficult or impossible to reconcile the perspectives of partners on market and product goals. Misunderstandings and distrust at higher levels of the organization can often impact working level relations between companies. As companies from different countries gain experience in working together, both the larger strategic issues and the differences in business and engineering culture can be overcome. The U.S. respondents point out that the real benefits of collaboration are savings of time and resources, which are realized as a partnership matures.

"Engineering" Aspects of Global Engineering

One question raised by a member of the NRC's Committee on Japan in discussing the concept of global engineering was "what does global engineering have to do with engineering?"[4] In other words, are differences in engineering education and practice all related to language and culture (including management practices), or are there real differences related to technology? One of the U.S. interviews explored an aspect of engineering practice that is fundamentally technological, but where implementation can raise cultural issues. This is the field of quantitative risk assessment.

The U.S. engineer that was interviewed is a member of the top management team at QMH Inc., a U.S. engineering consulting company whose business focuses on risk-based and performance assessment technologies for large engineered projects such as power plants, chemical plants, defense projects and space systems.[5]

QMH has worked for Japanese clients in the nuclear power and space industries. Most of the consulting contracts have been for technology transfer rather than large pieces of applications work. The technology transfer has taken the form of workshops, conferences and seminars given in Japan or of very selected work assignments in the United States often involving Japanese engineers.

Many QMH personnel have experience in engineering education in the United States. When teaching Japanese engineers, they have found that certain style adjustments need to be made. In general, teaching U.S. engineers tends to be highly interactive and at times even confrontational. Students are expected to respond to direct questions from the instructor. Interaction between the instructor and students consists of a dialogue with both instructor and student playing active parts. While the situation expected by Japanese engineering students is changing, they generally are less comfortable responding to direct questions and prefer that the instructor lecture rather than engage students in a dialogue.

This difference becomes very apparent in the teaching of the more abstract topics such as probability, including quantitative risk assessment, an area that QMH has pioneered in applications. Instruction in those topics is greatly enhanced if it is highly interactive, with the instructor repeatedly challenging the student to demonstrate his or her understanding of the concepts involved. This format is unusual in Japan. Instructors must continually push Japanese students to participate more, and some students, usually those with prior educational experience in the United States, have had some measure of success. Still, this difference leaves U.S. instructors uncertain whether the Japanese students have gained sufficient grasp of the necessary concepts to enable the students to apply them effectively. This uncertainty requires follow up in the field to assess the skills of the Japanese students.

Recent curriculum changes in U.S. engineering education have put more emphasis on such subjects as probability and statistics in order to quantify the engineer's confidence in deterministic results. In particular, engineers now must often perform probabilistic analysis to quantify the uncertainties in their engineering calculations. This movement towards accountability for uncertainty conflicts with a Japanese technical culture that is often uncomfortable with admitting uncertainty in results. And yet, modern engineering needs such expressions of confidence more and more in areas of risk assessment, reliability, and other quality metrics.

INSTITUTIONS AND RESOURCES FOR PREPARING THE GLOBAL ENGINEER IN THE UNITED STATES AND JAPAN

When in Their Careers is it Advantageous for Engineers to Develop International Skills?

As a general principle, the Joint Task Force believes that just as engineering education should be a lifelong learning process, so should global engineering training. There are tasks and insights from international exchange that could benefit K-12, undergraduate students, graduate students and adult engineers pursuing careers. Indeed, the earlier the start, the better. This is particularly true of language learning.

In practice, however, the U.S. and Japanese systems provide different opportunities and incentives for gaining international experience. Much of the international training and experience provided by Japanese companies to employees fairly early in their careers may be functionally equivalent to what U.S. graduate students experience through international internships and other mechanisms.

One of the Japanese respondents states that engineers should be provided with an international experience 4–5 years after entering a company, and that these capabilities should be provided as part of more systematic career planning. Participation in international technical meetings is also a useful mechanism.

University-Based and Other Formal Educational Programs

The Japanese respondents indicate that currently there are not many opportunities for Japanese undergraduate or graduate engineering students to gain international knowledge and skills. Several respondents stated that there should be more opportunities for Japanese engineering students to gain experience abroad and develop language skills, particularly during the university years or perhaps between university graduation and beginning a career. A related concern was that engineering education in universities should allow students to become familiar with current communications and information technologies.

Several examples of U.S. and Japanese programs are listed in Box 6-3. If we think of the basic global engineering skill and knowledge areas as language and culture, business and engineering culture, team work and group dynamics, and technical environment (including standards), there has been a slow development in the United States of specific programs and curricula to address those areas.

The MIT Japan Program has a long track record of training scientists and engineers in Japanese language and culture, and providing opportunities for research in Japanese university and industrial laboratories. One of the strengths of the program is its flexibility. It does require two years of language study before undertaking the internships, but students are able to structure their engineering and humanities studies in a way that meets their needs.

An interesting, recently launched program at the University of Illinois allows engineering undergraduates to take an international minor in a specific geographical region.

Several U.S. respondents mentioned that the inflow of engineering talent from overseas constitutes another advantage for the United States in the area of global engineering, in that immigrant engineers often possess capabilities to function effectively in more than one culture and language.

Other mechanisms allow collaborations between engineering students in different countries. One example is Robocon, an international engineering competition that teams students from various participating countries to design and build remote controlled machines.[6] The students benefit from the experience of working through the challenges of communicating ideas, negotiating work strategies, and problem-solving as an integrated team. The competition also provides exposure to peers with different skill sets, educational backgrounds, and approaches to engineering.

BOX 6-3 EXAMPLES OF U.S. AND JAPANESE ACADEMIC AND GOVERNMENT PROGRAMS TO PROVIDE GLOBAL ENGINEERING CAPABILITIES

U.S. Programs

MIT Japan Program

NSF Programs (Tsukuba Summer Institute, Short/Medium/Long-Term Stays)

U.S.-Japan Manufacturing Technology Fellowship Program

University of Illinois International Minor in Engineering

Japanese Programs

JAIMS (Japan-America Institute of Management Science)

Joint Programs

JAMS (Japan-American Math and Science Institute—summer meeting alternating between the United States and Japan)

JSPS-NSF Cooperative Science Program

SOURCE: Compiled from various sources by OJA staff.

The Need for New Approaches and Expanded Efforts

The U.S. working group believes that U.S. engineering schools, funding agencies (such as the National Science Foundation and private foundations), and industry should devote more attention and resources to increasing U.S. global engineering capabilities. U.S. institutions have collectively amassed considerable experience in this area. This report naturally focuses on U.S.-Japan issues and insights, and much of the U.S. effort in international training for engineers and scientists in recent years has been focused on Japan. Yet, obviously, there is a need to prepare engineers to work with a wide range of countries and partners around the world. The experiences of the MIT Japan program and other efforts could be very useful in developing broader approaches.

Possible tasks

The Japanese group recommends expanded efforts in the following areas:

- Promotion of training for global engineering through internships at Japanese facilities in the foreign host countries.
- Development of communication skills through interaction with foreign counterparts.
- Encouragement for senior personnel to accompany students and trainees during international exchange programs.
- Promotion of collaboration between Japanese engineering universities and their foreign counterparts.
- Requirements for foreign language training.
- Encouragement of training through collaborative projects with students from other countries.
- Utilization of expertise and experience of engineers who have been trained in foreign countries.
- Development of training programs for engineers from developing countries.
- Development of training programs for young Japanese students and engineers to work in developing countries.

The U.S. working group has identified a number of possible tasks that could be the focus of expanded global engineering training and education efforts:

- Training for graduate engineering students that incorporates language learning and 6-to 12-month internships in the country of interest.
- Expanded study-abroad and language study opportunities for undergraduate engineering students.
- Development of case-based and other teaching materials aimed at building knowledge of the business and engineering cultures of various countries.
- Development of continuing education programs (seminars and short courses) aimed at a corporate audience, perhaps in collaboration with business or management schools.
- Tapping foreign engineering students and non-native faculty as a resource for learning about global engineering approaches.

- Development of “sister” relations with foreign engineering schools, including linked course work and exchange opportunities.
- Development of training programs for engineers from developing countries and for U.S. engineers planning to work in developing countries.

Options.

The U.S. working group developed several possible options and approaches for future consideration by various stakeholders. The U.S. working group hopes that this report spurs a broader discussion of these issues and what might be done.

- *Option One: Expand grant programs targeted at individual students and researchers for education and training related to global engineering.* One option would be for NSF and private foundations to expand funding available for individual students, researchers and schools pursuing one or more of the tasks outlined above.
- *Option Two: Establish a new program of global engineering centers.* The U.S. working group members also discussed establishing a new program of funding for global engineering centers. This approach might build on the experiences of the MIT Japan Program, with centers at different schools specializing in training and education aimed at particular countries, regions, or industries. Several working group members and experts consulted during the study are skeptical about the value of new centers, particularly large ones, and would prefer to focus resources on individual efforts. Other members believe that establishing smaller centers focused on particular countries or industries might allow for the accumulation of a critical mass of expertise.
- *Option Three: Expanded discussion and exchange among stakeholders.* In order to further explore these and other options, perhaps various U.S. stakeholders could hold a conference to share their insights and discuss U.S. needs. The relevant stakeholders would include a range of engineering schools, industry, government funding agencies, private foundations, and engineering societies. The National Academy of Engineering might play a useful role in furthering this discussion.

NOTES AND REFERENCES

[1] The Joint Task Force realizes that companies based in smaller markets, particularly in Europe, are often more internationally focused than U.S. or Japanese companies, and may therefore have more international business and engineering experience.

[2] Leaders in engineering education and practice have been aware of these growing international imperatives for some time. See National Academy of Engineering, *Strengthening U.S. Engineering Through International Cooperation: Some Recommendations for Action* (Washington, D.C.: National Academy Press, 1988).

[3] Hideo Ohashi, “Guroubauru Jidai no Kogaku Kyoiku” (Engineering Education for a Global Era), *Gijutsu to Keizai* (Technology and Economics), April 1998.

[4] Several U.S. respondents emphasized that in order to be an effective global engineer one must first be an excellent engineer.

[5] Not the actual company name.

[6] Communication with Evelyn Wang, Massachusetts Institute of Technology student who participated in Robocon.

7

The Future University

SUMMARY

• *The pressures and incentives of global business and the new capabilities of information technology are enabling radically different approaches to education. Although complete exploration of the topic is beyond the scope of the present study, review of several Japanese and U.S. initiatives shows how engineering education is being affected.*

CONTEXT

As the joint task force study was nearing completion, the Japanese working group suggested adding a discussion of how the roles of engineering schools and universities in Japan and the United States might change in the future. Significant changes could result from shifts in the engineering environment, such as the globalization of engineering activity discussed in Chapter 6, and the potential for new approaches to education enabled by information technology. This chapter is meant to extend and supplement the discussion of undergraduate and graduate engineering education contained in Chapter 4, and the discussion of continuing education in Chapter 5. Although a comprehensive examination of these issues in either the United States or Japan is beyond the scope of the study, the joint task force hopes to stimulate discussion among engineers and engineering educators on the future university.

CHALLENGES FOR U.S. AND JAPANESE ENGINEERING SCHOOLS AND UNIVERSITIES

A recent article in the journal *Issues in Science and Technology* puts forward a vision for a future U.S.-based "Global University" appropriate to a world in which business and engineering activities are global and continuous, with U.S. citizens making up a smaller proportion of the global engineering workforce.[1] The model calls for academic institutions to utilize new technologies and branch campuses to better serve the needs of industry, especially in engineering fields. In order to facilitate this change, new international approaches to standards and accreditation would allow an expansion of cooperative degree programs between universities, and the creation of new educational programs tailored to the needs of individual students and their ultimate employers. Each university would emphasize its core strengths in pursuing this vision and could "franchise" their programs to commercial service providers or other universities. Some U.S. institutions are already moving rapidly in this direction, as will be discussed below.

This particular vision of the "Global University" has stimulated discussion and debate in the U.S. engineering community, and abroad. To many members of the U.S. community, including several U.S. members of the task force, the vision correctly identifies some important tasks for engineering education in the coming years. However, the U.S. members believe that the vision takes too narrow a view of the university's role in general and engineering education in particular. Even in a world characterized by global business, universities will be expected to advance knowledge and to deliver education that enhances personal development as well as to prepare students for careers. Even in engineering, which can be seen as being more career-oriented than other parts of the university, education must impart knowledge that goes beyond the short-term needs of industry.

For example, Chapter 6 covers the language and cultural knowledge required for global engineering, much of which draws on the liberal arts and social sciences. In a broader sense, engineers will need to be attuned to a wide variety of issues in the future, including the integration of ethical-humanistic issues into their work.[2] In addition, laying the groundwork for lifelong technical currency that serves the long-term interests of industry as well as the individual engineering student will require exposure to scientific advances outside of the typical engineering school, most notably in biology and in newly emerging fields. In short, reorganization of the university that facilitates closer connections between engineering schools (and other professional schools) and their major "customers" should not occur at the expense of needed integration.[3]

The implications of the Condit-Pipes "Global University" vision are somewhat different for Japan. Most of the Japanese task force members find the vision very attractive and even compelling for Japan. The Japanese members believe that Japanese engineering schools and universities in general need to become much more responsive to the needs of employers and individual students. Promoting the utilization of information technology (distance learning in particular) and more flexible institutional approaches would allow movement beyond today's "just in case" educational paradigms in which learning is concentrated in degree programs in the hope that it will be useful.[4] Already, "just in time" learning approaches are emerging, with education provided when and where it is required. In the future, customized "just for you" educational services will be developed to meet the needs of individuals.

Japan faces significant barriers to implementing new educational approaches. For example, the strong role of the Ministry of Education, Science, Sports, and Culture (Monbusho) in funding, setting curriculum, and certifying universities leads to greater uniformity in approaches across Japanese universities. The Japanese members believe that the problems such as excessive uniformity and large class sizes are more acute at private universities.[5] In addition, the emphasis in Japanese society on the university's credentialing role, as seen in the importance of the university entrance examination and the hiring practices of companies, means that students are less motivated to develop clear targets for university study. The Japanese group believes that university curricula should be more flexible and responsive to societal needs, and that students should be provided with more intensive guidance in these early university years to choose appropriate subjects. Since no one university can be expected to contain all of what is required in the future, the Japanese members believe that expanded exchanges among schools utilizing distance learning will be necessary.

EXAMPLES OF JAPANESE APPROACHES

Tokyo Denki University.

Tokyo Denki University, a private engineering university, is undertaking several initiatives aimed at adapting its educational offerings to the changing needs of students and the larger society. One example is a small-scale engineering college within the university that is now in the planning stages. The focus will be on providing a combination of “just in time education” and “just for you education” as discussed above.

One tool that the new college is introducing is designed to raise the consciousness of university students. Students will be required to take an introductory curriculum planning course to develop subjective goals and a learning plan for their four years of university study. This planning is based on a review of materials provided by the departments. The plan is discussed with peers and faculty members. Since students will naturally develop new interests and goals as they progress through their undergraduate years, the plan would be periodically revised. This exercise would encourage students to think more carefully about their education and take greater individual responsibility.

Freshmen and sophomores in the new engineering college will be able to choose classes from the basic curriculum according to their ability, and in addition take liberal arts and foreign language classes. Laboratory classes are included in the lecture series, with some lab experiments developed in cooperation with industry. This is fairly unusual for freshman and sophomore engineering students in Japan. New, interdisciplinary classes are also being developed for the new college. Grading will be done according to standardized criteria.

Japan-Indonesia Science and Technology Forum

Shibaura Institute of Technology organized a distance education experiment between Japan and Malaysia in cooperation with Tokyo Denki University and Takushoku University. A test was conducted recently in which 40 Malaysian students located in a studio in Malaysia received classes originating in Japan (but also aimed at Malaysian students) over an ISDN network. Lectures concerned mathematics and Japanese language. The technology allows two-way communication between sites. The results of the experiment are now being evaluated.

University of the Air

The University of the Air was established in 1981 as a means of providing continuing education opportunities to adults. The University of the Air is located in Chiba Prefecture and its broadcasting area covers Tokyo and its suburbs. Six affiliated learning centers are spread through the area. Additional videotape learning centers are located in 36 of Japan's prefectures. Since January 1998, the university's class broadcasts are carried on a nationwide digital television channel by communication satellite.

Most of the 67,000 students (as of 1998) receive lectures by television and radio at home. Over 300 undergraduate liberal arts classes are provided. University of the Air does not conduct an entrance examination, and awards a bachelor of arts degree.

Hokkaido Information University

Hokkaido Information University, a private school, established a correspondence course in 1994 in its undergraduate faculty of management information. The corporation which operates HIU, Denshi Kaihatsu Gakuen (EDC), also manages 10 technical schools for information engineering located throughout Japan. The technical schools have two to four year courses of study. EDC has also developed PINE-NET, a distance learning system allowing two-way communication by satellite and video conference system. The HIU correspondence course is carried on PINE-NET. Students can enroll in both HIU and one of the technical schools, and are able to earn a baccalaureate and a specialist degree.

Tokyo Institute of Technology

Tokyo Institute of Technology has developed ANDES (Academic Network for Distance Education by Satellite), which is aimed at delivering Institute courses to companies. ANDES has been in operation since 1996. Company employees earn a certificate of attendance from the school. Interactions between students and faculty are facilitated by fax and email.

The Institute also undertakes a lecture exchange with Hitotsubashi University, a university located in Tokyo that is strong in economics and the social sciences. The exchange is supported by satellite communication links between the campuses. About 600 students per year enroll in the joint course.

Space Collaboration System

The Space Collaboration System (SCS) is comprised of a Japanese University Network and a Medical Schools Network linked by communications satellite. The university network includes 74 national universities (122 VSAT stations), 14 technical colleges, 10 national research centers, and 10 private universities (11 VSAT stations). The network supports point to point and multi point communication, and is managed by the National Institute for Multimedia Education. About one-third of the usage is for teaching, another one-third for lectures, and the remainder for meetings and other purposes.

The Japanese Medical Schools Network linking university hospitals utilizes satellite high definition television (HDTV). Image exchange among medical schools is facilitated, including medical procedures, X-ray and CT images, and surgical data. This network can be expected to promote the growth of telemedicine.

EXAMPLES OF U.S. APPROACHES6

Polytechnic University.

International students are able to earn a Master of Science degree from Polytechnic University in New York by combining study in a cooperating university and on-line distance learning courses offered by Polytechnic with a specially organized program at the University in New York. [7] Up to one third of the required courses may be transfered from the cooperating university, with another third taken on-line through highly interactive, asynchronous internet based courses. The degree is completed in residence at Polytechnic University in a focused program which includes advanced coursework, supervised research, and experiences in business and industry.

National Technological University

National Technological University (NTU) is a private, accredited, nonprofit institution founded in 1984, and a pioneer in satellite delivery of advanced technical education.[8] NTU offers both academic credit courses and non-credit short courses, provided by 48 member universities. NTU's programs are targeted at technical professionals. As this is written, over 1,300 courses are available through NTU's participating universities, providing 14 Master's of Science Degree programs. NTU awarded 160 M.S. degrees in 1997.

In order to enroll in NTU courses, students must be employed by an organization or university which is a member of the NTU Satellite Network. In some cases, non-members may take classes at community sites. There are over 900 participating NTU sites across North America.

Stanford University

The Stanford Center for Professional Development (SCPD) offers graduate level programs to technology professionals.[9] During the past 30 years, over 3,000 graduate degrees have been earned through SCPD programs. Stanford is one of the largest single university providers of distance education in engineering, and science and technology management. SCPD plays a leading role in serving the continuing education needs of industry, and is often credited as a significant contributor to the growth of Silicon Valley.

SCPD provides a number of different educational opportunities to pursue graduate degrees, complete certificate programs, earn course credit, and audit classes. Courses are delivered directly to the workplace via television broadcast, videotape and the internet. Other outreach mechanisms include workshops, seminars, executive education conferences, and custom-designed courses, both on and off campus. The four core components of the SCPD are Stanford Instructional Television Network (SITN), Multimedia/Video Production, Stanford Online (internet-accessed courses), and Professional Education (executive training).

Stanford University offers a complete engineering master's degree program entirely online. The technologies involved in offering the online program, through SCPD, includes audio/video streaming with synchronized slide shows, electronic distribution of class materials, synchronous and asynchronous interaction among the students and instructors, and in some cases the electronic posting of homework and exams. Individuals will also have the option to participate as nonmatriculating students on a course-by-course basis for credit or audit, rather than applying for admission to the master's program.

Massachusetts Institute of Technology

The Massachusetts Institute of Technology (MIT) has created the Center for Advanced Educational Services (CAES) in order to expand access to MIT's educational offerings through utilization of advanced technology.[10] Through the efforts of CAES and other initiatives, MIT hopes to enhance its leadership role in education, both nationally and internationally.

CAES offers a number of short term (non-degree) programs. Longstanding on-campus programs include the Advanced Study Program (now in its 33rd year) and the Professional Institute (in its 46th year), aimed at working professionals. These programs are now offered off-campus as well. CAES is focused on expanding off-campus programs through multi-modal distance learning. For example, CAES produces live satellite broadcast courses that are carried by PBS The Business Channel, and are aimed at professional engineers, scientists, and managers. The classes are broadcast once a week for eight weeks, with interaction facilitated by a web site. A certificate of completion is awarded. In addition to satellite broadcasts, a variety of non-credit and for credit courses are available with a range of participation options. Most courses are multi-modal, employing both asynchronous and synchronous learning modes.

CAES also offers products for reference or self study, and media and communication services to the MIT community. In addition, CAES is home to several independent research groups aiming at advancing the use of information technology in academia.

Another indicator of MIT's growing global role is an agreement reached in 1997 with the Ehsan Foundation in Malaysia to help create the Malaysia University of Science and Technology (MUST), scheduled to open early in the next decade.[11] MIT will receive $25 million for its help under the agreement. The MUST project is similar to programs already under way in Thailand and Argentina.

The goal is to create an elite private teaching and research university in the state of Selangor Darul Ehsan. Initially, the university will cater to the brightest Malaysian graduate students, with an undergraduate engineering program to be developed later. In creating the university, MIT will provide expertise in four areas: academic program; research agenda; institutional development, focusing on administration, organization management and financing; and forming partnerships with government and industry. Graduate opportunities for Malaysian students at MIT will also be promoted.

NOTES AND REFERENCES

[1] Philip Condit and R. Byron Pipes, “The Global University,” *Issues in Science and Technology,* Fall 1997.
[2] George Bugliarello, “Comments on ‘The Global University,’” unpublished, October 1997.
[3] Ibid.
[4] James Duderstadt, “Letter on the future of the university,” *Issues in Science and Technology,* Winter 1997–98.
[5] As noted in Chapter 4, Monbusho regulates and authorizes private universities, and provides funding, but financial support is not as generous as that provided to national universities.
[6] This set of examples is illustrative of U.S. approaches and is not meant to be an exhaustive list of U.S. initiatives in this area.
[7] Polytechnic University materials.
[8] See the NTU World Wide Web page at http://www.ntu.edu.
[9] See the SCPD World Wide Web page at http://scpd.stanford.edu.
[10] See the CAES World Wide Web page at http://caes.mit.edu.
[11] See MIT press release at web.mit.edu/newsoffice/nr/1997/43450.html.

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Conclusions and Recommendations

CONCLUSIONS

Although the U.S. and Japanese systems for educating engineers are quite different, they share a number of common challenges. These include:

- Attracting talented young people to engineering careers,
- Developing educational systems that ensure a firm grasp of fundamentals while promoting creativity and a spirit of inquiry,
- Maintaining the skill base of the engineering work force by providing access to learning opportunities throughout the working life of engineers,
- Developing new approaches to engineering education that make the best use of the Internet and other information technologies,
- Ensuring that educational systems provide the two countries with sufficient capability for global engineering by transmitting to engineers the skills and experience needed to perform effectively in international collaboration.

Each country also has specific challenges. For the United States, the highest priority tasks are:

- Improve the quality and consistency of K-12 science and mathematics education for all students, including future engineers.
- Ensure that graduate engineering education maintains a strong link with research, while taking into account the growing career opportunities for doctoral engineers outside of academia and research.
- Build systems that facilitate increased investment in continuing education for engineers in an era of growing job mobility. For Japan, the highest priority tasks are:
- Improve the university entrance process in order to promote creative learning in mathematics and science while maintaining high standards.
- Improve undergraduate engineering education so that students receive a more intensive and fulfilling educational experience.
- Increase the number of students who receive graduate training in engineering at universities, and link graduate education more effectively with fundamental research.

RECOMMENDATIONS

By the Japanese Working Group (for Japan)

1. The Ministry of Education, Science, Sports, and Culture (Monbusho) along with Japanese schools, teachers, and parents, should redouble efforts to expand computer education and computer literacy for K-12 students. Universities should also aggressively utilize information technologies to disseminate admissions and other information to potential applicants.
2. Public and private universities, working with the Monbusho and the National Center for University Entrance Examinations, should continue efforts to simplify and improve the university entrance system with the goal of lessening negative impacts on K-12 education and promoting a richer undergraduate experience.
3. Japanese industry, universities, and government should promote expanded industry-university cooperation in engineering education through visiting lecture programs for corporate visitors at universities, internship programs for students at companies, continuing education initiatives, and training aimed at building Japan's global engineering skill base.
4. Japan should redouble efforts to improve graduate engineering education and research. In particular, the Monbusho and other research funding agencies should expand competitive funding of research.
5. Japanese universities and Monbusho should enhance the breadth of the Ph.D. degree in engineering by requiring recipients, particularly those taking the thesis dissertation route, to achieve broad mastery of the field in addition to original research achievement through the Ph.D. thesis.
6. Japanese universities should diversify their criteria for admissions, with the goal of encouraging industry to diversify the skill and experience profiles of new hires.

By the U.S. Working Group (for the United States)

1. U.S. school systems, teachers, and parents should continue to learn from international models, including Japan, in improving K-12 mathematics and science education.
2. The United States, perhaps through the National Science Foundation, should increase opportunities for U.S. engineering students and younger professionals to gain international skills and expertise through language study, year abroad programs, research exchanges, and overseas internships.
3. The United States should make renewed public-private efforts to encourage increased investments in continuing education for engineers. Information technology can provide an important and effective tool.
4. The impact of the shifting funding trends for science and engineering students and for research should be examined.
5. The implications of the majority of engineering doctorates awarded to foreign citizens should be examined and better understood.
6. There should be a wider effort to educate engineering students, especially at top-tier research universities, about nonacademic and nonresearch career options.

By the Joint Task Force (for both Japan and the United States)

1. Japan and the United States should lead international initiatives to improve engineering education exchanges and develop the capabilities necessary for nurturing “global engineers.” Possible specific tasks are listed at the end of Chapter 6.
2. The engineering communities of the United States and Japan should maintain and increase their own bilateral engineering exchange and training activities, and seek out opportunities for expanded cooperation with engineers in other countries.
3. The Japanese and U.S. engineering communities should continue to explore the potential for information technology to transform engineering education, and develop mechanisms to regularly share perspectives and insights.
4. Japan and the United States should move toward harmonizing standards for engineering students so that the skills of engineers in both countries allow them to more effectively work together in the global context.