INTRODUCTION: ENGINEERING EDUCATION IN THE UNITED STATES AND JAPAN

INTRODUCTION: ENGINEERING EDUCATION IN THE UNITED STATES AND JAPAN

Carole Ganz-Brown
National Science Foundation

PROLOGUE

Despite engineering's widely acknowledged contributions to modern economic advance, public forums on the impact of science and technology on national and global economies have not traditionally included examination of the engineering profession. By the early 1980s, however, for the United States, the engineering profession was in ferment over its future. High undergraduate enrollments together with faculty shortages weakened the quality of engineering education. Industry struggled to recruit adequate numbers of engineering graduates to meet growing needs.

Prompted by these concerns over the health of U.S. engineering, the National Science Foundation asked the National Research Council to conduct a major study of the status and future of engineering education and practice in the United States. There was sufficient concern for the quality of engineering education to warrant an American Society for Engineering Education effort to mount a project addressing the issue of the quality of engineering education. Further, particular concern was expressed over manufacturing-related research and engineering. In the first half of the century, American universities had strong programs. But after World War II, manufacturing-related engineering declined markedly in prestige in the United States, with the American engineering faculty and graduates having less understanding of the technological realities of manufacturing. U.S. factories were being designed and run by those educated in other areas. This was seen to be in sharp contrast to the situation in Japan, West Germany, and some other Western European countries.

Responding to these efforts by prominent groups and organizations in the United States, the topic of engineering education was an agreed-on topic for the fourth U.S.-Japan Science Policy Seminar. For Japan, where efforts devoted to basic research and innovation were being expanded, the role and training of engineers was also of critical concern. The fourth U.S.-Japan Science Policy seminar was held October 19-23, 1986 at the East-West Center in Hawaii under the auspices of the National Science Foundation and the Japan Society for the Promotion of Science. A U.S.-Japan Conference on Manufacturing Research was held October 27-28 in Tokyo, Japan, to strongly complement the engineering education seminar.

THE ENGINEERING EDUCATION SEMINAR: THE AGENDA

Several themes were suggested for consideration in all papers presented at the seminar: First, each paper should include some comments on the environment for engineering in the future and the impact this future was likely to have on the issues considered in the paper. Second, each paper should consider how engineering education could meet societal needs and requirements. The attention paid to these themes of course varied widely with the subject of the paper.

For Session I, Historical Status and Current Perspective on Engineering Education in the United States and Japan, questions posed were: What is the current status of engineering education in the United States and Japan? Both papers -- the historical and the current -- were to address the following kinds of questions.

- What have been the traditional issues/problems/needs in engineering education in the U.S. and Japan? What have been the role and experience of the national governments in addressing these needs? What has been the role of the accreditation process in the engineering profession of each country? What have been the lessons learned from these experiences? What are the current issues/problems in engineering education in the U.S. and Japan and how are they being met?

- What have been the supply and demand of engineers in industry, university, and the government in the U.S. and Japan? Does "market demand" play a role in determining the number of engineers trained? What are quality measures for such populations as the engineering work force, entering graduate students, etc.? What is known about the quality of these populations? What sort of comparisons can be drawn between the two countries?

- What are representative career paths for engineers in the U.S. and Japan? In particular, do upper management and civil service positions constitute career opportunities for engineers? What factors (salary, research opportunities and equipment, prestige, lifestyle) influence the relative attractiveness of university versus industry jobs? What is the role of rotational positions (e.g., industry engineers rotated into government posts for limited periods) in engineering careers in each country?

For Session II, Cross-Disciplinary and Cross-Institutional Relationships in Engineering Education, questions posed were:

- For areas such as computer software, biotechnology, manufacturing research, materials, and other rapidly emerging engineering disciplines, the growth of programs in these fields in the U.S. and Japan, where they are located within university

structures, what are the contents of the curriculums, the characteristics of the student bodies and the faculty? Have industrial firms taken steps to train or retrain their engineers in these disciplines?

- What are university-industry-government interactions and responsibilities in engineering research and education? How do the two countries compare with respect to the scope of industrial engineering education and training, and what strategies do firms follow in on-the-job training? What role is played by "informal" training such as moving people around within the organization? Is there an impact on academic education of industrial training? How much training is the responsibility of industry and how much the responsibility of universities/engineering schools?

- What state and national government efforts and programs have evolved, such as the interministerial efforts on the Japanese side, to encourage closer university-industry research relations? How successful are these programs?

For Session III, The Role of Creativity and Innovation in Engineering, questions posed were:

- Such factors as the rapidity of current scientific and technological change, the growing dependence of new technologies on science, the importance of radical technical change in terms of economy-wide impacts, have turned increasing attention in the U.S. and Japan to the appropriate role of creativity and innovation in engineering. What strategies should be followed to accomplish these goals in engineering education and practice?

- In the United States, some observe the revolution in use of computer-based tools that engineering practice has undergone over the last several years. Should engineers be less involved in the performance of routine engineering work and turn increasingly from the mechanical to the conceptual?

- Others observe the principal force behind technical progress as the acquisition of relevant production skills rather than advances in theoretical knowledge. Should investment in the acquisition of production skills at the expense of investment in formal R&D activity act as an important incentive to innovation? Also noted is the need to educate technical people better about marketing, financing sources, and the management of small business.

- In Japan, the emphasis on increased creativity and innovation stems from concern that Japan has not balanced its technological development with investments in science. Should Japan lessen dependence on the research of other countries to assure a

leadership role in advanced technologies for Japan in the future?

- Should Japan pay more attention to encouraging scientific research, and to organizing and managing R&D projects and institutions to enhance the creativity of its involved scientists and engineers?

- What is meant by "creativity" and/or a high propensity to "innovate" in engineering? What is the appropriate role of creativity and innovation in engineering? Can there ever be too much "innovation" or "creativity" in engineering? What are examples of recent breakthroughs or incremental innovations in the U.S. and Japan? What kinds of individuals have been involved in terms of background and training? Have they taken place in small or large business? What has been the role of such factors as venture capital and entrepreneurship?

- What are the conclusions and recommendations to be drawn from these experiences about strategies for appropriately fostering innovation, in particular, and about overall strategies for engineering education and practice? Does current engineering education in each country teach about such factors as entrepreneurship and venture capital?

- What is known about effective firm organization, decision-making, management, and incentive-reward systems for R&D groups and institutions in Japan and the U.S. to foster innovation and creativity? What roles do "national" factors such as mobility of researchers among organizations and sectors, technology and information transfer play in innovation in the U.S. and Japan? What roles do societal, cultural and attitudinal factors play?

For Session IV, Internationalization of Engineering, questions posed were:

- How are engineers to be trained and employed at a time when the U.S. and Japan are increasingly at odds in the world economy? What is the role of foreign language training in engineering education? How does engineering education develop sensitivity to regional and cultural differences and their impact on worldwide demand for engineering goods and services? How is appreciation and understanding of financial, political, and security forces at work internationally to be developed? What is the role of international exchange programs in meeting these goals?

- What is the participation of foreign and especially U.S. engineers in Japanese engineering education and research? What is the participation of foreign and especially Japanese engineers in U.S. engineering education and research? What

kinds of incentives are offered by each country to encourage foreign engineers to participate in the engineering research and education systems of that country? What kinds of constraints are there against the participation of foreign engineers in the research and education systems of each country?

For Session V, Workshop Conclusions and Recommendations, summaries of workshop sessions, and findings, conclusions, and recommendations by seminar participants were presented.

THE ENGINEERING EDUCATION SEMINAR: DISCUSSION

Education was a topic well-chosen. For two-and-one-half days, experts from both countries considered the ambitious agenda. Important discussion points included:

1. First, the meeting clarified differences between the two countries in education below the university or college level. A strong case was made for the United States to develop the financial incentives and approbation which the Japanese system provides to those with responsibilities for teaching science and mathematics to the younger generation. The United States is changing but not rapidly enough. On the other hand, there was Japanese appreciation that the United States is a heterogeneous society, heavily influenced by an immigrant population.

2. That an engineering background often leads to highly prestigious occupations in Japan was made very clear in the seminar. This has not traditionally been the case in the United States, and thus engineering education and training has not emphasized encouraging leadership qualities in U. S. engineers as in Japan. The value of Japanese leaders in industry with a technical background and the need for such leadership in the U.S. came to the front in several discussions. An undue influence by accountants is believed to minimize long term goals for U.S. industry.

3. Industry, government, and university relationships are much more formal in the United States than in Japan. But they are not necessarily less significant or strong in Japan. The importance of formal and informal relationships between important institutions was clearly emphasized in discussion.

4. Engineers most often are hired for lifetime employment by Japanese companies. Thus, companies make major commitments for continuing education and professional development. In contrast, U.S. companies are hesitant to invest major sums in these activities because the employee may go to a competitor.

5. The Japanese are trained from their first days in engineering to participate as members of teams, whereas U.S. education begins

with individual approaches, and encourages team approaches only as one considers design problems. Thus, the Japanese have a more overall or holistic approach to a product than do U.S. engineers. The Japanese have not developed any new rules of design, but have made their advances based on social structure and personal interrelationships.

6. The Japanese believe U.S. engineers have been more creative in research; American engineers believe Japanese engineers are more innovative in products and processes. Both are trying to learn from the other. Some courses are being introduced in Japan to identify creativity and to encourage innovation.

7. Japanese engineers view the process of technological innovation as holistic: this lessens problems of relating the research, production, and marketing aspects of this process for Japanese firms. But Japan is also moving towards a more research-push type of innovation. To accomplish this, there may be important lessons to be learned from the United States in how to manage the process of technological innovation. Moreover, the important aspects of technological innovation process must be reflected in the education of engineers.

8. Finally, discussion centered a great deal on the internationalization of engineering. International contacts and cooperation are playing a larger role in the education and research systems of both countries. Japan now has a major effort in "internationalization" which includes (a) efforts to get more outstanding people from foreign countries to go to Japan for study and research, and (b) having special courses and curriculum taught in English in Japan to scholars from other Asian countries. How to structure programs of institutions to accomplish the entry of engineers into today's world economy received much attention.

EPILOGUE

The meeting ended on a note of much speculation about the future. Practically, even the best predictions of future demand for scientists and engineers are notoriously unreliable. To be realistic in anticipation of future needs for human resources was emphasized. Second, the critical balances between these human resources and other inputs -- for example, instrumentation -- into research processes may be changing. Machines, even if they cannot think, have gained important sensory powers. Current growth trends -- in computer power, for one -- will accelerate dependence by researchers on sophisticated instruments, and in the future, on small, even intelligent, machines.

There was a third consideration for the future. The demands placed upon engineering communities are going to be different tomorrow than today. But the ways in which they will be different are highly unclear.

One reason is that there is a lot that is not understood, for example, how and at what rate science becomes technology; and the interdisciplinary nature of critical areas such as materials engineering and biotechnology. Strategies for engineering education and the kinds of human resources needed to develop it effectively and productively must consider these uncertainties.

Finally, the seminar made an important step forward in looking seriously and explicitly at the objectives of engineering research. Only with better understanding of the work of engineers and the processes in which they engage -- research, design, innovation, management, leadership -- will engineering education reflect the realities with which our technical human resources must deal in the future.