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■ The American Association for the Advancement of Science was founded in 1848 and incorporated in 1874. Its objects are to further the work of scientists, to facilitate cooperation among them, to foster scientific freedom and responsibility, to improve the effectiveness of science in the promotion of human welfare, and to increase public understanding and appreciation of the importance and promise of the methods of science in human progress.

COVER Golden Gate Bridge, San Francisco, CA. For details of the 1989 AAAS Annual Meeting, 14–19 January 1989, see pages 586–601. [Photograph courtesy of San Francisco Visitors Bureau, San Francisco, CA]

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Improving U.S. Capabilities in Technology

Many components determine a nation's ability to function in global competition in technology. An important factor is the number and quality of physical scientists and engineers. Recent reports by the Office of Technology Assessment and the National Academy of Engineering (NAE)* indicate that this country could improve its capabilities substantially by investments of federal funds in support of graduate education and lifelong training. The need for constructive action is especially apparent for engineering. Today the majority of graduate students in U.S. engineering departments are foreign citizens. About 60 percent of assistant professors under 35 years of age are foreign-born. Another noteworthy phenomenon is that practice of some branches of engineering is changing rapidly. The NAE report suggests that the half-life of an engineer's skills in 1986 is 2.5 years in software engineering, 5 years in electrical engineering, and 7.5 years in mechanical engineering. With the practice of engineering changing so rapidly there is need for lifelong learning.

About 90 percent of individuals obtaining a baccalaureate degree in engineering in the United States are citizens. However, only 41 percent of the small number of Ph.D.'s are native-born Americans. The typical holder of a baccalaureate degree finds employment in industry at an annual salary on the order of $30,000. Fewer and fewer U.S. citizens are willing to forego such salaries in favor of several years of graduate student poverty and expense (sometimes including debt) that will yield a few thousand dollars more in annual starting salary. In the meantime, other members of the same age cohort may have received substantial boosts in pay.

Training foreign citizens here in graduate school is not all bad. Some remain in this country and are valued for their contributions. But most have temporary visas that require them to return to their native lands. The tendency of faculties of engineering schools toward becoming dominated by those steeped in foreign cultures is of some concern. Would-be women engineers have complained of attitudes of some of their professors. Others have stated that the lectures of foreign-born instructors are difficult to follow. Another troublesome phenomenon is the tendency of U.S. companies to contract part of their engineering in Korea, India, and other countries abroad. As the flow of foreign engineering Ph.D.'s back to their homelands continues, we may find ourselves at increasing comparative disadvantage.

Much of the new knowledge that leads to technological innovation comes from the physical sciences and their applications in research in such areas as materials science. The annual number of Ph.D.'s in chemistry and physics totals only about 3000. Part of the reason for this small yield is federal policies with respect to graduate student support. Full-time physical science graduate students with federal support at Ph.D.-granting universities in 1986 totaled only 3500. In contrast, in the life sciences 18,000 received full-time federal support. Were the federal government to devote several hundred million dollars annually to graduate fellowships in the physical sciences and in engineering, a substantial change would likely occur in the flow of Ph.D.'s and eventually in our competitiveness. The situation would be further improved if some of the fellowships were made available under a rubric similar to the Congressional Awards for Science and Engineering proposed by Doug Walgren (D–PA).†

Some major companies have substantial programs for continuing training of their employees and have found them effective. Charles W. Hoover, Jr., of Bell Laboratories has provided an example of payoff for continuing education. A fivefold increase in productivity of the design engineering staff on circuit board design over a 10-year period resulted from application of training and computer-aided design facilities. Post-university training is often goal-oriented and is usually not very feasible for either personnel of small companies or faculties of universities. Exploratory programs aimed at devising the best procedures for retraining mature scientists and engineers merit federal support. An upgrading of our existing work force could be the fastest and most humane way of improving our capabilities in physical sciences and technology.—PHILIP H. ABELSON

*Office of Technology Assessment, "Educating scientists and engineers" (Government Printing Office, Washington, DC, June 1988); National Academy of Engineering, "Focus on the future" (Washington, DC, 1988). †D. Walgren, "A proposal to Congress and the nation" (editorial), *Am. Sci.* **76**, 428 (1988).