
THE GLOBALIZATION OF SCIENCE AND ENGINEERING STUDIES

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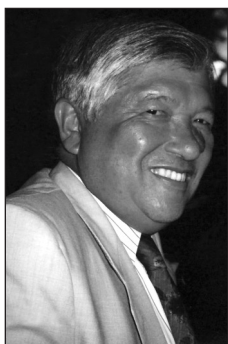


The challenges of preparing scientists and engineers for tomorrow's workplace

Globalization is a word frequently heard in today's political and economic dialogue, though the focus typically is on issues of outsourcing manufacturing and services to countries with lower labor costs—and the resultant loss of jobs at home. Considerably less attention has been paid to the globalization of science and technology that is being driven by instant communications and the ease of intercontinental travel.

Just as US companies have been shifting their manufacturing operations to rapidly developing countries such as China and India, companies that engage in applied research are following a similar trend. The traditional practice of sending senior expatriate managers out on long-term assignments is giving way to new approaches. Increasingly, multinational corporations transfer mid-level managers or experienced scientists and engineers for a short-term overseas assignment of up to one year. A second change is the growing numbers of “virtual assignments,” which involve a combination of long-distance management using electronic communications and data transfer, and long-distance commuting.

Here in the United States, training the workforce of tomorrow for the increasingly globalized work environment has not been a high priority. In Europe, in contrast, universities have been preparing for many years for the dissolution of national boundaries



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and the creation of the European Union, and the resultant free flow of labor. Several years ago, I helped organize a US-European Union workshop on best practices in university education in science, technology, engineering, and mathematics (STEM). The European participants showed great interest in ways to redesign university courses along more diverse and international lines. The harmonization of science and engineering curricula had become a central issue now that doctors trained in Milan could be practicing in Heidelberg, and engineers educated in Athens could be working in Lyon.

My own work in curriculum development involves the use of biotechnology for economic development in Asian countries. While technologies can be bought and transferred, sustainable growth of high technology is dependent on the creation of a highly skilled labor pool. It is of particular interest to note the emergence of global universities where elite institutions (including several from the United States) are setting up research and educational facilities in countries such as Singapore.

TRAINING THE FUTURE WORKFORCE

These observations and experiences suggest that there is reason to reflect on how best to educate the next generation of scientists and engineers, who will enter a workplace that has become truly global. This is an effort in which my colleagues in the social sciences and humanities have had far greater experience, and to which they have brought greater sensitivity. In science and engineering, there has been a tendency to feel proud of the supremacy of US technology. This pride is quite justified, but should not lead to complacency that there is little that we can learn from other nations.

Several US universities are taking big strides in globalizing their science and engineering curricula. In November 2003, I worked with other colleagues to organize a conference on the globalization of undergraduate science and engineering education in the United States. A significant number of colleges and universities were represented, providing a snapshot of the types of available programs.

By far the largest number of programs involved sending students abroad. Work or research abroad also was fairly common, originating mostly via collaboration between an American faculty member and a colleague abroad. In some cases, faculty exchanges also were driven by collaborative research. Distance learning, in which courses are shared through video conferencing and/or the Internet, remains at the experimental stage in a variety of institutions.

The most recent statistics (for the academic year 2001-2002) show that of the 160,920 US students studying abroad, only 16 percent were in STEM majors. This suggests that relatively few science and technology students go abroad. Those who do study overseas are unlikely to be pursuing activities directly related to their fields of study. Many STEM students, it seems, find it difficult to integrate credits earned overseas into the overall curriculum requirements for graduation.

If current STEM curricula in the United States do not adapt to the globalization trends, US graduates in science and engineering will be unprepared for the emerging marketplace. By far the least frequent and most challenging approach to a more globalized education is course and curriculum design on individual campuses. At the same time, it is this approach that is likely to affect the largest number of students.

CAMPUS INITIATIVES, GLOBAL CONNECTIONS

The globalization of a STEM curriculum has three principal components: course content; teaching materials; and pedagogical approaches. In practice, curriculum changes can proceed incrementally by creating modules for existing courses, creating new courses, and, finally, integrating these courses into the curriculum for a specific major. Then there is an altogether different dimension that involves a linkage or partnership with one or more foreign universities that are committed to developing similar curricula.

It is interesting to examine and compare two novel educational initiatives that focus on globalization carried out at the University of Washington in Seattle

(UW) and the University of Maryland, College Park (UMCP). UW has worked to create binational courses with foreign universities, and also has an ambitious initiative integrating a year of study and research in China into specific four-year undergraduate programs. UMCP's efforts have been complementary to those at UW in that they focus on course and curriculum development on the home campus.

The University of Washington in Seattle has developed an international initiative called UW Worldwide (UWW) under the leadership of Dr. Gretchen Kalonji, professor of materials engineering. This project involves a partnership between UW and foreign universities focusing on a research-based course, or on a four-year collaborative curriculum. Support for these initiatives has come from the Fund for the Improvement of Post Secondary Education and the National Science Foundation (NSF).

As part of this initiative, a UW-Tohoku University partnership on a first-year course on engineering design resulted in binational teams that work on the research projects of faculty members. Communication occurs through email and other forms of information technology. In UW, this initiative is linked to a seminar course entitled "Japanese Society, Technology, and Culture." This bite-sized approach also has been used in collaboration with seven other foreign universities, including the University of Tokyo (contract law), Tsinghua University in Beijing (art and graphic design), and Eritrea's University of Asmara (social work).

A more far-reaching initiative is the four-year curriculum project between UW and the University of Sichuan, located in central China. Following the general theme of "Challenges to the Environment," five research teams focus on anthropology/archaeology, biodiversity, ecomaterials, forest ecology, and water resources. The students come from a variety of academic majors and spend their third year in the collaborating country mainly working on a research project. This involves roughly 25 US students in Chengdu and 25 Chinese students in Seattle. The US students take a year-long seminar on Chinese society, history, and science prior to their year abroad. Once they return to their home campuses, the students spend their final year doing an honors thesis based on their overseas project. The first cadre of students graduated in 2004 with their baccalaureate degrees.

The UW-Sichuan program provides students with a unique experience that combines research in a foreign country and a curriculum that is enriched with social

and cultural elements. At the same time, their studies abroad are integrated fully into the designated course of study for their UW degrees.

The University of Maryland approached the issue of globalization from a somewhat different direction. My experience with the globalization of biology courses began about 14 years ago with initial NSF support, and has accelerated over the past two years with a major grant from the Freeman Foundation. The original strategy was to develop a set of courses in the University Honors Program directed towards a group of academically gifted and highly motivated undergraduates (usually freshmen and sophomores). These honors courses would act as test beds for new teaching materials and pedagogical methods, which could then be transferred to mainstream courses taken by the student body at large. Three honors courses have been created and taught:

■ **Case Studies in Biology and Culture**—Student teams researched and wrote two case studies during the semester. The central theme was the use of biology to solve major problems in the developing world in areas of medicine, agriculture/food, and the environment.

■ **Biotechnology in Asia**—Student groups were assigned to country teams. Each team conducted research into the interface between biotechnology, its use for economic development, and the socio-cultural context in which this took place. The countries studied were Japan, China, Singapore, Taiwan, and South Korea.

■ **Traditional Chinese Medicine (TCM): A Complementary Approach to Modern Western Medicine**—Coursework involved a study of the philosophical and conceptual underpinnings of TCM and its therapeutic approaches, as compared to modern Western medicine. Student teams focus on specific diseases or health conditions, with a particular focus on possible integration of two such different approaches to human health.

The UMCP honors courses are a rich source of interdisciplinary and cross-cultural course material used in problem-solving tasks. The creation of mixed teams (mixed by race/ethnicity, gender, and field of study, and by academic achievement) is a particularly powerful tool in eliciting different perspectives on a specific problem. Grades depend largely on preparation of research documents in a format that mimics those encountered in the workplace. Preparing case studies was the core task of those in the Case Studies in Biology and Culture course, for example, while students in the biotechnology course

prepared embassy cables and country reports. The collection of case studies is then used for the large-enrollment General Microbiology course (for biology majors) and for *Microbes in Society* (a general education course for non-science majors). Mixed teams now are being used in these regular biology courses.

Oral presentations also are an integral part of the courses. One new tool is the use of role playing and complex scenarios that combine science, policy, and diverse cultural perspectives. In addition, access to skilled librarians, along with the use of WebCT and the Internet, result in a rich and multifaceted course content. The WebCT instructional software system provides access to course material and readings, while facilitating links and email between instructors and students. Dedicated chat rooms enable student teams to collaborate on research projects.

The Freeman Foundation grant has as its objective the creation of East Asian modules and courses in the curriculum used to educate science, technology, engineering, and mathematics students. The grant enabled UMCP to select a group of highly experienced faculty and resource staff to participate in a summer workshop, and provided these staff with fellowships to enable them to continue working on their educational projects during the academic year.

The individual projects are varied in nature and scope, ranging from course module development to the creation of new global courses. One faculty member in landscape engineering now teaches a course on the planning of science parks in the United States, and also is creating a module to examine similar projects in Taiwan and China. Faculty members in civil engineering and government and politics are developing a course on the environmental impact of major engineering projects in countries such as China and Japan.

By far one of the most exciting and innovative projects under way at UMCP is a global course developed by a group of animal sciences faculty both at Maryland and in Beijing. The course content (physiology of dairy cattle) basically is the same, but is adapted for each specific institution with a shared group of readings, some of which require translation. The global coursework also incorporates distance communications using the Internet, with lectures and discussions transmitted electronically.

Progress in such courses will lead to their dissemination both on campus and across the country. This will be particularly true if the global courses are effective in bridging cultural and political barriers.

Both UW and UMCP have set new directions in the globalization of undergraduate STEM curricula in ways that are complementary. One provides in-depth research experiences in a foreign country and integrates it into the established curriculum. The other is aimed at the creation of new course modules and courses. These efforts are, nevertheless, the beginnings rather than the end of the story.

Preparing US STEM students for the global workplace will be an ongoing task. Much needs to be done in the following directions:

■ **Dissemination**—Expanding upon these efforts and sharing the results with other universities, both in the United States and abroad, has to be part of the curriculum globalization efforts.

■ **Faculty development**—The success of such efforts ultimately is dependent on training faculty members to think of their courses in global terms. This applies to US faculty as well as their counterparts abroad.

■ **Global courses**—Ultimately, US universities should move towards incorporating larger numbers of global courses developed by international faculty teams. While similar in their coverage of the technical material, such courses also should provide different perspectives for different countries.

■ **New global teaching materials and approaches**—By necessity, global courses are both interdisciplinary and cross-cultural, and there are few textbooks or materials available. The Internet and distance communications provide the basis for a richer and far more flexible source of teaching materials for these types of courses. Much work in the years ahead will focus on such efforts.

AN INCREASINGLY VIRTUAL GLOBAL WORKPLACE

All of these efforts should foster new global ways for thinking about the education of future generations of scientists and engineers. In what ways do they address the changing nature of the workplace?

Recent high-technology developments in Asian countries such as China, Taiwan, and Singapore have shown the emergence of a virtual framework for modern corporations and an increasingly fluid labor environment. Taiwan's new pharmaceutical company ScinoPharm, for example, has its head office and a modern manufacturing plant in Taiwan, but sources raw materials in China. The company's financial and marketing groups are based in the United States, while

the research laboratories are in China. In Singapore, major pharmaceutical multinationals carry out both applied research and the manufacturing of finished products, and have established centers directed towards applied research and clinical trials that are synchronized with parallel efforts both in home countries and other industrialized countries. As high-tech companies move towards more seamless global operations, closer integration of such upstream operations in different countries will be made possible through modern information technology, centralization of unique facilities, and short-term assignments.

Here in the United States, particularly in any election year, the question many ask is where all the jobs have gone. The real issue, however, is the global transformation of industry. Perhaps the real question should be: How will your work change and where will it take you? Again, Singapore, with its rapid expansion of research institutes and centers, provides an interesting model. Within the country's public research institutes and centers, only 22 percent of the scientific and engineering staff is Singaporean, compared to 48 percent overall in Singapore's industrial sector. Many senior investigators and managers have been recruited from the United States.

Even non-managerial employees are finding new opportunities in Singapore and other countries. An interview with two Americans working at ScinoPharm revealed that they were employed on the production line. While experienced line workers, they had no previous experience working overseas, but were attracted by generous compensation packages and the opportunity to build a new pharmaceutical operation. While such expatriates usually return home, it is hard to believe that their overseas experience will not give them a competitive advantage in their next jobs, as well as a broader appreciation of the economics and workings of the global marketplace.

The modern labor market, whether in Singapore, the United States, or elsewhere in the world, demands higher skills at all levels in the laboratory, on the production line, and at the administrative level. As more and more companies orient their operations for the global marketplace, such skills will have an increasing global component. Simply put, more and more work will take place across national borders. Job transfers abroad, along with virtual assignments, will be continuing trends to watch. Framing the education of US science, technology, engineering, and mathematics students along these lines has now become a necessity rather than a luxury.