FRONTIERS:
THE INTERDISCIPLINARY JOURNAL OF STUDY ABROAD



# Science and Engineering Education Abroad: An Overview

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Introduction

W H E N C O R N ELL University was founded in 1865 as the land-grant institution of New York State, major changes were taking place in American education. Four principal elements characterized these changes: (1) a rejection of the dominance of classical and theological studies; (2) a championship of the sciences; (3) an insistence on attention to agriculture and the mechanic arts; and (4) a demand for greater democracy in education. These principles were a response to the emerging needs of nineteenth-century society, which was dramatically transforming itself as a result of the industrial revolution.'

The importance of science was equally emphasized in Europe, notably in England and Germany. In 1880, for example, on the occasion of the opening of Mason College, Birmingham, which subsequently became the University of Birmingham, the British scientist Thomas Henry Huxley (1825-1895) delivered a lecture titled "Science and Culture." In it he complained that "physical science was practically ignored, while a certain literary training was enjoined as a means to the acquirement of knowledge, which was essentially theological." Huxley made a strong case for elevating the natural and physical sciences to the rank of the arts and humanities, especially literature, which in his time was regarded as equal to the sum total of culture. Huxley suggested that "for the purpose of attaining a real culture, an exclusively scientific education is at least as effectual as an exclusively literary education."2

On both sides of the Atlantic, educators were searching for a more proper balance in the curriculum: in the United States, Andrew Dickson White, the founding President of Cornell, was disillusioned with his own classical education because it had been too narrow; and in Europe, Huxley, among others, objected to literature as constituting the sum total of all culture in his day, and pleaded with the founders of the University of Birmingham to introduce a better balance in the curriculum, between the humanities and sciences.

Today, we live in a very different world-an international and multicultural world-and once again, the university must adjust to the new emerging needs of our rapidly and profoundly changing society. For we too see an educational imbalance that this conference is addressing: all students, not just students of the humanities and social sciences, but of the sciences and engineering too, must be prepared for the global society in which they live and work. When asked why few American undergraduates study science and engineering in other countries, there are still faculty and administrators who respond "Why bother? It may be useful, though not essential, for students of the humanities and social sciences to study abroad, but it is certainly not necessary and perhaps even wasteful for students to do so in the physical and natural sciences."

The remainder of this paper will address four aspects of this topic: (1) the rationales for study abroad in the sciences and engineering; (2) the demographic patterns in study abroad in science and engineering; (3) the perceived barriers to study abroad in science and engineering; and (4) some recommendations for the development of study abroad programs in science and engineering.

1.Rationale. "Why Bother At All?"

1. Science and engineering are without borders.

1. No country in the world has a monopoly on learning, research, and teaching science. Important learning takes place in every corner of the globe where one can find a core of well-educated people who are knowledgeable about science and technology and contribute in various degrees to the expanding base of scientific and technological knowledge. The contributions from the other speakers in this symposium provide ample evidence of the breadth and depth of scientific and technological knowledge and research conducted throughout the world.

2. Science cannot, and shogld not, exist withovt stgdents at all levels, particularly at universities.

   Students bring intellectual curiosity to the scientific enterprise and help us build scientific and technological capacity for the future. Science and technology studies, as in every other field, must begin at the earliest levels of education, not just at the Ph.D. or postdoctoral levels. Undergraduate and graduate students conducting research on the habitatand behavior of the jacanas (birds) in the tropical forests of Panama are not only expanding their knowledge of evolutionary biology, animal science, botany, and the methods of scientific research, but bringing enormous vitality to the project, interacting with scientists from all over the world, and building their and our scientific capacity for the future. Moreover, mobility and exchange are habits that are forged early; it is often too late to begin after one has completed the Ph.D. and taken on numerous professional and personal responsibilities.

3. Science and technology expertise is at once global and local.

   This is particularly evident in areas of agriculture, the environment, and health, where on-site experience is critical for a fuller understanding of global problems and potential solutions. Through study abroad, students gain an awareness of the social and cultural context that dictates some of the priorities and approaches to science, most obviously in the areas mentioned above. Moreover, as students increase their knowledge of the local setting, they also increase the ways of interconnecting their external and local knowledge, frequently in unexpected, and very effective, combinations.

4. Information and communication technology makes for a qualitative change in study abroad programs.

   This is particularly evident in the use of e-mail and the capacity of the global Internet system, and other forms of technology, such as video conferences, all of which have significant potential for cost-effective.distance education that must be incorporated in study abroad programs.

5. lnternational science and engineering has an ethical and hs:manistic dimension.

   There is still a large gap, and perhaps a growing gap, between developed and developing countries, that can be addressed through mutual cooperation, and sometimes more effectively through the intermediary of undergraduate and graduate students than through more senior but very expensive researchers. Institutions with significant human and material resources must develop linkages with institutions in the developing world for the mutual benefit of both.

6. Science and technology are not only for scientists and technical experts.

   Science and technology must be a significant component of everyone's general education, including that of future world leaders. It is not enough to say that world leaders are trained in the humanities and social sciences, and rely on scientists and engineers for assistance in major policy decisions. Scientists and engineers also become world leaders and, therefore, they must have access to some of the same opportunities enjoyed by other students to develop a global perspective, and address the fundamental problems of the world by combining theory and practice, learning and service. Professionals, including scientists and engineers are increasingly expected to combine in their careers both technical (domain) knowledge and general (contextual) education, with an added measure of foreign language and intercultural skills.3

7. Study abroad provides an effective means of learning

When instruction and enjoyment come so superbly combined, as it does in so many study abroad programs, who can resist the attraction of studying science and engineering? Study abroad humanizes the scientific enterprise, making it less mechanistic. Moreover, in a period when governments and the public are questioning their level of support for science as well as the rationale for this support, the enthusiasm of students who study abroad in the sciences and engineering might well add a measure of support for scientific and technological research.4

2.Patterns of Student Mobility

The statistics on student mobility worldwide give us reason to think seriously about long-term goals and strategies for study abroad in science and engineering.

There is a great imbalance in the number of international students coming to the United States and U.S. students studying abroad. The Institute of International Education (IIE), which publishes an annual summary of statistics on international student and staff mobility, estimated that in 1994-1995, 452,635 international students enrolled in U.S. colleges and universities, about equally divided between undergraduate (48.9 percent) and graduate students (42.4 percent), with a few other students coming here for intensive English language (3.6 percent) and practical training (2.9 percent) and nondegree studies (2.2 percent). This total number represents a very slight increase (.06 percent) over last year.5

However, it should be noted that the number of students from abroad as a percentage of higher education enrollment in the United States has not grown significantly in the past forty years, from 1.4 percent in 1955 to 3.1 percent in 1995, even if it has doubled during that period; in the United Kingdom and other European countries it is over 10 percent. And twenty five years ago, in 1970, the United States share of internationally mobile students was 36.7 percent; in 1992 it was 32.4 percent and appears to be gradually declining. The number of graduate students coming to the United States declined this past year by 4.6 percent from last year's total; this decrease was especially evident in the science and engineering fields: they dropped by 3.4 percent in mathematics and computer sciences; 4.3 percent in engineering; and 8.2 percent in the physical and life sciences. On the other hand, this shortage is made up by more undergraduates, who come to the United States in their formative years.

Engineering remains the top choice of students attending research institutions; however, in the late 1980s and early 1990s the average of growth in engineering, math and computer science fields was less than 1 percent, whereas in the latter part of the 1980s, the average yearly rate of growth of physical and life sciences was about 7 percent.

In marked contrast to the nearly half a million students coming to the United States, only 76,302 U.S. students studied abroad in the same year. Most of the growth in study abroad occurred during the 1980's (from an estimated 48,483 in 1985-86); however, since 1990 enrollments have plateaued, increasing only about 2 percent each year. The overwhelming majority of U.S. students going abroad are undergraduates; graduate students remain a very small proportion (7 percent) of all study abroad enrollments, although it is difficult to track the mobility of graduate students, especially of those pursuing short-term dissertation research abroad.

Even more difficult to track is the number of scientists and engineers working overseas on either a short-term or long-term basis, a group that may actually be smaller than is commonly thought.6

Last year over two thirds (67 percent) of study abroad students studied in Europe, followed by 13 percent in Latin America; 7 percent in Asia; about 3 percent each in Oceania and the Middle East; 2 percent in Africa; and less than 1 percent in Canada. Our exchange relationship with European nations is rather well balanced. However, the relationship with Western Europe is unbalanced in terms of field of study choices: European students who study in this country are enrolled in a wide variety of fields of study, including math, computer sciences, business and social sciences, whereas U.S. students abroad are overwhelmingly drawn from the social sciences, humanities, and foreign languages. Less than 2 percent of U.S. students are enrolled in engineering or math or computer sciences abroad, which are the fields where Asian and European students are heavily concentrated.

What do some of these statistics tell us?

1. U.S. science and engineering students are an underrepresented block of students among those studying abroad. Also, the shifts taking place among international students coming to this country, away from science and engineering and more to business and social sciences, and perhaps away from graduate study to undergraduate study, also suggest the potential decline of talented young people to contribute to our graduate programs, and potentially diminishing overall international contact in the fields of science and engineering.
2. Countries that send large numbers of students to the United States, such as developing countries in Asia, receive small numbers of U.S. students in return, reflecting a lost opportunity for both U.S. and Asian students alike to develop cooperative relations and opportunities for field study.
3. U.S. students, compared with students coming from abroad, have limited exposure to the global society in which they live and work, and consequently little opportunity to develop a greater awareness of the history, culture, political and economic systems of

those with whom they, as educated professionals, must interact for the rest of their lives.

New York State institutions, home of the Pew Cluster of colleges and universities, mirror the national profile. The ratio of incoming to outgoing students is approximately 5 to 1, with a student profile that is very similar to the national one.7

A few more statistics related to study abroad:

An inventory of 2,250 study abroad programs listed in the annual IIE guidebook of study abroad programs, indicates that about one quarter (27 percent) are listed for science and engineering students. Relatively few U.S. colleges and universities have successful study abroad programs designed specifically to meet the needs and interests of science and engineering students.

And of the 76,302 U.S. study abroad students in 1994-1995, only 9 percent had declared majors in the fields of engineering, physical and life sciences, and math and computer sciences combined. By comparison, 37 percent of the international students coming to the United States were majors in science and technical fields.

At Cornell, 22 percent of study abroad students major in science and technical fields, which is over twice the national average. The number of science courses these students take abroad is gradually rising: an analysis of students' transcripts of academic work completed abroad during the past two years, shows that in 1993-1994, 29 percent of all courses taken abroad were in the fields of science and engineering, and last year (1994-1995) science and engineering courses taken by Cornell students made up about 38 percent of all courses taken abroad.8 Among the titles included in their transcripts one finds, for example, Microbiology and Virology (Ecole Centrale de Paris); Biochemistry (University of Reading); Electricity and Magnetism (Universidad Iberoamericana); Algorithmes, Structure de donnees et systemes d'exploitation (University of Paris); Operating Systems, Waste Recovery and Recycling (University of Wollongong, Australia); Introduction to Environmental Engineering, Astrophysics, Fluids I, Engineering Geology, Haemoglobulin and Immunology, and Transition Metals.9

One final statistic: the vast majority of Cornell students, and likely of U.S. students in general, studying science and engineering abroad, do so in programs where the language of instruction is English: in 1993-1994 only 1().5 percent and in 1994-1995 only 16 percent of their science courses were taken in a non-English language. However, student surveys indicate that, whether they studied in English or a foreign language, their experience abroad was overwhelmingly positive.

3. Barriers to Increasing Participation There are several barriers to greater participation by students in science and engineering study abroad programs:

1. *Limited commitment to international education.*

1. The concept of globalism is still not sufficiently ingrained in the philosophy, curriculum, and programs of institutions; there is a perceived lack of stated goals, objectives, and strategies for international education. For example, an international dimension appears as a major component of every aspect of the mission statement of the College of Agriculture and Life Sciences at Cornell, but the word international does not appear in the mission statement of the College of Engineering.

2. *Limited faculty interest in international science and engineering exchanges.*

   Scientists and engineers are generally international in their own research and professional activities, many of whom enjoy contacts with scientists and engineers in many parts of the globe. However, they are not yet systematically assisting their students to take advantage of their vast experience and broad contacts, encouraging them, particularly as undergraduates, to study abroad.")

3. Structural issues, including curricular design and requirements, transfer of credit and modes of assessment, and academic calendars.

   There is agreement in principle on the part of many institutions to collaborate on student learning across campuses, but the implementation is problematic, due in large part to the vertical structure of the curriculum in the United States and the requirements in many science and engineering fields, which make it difficult to find exact course equivalents. Organic chemistry may be taught over the course of several semesters or modules abroad as compared with one intensive semester in the United States. U.S. students are reluctant to leave their home campus for more than one semester, and many courses abroad are taught on an annual basis. Assessment may come at the end of the entire program in one country as opposed to at the end of the semester or module. Grades earned abroad are not always accepted by the home institution or must be translated into strict equivalents that are sometimes impossible to match."

4. Inadequate preparation in foreign languages.

   Knowledge of a foreign language is essential for a proper understanding of another people and its culture. In learning another language, the principal challenge is to understand the idea each term expresses, especially since every term may not have an equivalent in English. In learning a new language, students open themselves not only to new words and linguistic structures but to new and ever-widening circles of ideas that modify and broaden their understanding of the world. A person who knows different languages will more likely develop a greater awareness of the varieties of meaning and perceive multiple aspects of reality.'2

   It is still true that few U.S. students are adequately prepared to function in non-English speaking academic and work environments, even in the sciences and engineering, which are easier to study in a foreign language than, say, history or political science. Therefore, courses abroad often must be taught in English, even in non-English-speaking countries, requiring expensive infrastructural arrangements.

5. Uneven mathematical skills.

   There is some question about the readiness of the American undergraduate, especially concerning mathematical skills, particularly in France and other European countries. For example, in France the baccalaureat, which is required for entrance to the university, represents a significantly higher qualification than the average American high school diploma.

6. Limited support services on campus and abroad.

Students interested in studying in science and engineering abroad have few advisors on whom they can rely for assistance in finding an appropriate program of study abroad. Finding appropriate programs and matching courses on campus with courses abroad is a labor-intensive activity that requires strong support from knowledgeable faculty and administrators, who are in short supply.

7. Financial strategies can inhibit study abroad in the sciences.

Many science and engineering students who might want to study abroad must add a fifth year, which is costly, or study in the summer, for which they receive no financial aid and must forgo summer employment. Scholarships are not always portable.

1. Government regulations.

Proposed legislation may impose new fees on international students and reduce some of the flexibility that institutions currently have to bring international students to the United States. Conversely, visa requirements abroad can make it difficult for U.S. students to do short-term internships.

4. Recommendations

Cornell, not unlike some of the institutions in the Pew Cluster, has enjoyed some successes and experienced some failures in sending science and engineering students abroad. In the past four years, for example, over one hundred engineers have studied abroad, over one third of them through a Cornell program in Germany, and many more Cornell non-engineering students have taken science courses in institutions overseas.

Approaches used by Cornell:

1. Direct enrollment-students have enrolled in a wide variety of institutions, mainly European and Australian universities that offer broad curricula in the sciences and engineering. As a result of the student mobility created by the Erasmus and Socrates programs, many European institutions have developed offices of international education that are well equipped to receive international students, including U.S. students. These universities are attractive to U.S. students who want to combine studies in science and engineering disciplines with a different perspective of the world. Many undergraduates subsequently return to these countries for advanced degrees or work.
2. Specially designed programs-university/college programs, sometimes in close cooperation with other U.S. colleges and universities, that offer some of their own courses and special academic support services (e.g., tutoring), and partial or even total integration into a host institution: the Cornell-Duke program in Paris; the Cornell-Nepal Study Center in Kathmandu/Kirtipur in cooperation with Tribhuvan University; and the Boston University Tropical Ecology Program in Ecuador.
3. External sponsors and consortia-such as the Denmark International Studies Program (DIS) in marine biology and ecology; the School for Field Studies (SFS), and the School for International Training (SIT), which operate worldwide programs, especially in Asia and Latin America; the Institute of Asian Studies (IAS) at Japanese institutions; the Budapest Seminars in mathematics or computer science or programs at the Technical University of Budapest.

To develop international study programs in science and engineering it is necessary to focus time and resources both on and offcampus.'3Below are a few suggestions.

Actions on Campus:

- articulate at the highest level a strong commitment to the integration of an international dimension in science and engineering education; also, faculty and administrators must give a clear and forceful message, because only then will students begin to understand the importance of thinking globally;

  - establish within each college curricular committees to consider the international dimension of fields in science and engineering; where it is appropriate, propose linkages between specific fields and opportunities for study abroad, (e.g., in geology of the Andes; the environment and natural resources in Ecuador or Nepal);
  - develop, at the departmental level, student advising structures; assign the director of undergraduate studies to encourage, advise, and monitor study abroad for department majors;
  - modify traditional foreign language courses by regularly including material on cultural aspects of the foreign country; for example, in German, systematically introduce ample material in German on German life and society, institutions, scientific and technological contributions, and make extensive use of videos, including industry videos, TV programs, technical manuals, newspapers and magazines. One can easily envision a separate section of German for engineers class that would be complemented by the German section of the Language House Program for regular meals and other scheduled events with invited guests from the German scientific and industrial communities;
  - take better advantage of international graduate students as resources for undergraduates; participate in formal and informal seminars and meetings focusing on the working conditions of scientists and engineers abroad. Their cross-cultural experience can serve as a valuable role model for U.S. students;
  - make use of information and communications technology, by establishing e-mail and video dialogues with students and faculty at collaborating institutions abroad;
  - provide better and more detailed information on institutions abroad, by identifying strong scientific laboratories and engineering programs, university faculties that are strong in each field; disseminate the information both on and offcampus to faculty, staff, and students, including entering freshmen; maintain data on international mobility of faculty and students.

Actions off Campus:

- develop study abroad programs in conjunction with partner institutions overseas, incorporating special high-value components, such as guided visits to scientific laboratories and multinational industries. Many U.S. students entering science and engineering programs in U.S. colleges and universities have had limited opportunities to be inside either kind of facility. Engineering students who participated in the Cornell program in Hamburg found the visits to industries one of the most valuable components of their experience in Germany, and frequently suggested that a similar array of site visits should be available to them on the home campus;

-develop short-term research opportunities or work projects, as was done, for example, by the Worcester Polytechnic Institute program in Thailand, for students both on and off campus, by building on the worldwide connections of the faculty and alumni

-provide summer travel grants for sophomores to work at research institutes throughout the world, for example, the Max Planck Institutes in Germany, the Louis Pasteur Institute in France, or in the global network of agricultural research stations.

-develop summer internships with multinational corporations operating in this country and abroad, enabling them to develop their professional and personal skills, and make contacts for future collaboration or employment. It is increasingly evident that once students have embarked on a short-term experience abroad they frequently return to that country or another one for more advanced and extended study and work.

-work with established exchange consortia, such as the North American Regional Academic Mobility Program (RAMP) supported by the IIE and the Fund for the Improvement of Postsecondary Education (FIPSE), a trilateral program in engineering, business, and environmental studies;l1 the EU-US Exchange of Science Students based at the University of North Carolina and the University of Strathclyde,'5 or develop institutional consortia in this country that make it possible to pool students, share faculty, and achieve economies of scale." The Pew Cluster of institutions in NYS, which has advocated a liberal arts and sciences education in the broadest way possible, is in a unique position to promote and develop undergraduate study abroad programs for its science and engineering students.

Universities throughout the world are today the principal providers of higher education, and while there are substantial differences from one institution to another, they are not fundamentally different in their mission. Once you strip away political, ideological, and economic considerations, the basic functions of the contemporary university are remarkably similar: the advancement of knowledge through research; the extension of knowledge through teaching and professional training; and the diffusion of knowledge, both old and new knowledge, for the improvement of society, that is, extension and service. The single most important change in higher education since the advent of the land-grant college and university of the nineteenth century, is the international context in which they must perform those triple functions: just as national technologies, corporations, and even national economies have yielded to international networks, the university has fast become international in its research, teaching, and outreach.

When faculty speak of their colleagues, they no longer refer exclusively to their colleagues on campus; more often than not, they have in mind colleagues all over the world from whom they learn and with whom they work in numerous ways, advancing the threefold mission of the university. Similarly, when our students go abroad, whether to London, Paris, Tokyo, Budapest, Beijing, Quito, Poona, or Kathmandu, they learn from an international faculty and student body; it is reasonable to say that at least one-third of what students learn, on our campuses and abroad, comes from other students as they work together, formally and informally, on a variety of projects. The habit of collaboration at all levels must be developed as early as possible: studying abroad provides an excellent mechanism for lifelong collaboration for the improvement of the global society in which we live.