AC 2008-2603: INCORPORATING GLOBAL PERSPECTIVES IN U.S. ENGINEERING EDUCATION

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Incorporating Global Perspectives in U.S. Engineering Education

Abstract

Global awareness is critical for preparing emerging engineers to work in the increasingly global marketplace, and US higher education institutions need to continue adapting by internationalizing their science and engineering programs. According to the Institute of International Education's Open Doors statistics, in 2005-06, fewer than 7,000 American engineers went overseas for study or professional development; nearly 90,000 came to the US for such purposes.[1]

Focusing on the challenges and successes achieved by the Institute of International Education and its partners in building global competence in engineering across the United States, this paper will present best-practices to building global competence in US engineering departments. It will discuss the implications and benefits of incorporating international perspective in the course of American engineering education, present options available to existing engineering departments, and offer solutions to the problem of imbalance.

Introduction

On one hand, in the US and Western Europe, countries are challenged to train and retain enough well-qualified engineers and scientists to meet the needs of their own economies, without having to rely increasingly on international students and professionals. Countries are addressing this challenge in various ways, based on their higher education systems and the interests of government and the private sector. On the other hand, increasing the challenge on the US side is a recognition that global awareness is critical in preparing emerging domestic engineers to work in the increasingly global marketplace. Although we have spoken here about the US and Western Europe, the basic tenets of this paper are equally applicable to the issues facing other continents and countries.

As a result, US engineering schools are seeking ways to make the curriculum and the undergraduate experience more international, and to build opportunities for students and faculty to gain global perspectives. But we have a long way to go: according to the Institute of International Education's ***Open Doors 2007*** Report, in 2005-06, only 2.9% (about 6,500) of US study abroad students were studying engineering. Meanwhile, about 15% of all international students (or close to 90,000) who came to the US for degree study were in engineering.[2]

The figures below, generated using the *Open Doors 2007* Report referencing current and historical data on the percentage of students abroad in Science, Technology, Engineering, and Mathematics (STEM) fields, sheds light on the scope and consistency of this discrepancy.[3] Note: "Sciences" in the figures below incorporates life, physical, and health sciences.

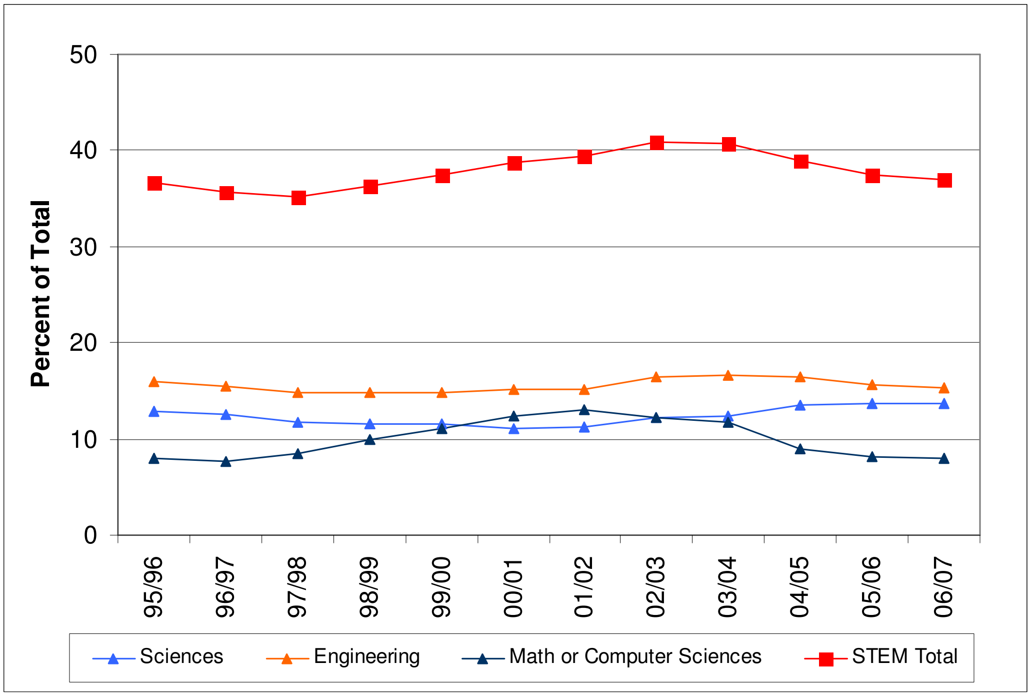

Fig 1. International Students on US campuses in the STEM Fields, 1995/96 – 2006/07

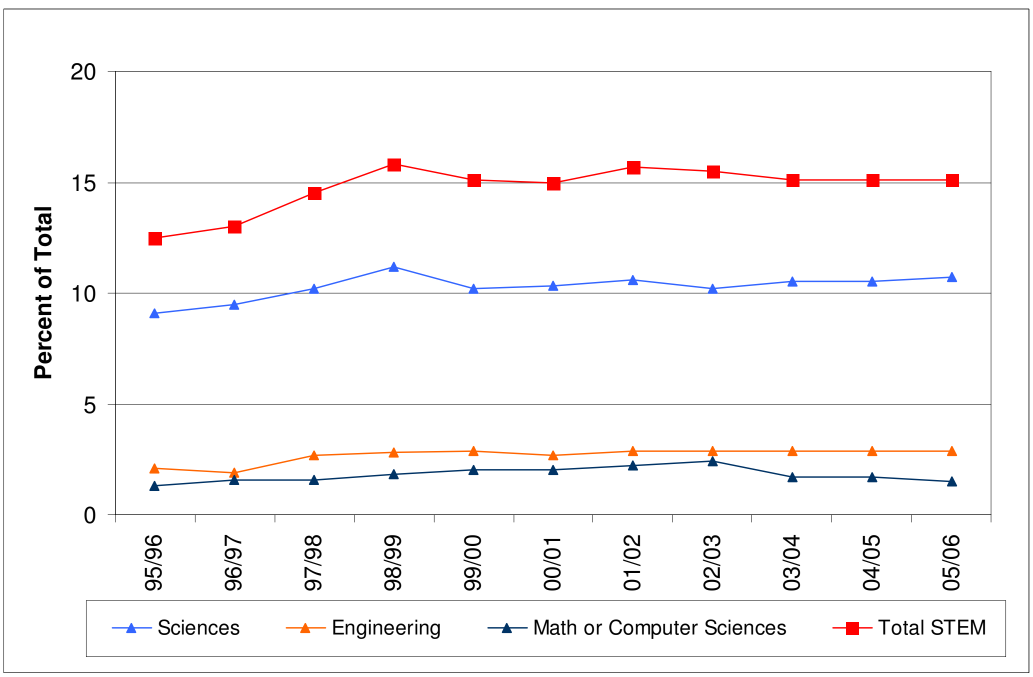

Fig 2. Percent of US Students studying abroad in the STEM Fields, 1995/96 – 2005/06

As can be seen in Figures 1 and 2, the American sciences, broadly defined, do have some "catching up" to do with respect to international education. However, the need is greatest where the percentage discrepancy between those who study in the US and those who go abroad is greatest – between incoming and outgoing engineers. It is worth noting here that the Open Doors reports consistently show that most Americans go to Europe, and most international students in the United States come from Asia.[4]

Focusing mainly (though not exclusively) on the challenges and successes achieved by programs administered by the Institute of International Education (IIE) and its partners in the consortium of 34 US engineering programs that comprise the Global Engineering Education Exchange (Global E^3), this paper will present benefits and drawbacks to building global competence in US engineering departments. It will discuss the implications of incorporating international perspective in the course of American engineering education, present options available to existing engineering departments, and point to resources that are available to engineering students who seek international experience.

The authors bring diverse perspectives from within the American academic marketplace. One has spearheaded international education activities at Rensselaer Polytechnic Institute, a leading US engineering university, and serves as the founding Chair of Global E^3, in addition to being an ASEE Fellow. The other two are based at the Institute of International Education, an NGO devoted to promoting and administering international educational exchanges. The paper will discuss vehicles to enhance the "soft skills" increasingly demanded by industry, promote more study abroad by US engineering students, and train a globally effective engineering workforce for the 21st century. We will present initiatives that have demonstrated short-term success, offer long-term potential, and are helping to balance the worldwide flow of engineers. Finally, we will offer some conclusions about the likely challenges going forward and how universities can address these challenges with existing solutions.

Broadening the Definition of Competence to Include Global Competence

There is a growing consensus on the broad outlines of what is needed to bring global competence. However, there is also an awareness that such innovations require time and funding to achieve, and that not all majors can readily accommodate study abroad, given the constraints of existing course requirements, especially in scientific and technical fields. Calls to bring back a foreign language requirement, for example, meet with strong resistance in science and engineering programs already under heavy pressure to accommodate an ever-expanding body of knowledge in the core curriculum, with fewer credit hours. Attention is increasingly turning to the vehicle of short-term study abroad as a way to infuse American undergraduate education with the global competencies listed above. Such study offers an intense educational opportunity and ideally stimulates longer-term interest in international education, language study, and global careers, while also providing students with skills that will better prepare them to be competitive in the global market place.

There is no consensus on the content or methodology that best develops global competency, and US higher education institutions are undertaking a number of different approaches, but the national dialog has clearly begun. It will evolve very differently than it has in European or Asian universities, since America lacks the kind of national/regional structures which can set higher education policy and mandate reforms. America's academic institutions are largely responsible for developing their own academic programs to respond to new challenges, and for doing so within the context of each institution's own educational vision and mission.

Increasingly, institutions have expanded their mission statements to include a commitment to producing "globally competent" graduates who are able to function effectively in the global marketplace and provide leadership in the international arena. The approaches of different types of institutions to implement this vision vary widely and are still evolving. But the direction is clear and is reinforced by a growing commitment to this same goal within various agencies at the federal and state level, and through the professional and regional accrediting agencies.

The issue is especially challenging for engineering schools, where the curriculum is tightly focused on acquiring a set of technical skills and where faculty have traditionally not seen much value in sending students abroad for an international experience. Referring to the *Open Doors 2007* report and Figures 1 and 2 above, of the over 200,000 students that study abroad each year, less than 3% are engineering students – this percentage that stayed fairly flat for the past decade.[5] With a great number of their graduate students (and much of their faculty) foreign-born, engineering schools may find it hard to see the logic in sending their own students abroad for further training, or how that will enhance their students' professional development. Without pressure from employers or government agencies, there has been little incentive to change this approach, although the leadership within the field of engineering is beginning to encourage change through the peer-based accreditation system, as well as through competitive pressure to recruit the best students domestically and internationally.

The accrediting body for engineering programs, ABET, Inc., expanded its expectation of skills required in graduates of accredited engineering programs, as well as its global scope. The following "soft skills" were added to Criterion 3 of the ABET guidelines:

- Ability to function in multidisciplinary teams
- Ability to communicate effectively
- The education necessary to understand the impact of engineering solutions in a global and societal context
- Knowledge of contemporary issues[6]

An earlier report published by the Institute of International Education (*Towards Transnational Competence*) presented the conclusions of a joint US-Japan Task Force for Transnational Competence, which spelled out a more general set of core competencies recommended for American and Japanese graduates in any academic field, including:

- Ability to imagine, analyze, and creatively address the potential of local economies/cultures
- Knowledge of commercial/technical/cultural developments in a variety of locales
- Awareness of key leaders and ability to engage such leaders in useful dialog
- Understanding of local customs and negotiating strategies

- Facility in English and at least one other major language, and facility with computers
- Technical skills in business, law, public affairs and/or technology, and awareness of their different nature in different cultural contexts.[7]

Government-Initiated Study Abroad as a Mechanism to Develop Global Competence

There have been, over the past century, many efforts to use study abroad to expand global competence of American students. Government efforts generally have been field-neutral. Most prominent among these is the Fulbright Program, created in 1947 and administered by IIE on behalf of the US Department of State. As a broad field-neutral program, it has become largely a vehicle for US students in the humanities and social sciences to obtain a global perspective. In the past three application cycles for the US Student Fulbright Program (for graduate-level projects and teaching assistantships), 8.2 % of applicants, and 10.2 % of grant recipients have been in the sciences.[8] In recent years, US government initiatives have focused on "critical" countries and languages, where there is strategic value for Americans to gain world area expertise. The National Security Education Program, funded by the Department of Defense and administered by IIE, is one such program, aiding students in gaining language expertise in "critical" languages.

In January 2006, the US president, along with the secretaries of state, education, and defense and the director of national intelligence, announced a series of initiatives designed to increase the teaching and study of the above mentioned lesser-taught languages, including significant increases in opportunities to study these languages abroad. One of these major initiatives is the National Strategic Language Initiative, focused on a dozen or more languages that are not sufficiently studied or taught in the US, such as Arabic, Chinese, Russian, Hindi, and Farsi. By expanding funding for programs like Fulbright, Gilman, and NSEP, as well as exploring support for language teachers and other strategies, the initiative seeks to improve US language skills and expertise in key world areas. Finally, the newly proposed Lincoln Scholarship Program seeks $50 million in federal funding this coming year (growing to $125 million in future years) to expand the number of Americans studying abroad to one million annually.

Imperative to Internationalize Engineering Education

The above programs are not science-specific, however, and do not target engineers. Engineers need global competencies and multi-cultural skills as much as any other professionals. Still, there is less of a tradition in this field to acquire such skills through study abroad than in many other fields. The academic benefit of study at a foreign university is less immediately obvious in engineering than, say, in languages or history. Engineering professors are sometimes more reluctant than others to grant credit for coursework conducted abroad, unless the syllabus and number of classroom and lab hours are very closely aligned with the home campus course. And the US engineering students themselves typically are not fluent in foreign languages, which limits their options in terms of pursuing engineering coursework at campuses abroad, since few engineering faculty teach in English at the undergrad level. (There is a growing expansion of Engineering programs being offered in English at the graduate level, however, which may expand access to English-taught Engineering courses abroad in the future at both undergraduate and graduate level).

Models in Internationalizing Engineering Education

Given the educational imperative of global competence, many initiatives have been developed to aid students in gaining international experience which are not stemming from government action. For the purposes of this paper, we will focus on those which affect mainly students in the sciences, and engineering specifically. Among these efforts, there are several modes of operation which generally fall into two categories: non-university-centric, and university-centric.

I. Non-University-Centric Models

Non-University-Centric solutions require low cost and time from the home university and the student, but allow universities to see their students gain global competence. The main drawback of these solutions is "shoehorning" – students who fit only certain requirements are eligible to apply, and not all students that we would like to send abroad are eligible. In addition, outreach to campuses by administrators of these programs is often necessary.

Here are four general types of solutions that are not university-centric. There may be (and likely are) other types of solutions, but these present distinct benefits and drawbacks.

1) Undergraduate Exchange

Example: Global E^3

The Global Engineering Education Exchange (Global E^3) is administered by the Institute of International Education and allows undergraduate engineering students at US member universities to study at a participating university overseas under a tuition-swap agreement. IIE administers the consortium of US-based institutions and international universities outside of Western Europe. IIE's partner in Paris, GE4, administers the Western European university membership. The current consortium membership is in excess of 70 universities worldwide, of which 34 are in the United States.

Benefits

The benefits of an undergraduate exchange are various. Most obviously, an exchange allows universities and students from both "sides" to benefit from a study abroad experience. The students that go abroad do not only benefit from the exchange, but also those students in classrooms that receive them. By hosting international visiting students, home students benefit from an international perspective in their engineering laboratories and classes. In addition, because undergraduate study abroad is typically in the middle of one's degree program, the student and home campus also benefit from the return of the student to the home campus from the exchange partner. The exchange alumni have the international experience to inform their studies at home.

However, the Global E^3 program offers unique benefits from being centrally-administered, and not a campus-based exchange. This centralized administration by IIE allows the following benefits to arise to Global E^3 members:

- Member universities need make only a single agreement with IIE (or GE4 if the institution is in Western Europe), and immediately has an agreement with all other members.
- Universities require less overhead because they need to maintain only one exchange agreement, instead of several separate agreements.
- A single exchange balance is maintained by the university with the program, instead of several individual exchange balances. Because these are maintained by universities with the program, this frees each member institution from needing to maintain balances with each partner campus.
- Because of this single exchange agreement, ad-hoc exchanges can easily develop between member universities. These include faculty exchanges, team-taught courses, and so forth.
- Finally, the central administration is beneficial because the tuition swap scheme allows students and universities to have predictability with regards to cost, as students are still considered enrolled students at their home institutions.

Drawbacks

There are drawbacks to undergraduate exchanges generally, and the Global E^3-type of consortium-based exchange more specifically. Generally speaking, the exchange is limited to the partner university(ies). Students interested in going to other schools in other countries are not served. In addition, as with most international programs, language competence is a factor, limiting the number of eligible participants in such an exchange program. Finally, because the individual universities do not administer the program directly, there may be concern about integrating the study abroad experience into the home campus curriculum.

Global E^3 has additional drawbacks unique to its centrally-administered nature. For example, course equivalency cannot be guaranteed by the program, and is dependent on the individual university to determine. In addition, overall exchange flows need to be balanced by the central administrators. This means that weak participation from one side (or in one year) could affect all the partners by limiting the ability of all institutions to send and receive students.

2) Graduate Summer Internship

<u>Example: CESRI</u>

The Central Europe Summer Research Institute (CESRI) is administered by the Institute of International Education and was funded by a grant from the National Science Foundation. Enrolled graduate and doctoral students in six fields (biology, chemistry, computer science, environmental science, engineering, and mathematics) can apply for a two-month fellowship in one of six Central European countries (Austria, Czech Republic, Germany, Hungary, Poland, and Slovakia). The fellowship supports laboratory research that aids the student in their pursuit of their advanced degrees. As a benefit of this program, selected students who are unable to find an appropriate host will be aided in placement by IIE's European office in Budapest, Hungary. CESRI Fellows are expected to arrive in Budapest for a one-week orientation to Central Europe, and then end their internship with a two-day debriefing session sharing results.

Benefits

Many of the benefits of a graduate summer internship stem from the fact that it takes place during the summer. Students are not expected to interrupt ongoing academic work, or replace their graduate studies, in pursuit of a graduate internship. Meanwhile, because these are research-oriented internships, students gain transferrable experience during the internship, which can be used in furthering ongoing work. In addition, because the emphasis of graduate internships like CESRI is research, language competency requirements of programs of this nature are typically low – laboratories overseas often operate in English.

CESRI specifically benefits from its design. It, like Global E^3, is centrally-administered and puts low (or no) stress on university resources. The focus on Central Europe allows and encourages students interested in Western European countries to consider Czech Republic, Hungary, Poland, and Slovakia without worrying about language needs. This means students can get a more unique international experience than their many peers in Western Europe, making them more attractive as employees or faculty. The enrollment requirement creates a similar benefit to the undergraduate exchanges – alumni can demonstrate the value of the international experience to their American peers. Finally, the most obvious benefit of the CESRI Program, and programs like it, is the fact that students receive funding to undertake this experience. The NSF provides ample funding for these students to not worry about out-of-pocket expenses.

Drawbacks

Drawbacks of graduate summer internships, like CESRI, include, most obviously, the fact that this takes place during "only the summer". A semester or year abroad would clearly provide a deeper international experience in the sciences. Because CESRI students, specifically, are going to countries where English may be less common, their ability to operate within the local communities could be limited, and the benefit of the program may only be limited to the laboratory. "Soft" language requirements, such as preferring students with some language ability, do alleviate the language concern somewhat, but not the question of time.

Another drawback of programs like CESRI is that they provide money to the participants, meaning that the program is only useful as long as there are funds to support students, and the number of students participating is limited to the funding available. Unlike an exchange which can have a theoretically-unlimited number of participants, the support for students is defined by the funding available.

3) Graduate Year-Long Study

Example: Churchill Scholarships

The Churchill Scholarships program is administered by the Winston Churchill Foundation of the United States, with some administrative support from IIE. The program allows students at participating US universities to apply to undertake a year-long study in the sciences at Churchill College, Cambridge University, in the United Kingdom. The program provides full financial support for one year of study at Churchill College for approximately twelve graduating seniors.

Benefits

Graduate year-long study programs typically alleviate some of the concerns that a short-term study program such as CESRI presents. Students are overseas for a year, in an academic (versus laboratory) setting, thus allowing them to gain maximum of an international experience. In fact, some programs, like the Churchill Scholarships, require students demonstrate a commitment not only to the year-long study, but also to be ambassadors by participating in extra- and non-curricular activities in Cambridge. As a result, these programs give participants a maximum of immersion.

The Churchill Scholarships benefits from allowing science students to study at a prestigious overseas university without needing a foreign language. In addition, as a centrally-administered program, member universities are not required to put significant resources in administering the program. At the same time, US universities put forward only their top two candidates, meaning the students who receive scholarships are ambassadors of their US institutions while abroad. Finally, the fact that there are spots reserved for Churchill Scholars means that students need not worry about establishing a host relationship.

Drawbacks

Drawbacks to the graduate year-long study vary significantly depending on the program, but most suffer from the economic limitation of being able to only support a limited number of students, like graduate summer internship. In addition, these programs are open to graduating seniors who are not necessarily returning to a US campus, so there may not be returning alumni who will enrich their US campus culture with the international experience. These two facts mean the impact of such programs may be limited only to the grant recipients, and may not have the beneficial side-effects that programs such as Global E^3 and CESRI can have on the US campuses. The Churchill Program, specifically, also has the drawback of being limited to an English-speaking country with limited cultural differences to the United States.

4) Graduate/Doctoral/Post-Doctoral Year-Long Study/Research

<u>Example: Whitaker Program</u>

The Whitaker International Fellows and Scholars Program (Whitaker Program) is funded with the endowment of the now-closed Whitaker Foundation to support emerging leaders in the field of biomedical engineering (or bioengineering) in pursuing an activity relevant to building international collaborative ties within the field. The Whitaker Program is administered by IIE, and supports biomedical engineers ranging from graduating seniors to recent post-doctorates for one year of work, study, or research overseas (and up to two years for post-doctoral applicants).

Benefits

Benefits to broad independent-research or study programs such as these vary significantly, but there are some core similarities. These programs benefit from the extended length of time overseas, and their diversity: participants can pursue almost anything relevant to the goal of the program in the most appropriate country. As a result, while it may be field-specific, the program can have great diversity in the academic level of the applicants, the focus of work, and placement locations. Being centrally-administered, like all non-university-centric programs, means that these programs put low stress on US university resources. However, the US universities can greatly benefit – a graduate student may be able to pursue an internship, with external financial support, with an expert in the field, and bring this expertise back to the US. By supporting post-doctoral students, these programs bring a long-term impact by supporting the work of those people who will end up in high-level industry and university positions.

The Whitaker Program, specifically, brings some additional benefits. For example, the grant recipients are required only to know enough of the host language to manage living in the country. Because the program is year-long, the student will benefit in gaining host-country language skills and becoming part of the local culture. Those biomedical engineers without adequate foreign language skills can still get an overseas experience at any one of the many English-speaking countries overseas. Additionally, as a program for emerging leaders in an inter-disciplinary field, the Whitaker Program also allows students to undertake very varied activities. This means the project could be lab work, study, policy research, or any other field-relevant pursuit.

Drawbacks

The drawbacks of these programs, because of how diverse the programs themselves can be, are quite varied. However, like all grant programs, finite grant funding limits the number of students who can participate. As a result, those who have worthwhile activities may not get the support they need, and thus may not be able to undertake important international activities.

The Whitaker Program, in addition, faces the limitation of being targeted at only one field. This means those scientists or engineers who are not focused on biomedical engineering are unable to access the funding. As a result, the impact of internationalization is limited only to one field.

II. University-Centric Models

University-Centric programs are campus-oriented solutions which allow the maximum in targeting student audience, and create immediate benefit to the school. As university-centric models, the schools immediately benefit from having a globally-competent class of students in the sciences and engineering who are immediately attractive to graduate institutions and industry. In addition, the curriculum is university-created, meaning that the faculty support the international experience and do not view it as an interruption to the academic trajectory.

The main drawback of such university-centric programs is that they may require greater cost to the institution or student. Implementing such programs costs money, as well as substantial investment of time by faculty and university staff.

Below are two solutions that have been developed on campuses in the US.

1) Mandatory Broad-Based International Requirements

Example: Rensselaer Polytechnic Institute REACH Program

Rensselaer Polytechnic Institute has been involved in several international initiatives for many years, mainly using individual MOUs and under other selective and opportunistic cooperative international research projects. Focusing on engineering undergraduates, Rensselaer was instrumental in helping to form the Global E^3 Program in the mid 1990s, and has been an active participant in it since its inception. Over the last decade, this voluntary engineering undergraduate exchange program has proven so successful, that in 2008 Rensselaer announced a unique mandatory international experience for all of its engineering undergraduates. It is called Rensselaer Education Across Cultural Horizons (REACH). This will begin in 2009 with the junior class. Initially, 25% of the then junior class will be involved in a study abroad semester, at a partner university. That university partner will host about 50 Rensselaer students, and Rensselaer will reciprocate by hosting an equal number of the partner university's students. It is anticipated that a level of 25% of engineering juniors will be maintained for two years, escalating then to 50% for two years, 75% for two years and then reaching 100%. At that time, campus wide participation will be addressed. With the size of the junior engineering class at about 600-650, 12-15 partner universities will be needed. The initial partners will be in Europe and Asia, and expansion to other continents will follow. Although the major component of the mandatory program will be a semester study abroad experience, other options will include the Semester @ Sea, special summer initiatives among others. Students who need to 'opt out' will participate in an on campus international component of the program utilizing the university's base of international graduate students.

2) Special Program Emphasizing International Perspective

Example: U. Rhode Island IEP Program

The University of Rhode Island offers a special program for engineering students, the International Engineering Program (IEP). Begun in 1987, this five-year undergraduate program allows engineering students the opportunity to receive dual degrees in engineering and a foreign language. Generally speaking, the fourth year of the program is spent abroad in the country where the language is spoken, with one semester spent as an intern at one of 40 firms that have partnered with the university. This extra year not only allows the university and the student to receive little stress about "interrupting" a rigorous course schedule, it in fact creates space for this interruption to occur. The result of such an in-depth program is a graduate who is a well-rounded globally-competent engineer.

Conclusion: The Challenge for Internationalizing Engineering Education

Clearly, obstacles to global competence of engineering students can be overcome through innovative programming. The international mobility of European undergraduate engineering students has increased dramatically over the last 15 years. This is to a great extent due to exchange programs involving faculty on the departmental level. Through specific agreements on courses and credits, they better understood each other's educational principles and developed trust in the quality of their partners' teaching, the indispensable basis for more flexible and generous approach to curricular differences.

There are interesting models allowing engineering students to gain access to meaningful international experience in which barriers like language and credit are circumvented, or at least lowered. Opportunities for research experience, internships, and summer programs taught in English may encourage more American engineering students to make that most difficult first step – and perhaps come back later for longer and more ambitious projects.

The same is true for campuses: non-university-centric opportunities like Global E^3 offer scalable solutions for universities having difficulty with the first step. National programs through which engineering students can apply individually, such as the Whitaker and CESRI Programs, allow campuses to see the benefits of an internationalized student base without many of the associated costs. All that said, what is needed now is the commitment of engineering faculty and deans to encourage study abroad by their students, and to view it as a valuable component of their education, as the Rensselaer Polytechnic Institute and University of Rhode Island.

This paper demonstrates that though the task is significant, it is possible to create space within and around existing engineering curriculum to provide engineering students a global scope. The examples described herein are certainly not the only solutions to incorporate a global perspective in engineering education, but they are some of the successful ones. In addition, the drawbacks described for each example are those that the authors observe, as engineering and international education professionals. Nevertheless, we are particularly encouraged by programs that look at the problem as one that can be solved through collective action, like Global E^3, and pool the resources of the many interested engineering faculty behind a single exchange program. We are also encouraged by the initiative taken on campuses like the Rensselaer Polytechnic Institute, where international competence not only suggested, but will be required.

Hopefully, the options presented here can be duplicated and enhanced by continued positive efforts throughout the American engineering community. Clearly, there are benefits and drawbacks to all the solutions, but they provide excellent steps towards creating the global engineer.

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