Undergraduate GEARE Program: Purdue University's School of ME Contribution to Educating Globally Sensitive and Competent Engineers

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Eckhard A. Groll and E. Daniel Hirleman

Purdue University
School of Mechanical Engineering
585 Purdue Mall
West Lafayette, IN 47907, USA

Abstract

There is widespread agreement that engineering education must transform itself to produce global engineers. Global engineers must be able to function effectively on global teams in distance and face-to-face project work, as well as be fluent in how effective engineering solutions vary with culture. In 2001, Purdue University, in collaboration with the University of Karlsruhe in Germany, started to develop a strategic partnership network that now also includes Shanghai Jiao Tong University in China, IIT Bombay in India, and Monterrey Tech in Mexico. These five universities have come together to realize the required transformation in global engineering education. The resultant Global Engineering Alliance for Research and Education (GEARE) includes faculty exchange, research collaboration, and reciprocal graduate and undergraduate education experiences for equal numbers of students from all partner universities. The undergraduate education component is a unique 24-month program that integrates: language education; cultural orientation; 3 month domestic and 3 month international internships at the same partner company or organization; one semester of study abroad; and a two semester face-to-face-, multinational design team project, with one semester abroad and one at home. Curriculum articulation is such that courses are transferable and offered so that there is no negative impact on time to graduation. Global industry partners are crucial to the success of the program as they provide the integrated domestic and international internship opportunities for all students, as well as supplying design projects. The first group of Purdue students went abroad in 2003, with 74 students either having gone abroad or are slated to go abroad in 2008. The Purdue participants are 23% female, compared to approximately 12% women overall in the ME program. Since 2002, the percentage of Purdue ME students participating in international experiences has grown from 3 to 10%. The placement experience of these graduates indicates that the global education provided by the undergraduate GEARE program is in great demand.

Introduction

The global imperative, as highlighted by offshore outsourcing, is not really new. Certainly universities have had international study abroad programs for many years. However, few universities in the U.S. have yet to systemically adapt their engineering curricula to address the needs of global engineers. Generally, the number of engineering students participating in study abroad programs is rather low, at least in comparison to students in other majors and from other countries. Traditionally the number of US engineering students studying abroad in any year [1] has been about 3% of those graduating in the same year with Bachelor's of Science degrees in

engineering, though in recent years that number has increased to above 5%. The number of colleges and universities with programs designed to provide a substantial global engineering experience for undergraduates is small, but growing. A summary of programs is available in Shuman (2005) [2].

There are notable programs providing intense and comprehensive experiences. One is the University of Rhode Island's International Engineering Program (IEP) [3] that leads students simultaneously to degrees in both engineering (B.S.) and a foreign language (B.A. in German, French or Spanish.) IEP students study language and culture each semester along with their engineering curriculum. In the fourth year of the five-year program, students complete a six-month internship with an engineering-based firm in Europe or Latin America. About 20% of all College of Engineering undergraduates at URI are completing a full second degree in a foreign language and spending six to twelve months abroad – even though there is no language requirement in the college. The University of Cincinnati's International Co-Op Program (ICP) has provided undergraduate students with overseas co-op assignments since 1990. Assignments are currently offered in Germany, Japan and Spain [4]. The Worcester Polytechnic Institute's Global Perspective Program (GPP) sends over 50% of WPI students abroad to complete intensive two-month academic projects at eight locations in Africa, Asia, Australia, Central America, and Europe [5,6]. The students work in small, multidisciplinary teams with local agencies and organizations to address open-ended problems that relate technology and science to social issues and human needs. There is no required language component; the educational emphasis is on research skills, contextual problem-solving, written and oral communication, teamwork, and cross-cultural skills. WPI faculty advisors accompany the students and work closely with them on the problem solution and development of a formal research report. About half of the projects, including most of those in developing nations, include a substantial service component. Over 2,500 engineering students have completed projects through this program in the past 20 years. At Virginia Tech a course entitled Engineering Cultures was developed and is now also offered at Colorado School of Mines. This course uses historical and ethnographic material to explore engineering cultures around the world including Britain, France, Germany, Japan, Mexico, Soviet Union/Russia, and the United States, focusing on what counts as engineering and engineering knowledge from country to country. The relative success of this elective course, as reported in Downey et al. (2006) [7], demonstrates that it is possible to provide undergraduates with some of the knowledge, skills, and predisposition required to work with engineers from different countries without a study abroad experience. Some programs support distance or virtual student design teams [8].

Despite the increasing emphasis, educational programs in engineering that provide an immersion experience close to that expected in the global workplace of the future, involving work on global design teams, is rare. The undergraduate Global Engineering Alliance for Research and Education (GEARE) program [9,10] provides the framework for a program that does address all the critical needs of the global engineer. GEARE supports undergraduate engineering students in a 24-month program that integrates domestic and international internships, study abroad, language and culture orientation, and a two-semester, multinational-design-team project into a comprehensive experience. GEARE is a strategic international partnership between four world-class international universities (Purdue University; University of Karlsruhe, Germany; Shanghai Jiao Tong University, China; and ITT Bombay, India) and eight global companies (Cummins,

DOW, GM, Ford, John Deere, Siemens, Shell, and United Technologies). The objectives of the undergraduate GEARE program are to educate engineering students who:

- are prepared for globalization of the manufacturing industry
- are able to function on global teams
- understand engineering in global context (environment, sustainability, economics)
- are versed in global product platforms
- appreciate other languages and cultures
- are proficient in tech-based global enterprise culture
- are prepared for and desires international assignments

This paper takes a closer look at the design of the undergraduate GEARE program component, the participation and program outcomes so far, and the development of additional programs that were the fallout of the undergraduate effort.

Design of Undergraduate GEARE Program

Students are being recruited and selected for the undergraduate GEARE program during the spring semester of their freshman year and fall semester of their sophomore year. They participate in a set of integrated activities before they go abroad. These activities include program elements concentrating on cultural orientation, language skills improvement, and a professional practice experience with an integrated global component during a summer or semester term. The students relocate abroad for at least a semester and a summer term. During this time period, students complete one semester of study abroad at a strategic global university partner and a nominal 3-month professional practice experience at a strategic global industry or organization partner in the same country or region. The study abroad semester and international professional experience can be completed in either order. Typically, students using industry internships for the professional practice component of the Program work for the same employer in both the domestic and international internships. During their semester of study abroad, students are teamed up with students from strategic global university partners and conduct a co-located design team project. A crucial consideration here is a substantial cross-cultural component to the design team experience which is experienced by working with students from another culture in their local cultural context, which is deemed more substantial in terms of global engineering competence than working on a team with international students who are matriculating at Purdue University. Students from the strategic global university partner conduct a reciprocal program that includes a professional experience in the U.S. and one semester of study abroad at Purdue University. During the semester while the partner students are at Purdue University, the student teams conduct the second semester of the global design team project. The domestic and abroad semesters of the design team project can be completed in either order. Table 1 illustrates the schedule for students participating in the program. In summary, students participating in the Program complete the following requirements:

- Students must demonstrate proficiency in a second language by completing 12 credit-hours of coursework in one foreign language program with an average GPA of 3.0 or higher. The 12 credit-hours include credits established by examination. The 12 credit-hours have to be completed before the student participates in the study and work abroad period. Language proficiency can also be demonstrated by successfully passing the Foreign Service Institute examination at Level 2 in both reading and writing.

- One semester of study abroad at a strategic global university partner. These institutions are currently identified as University of Karlsruhe, Germany, Shanghai Jiao Tong University, China, IIT Bombay, India, and Tec de Monterrey, Monterrey campus, Mexico. Other universities may be added in the future or considered on a case-by-case basis through an approval process by the Global Engineering Program Team (GEPT) at Purdue University.
- One three-month domestic internship at a strategic global industry partner or under the auspices of a global organization. Strategic industry partners are currently identified as Cummins, DOW, Ford, GM, John Deere, Shell, Siemens, and United Technologies Corp. Global organizations include Engineers Without Borders and Engineers for a Sustainable World. The list of the strategic industry partners and global organizations is maintained and continuously updated by the Global Engineering Program Team (GEPT) at Purdue University.
- One three-month international internship typically, but not necessarily, with the same strategic global industry or organization partner. The objective is to have an integrated experience where the second internship builds on the first and the global context of the work is important. The domestic and international internships can be conducted in either order.
- Successful participation (indicated by an average grade of B or higher) in at least two semesters of global project work, at least one semester of which is performed with a co-located global team. The key objective here is to enable and recognize the intense, personal experience of working with students from a different culture over an extended period of time on a project where the global context of the work is essential. As part of the global design team project, students must submit a written technical report and give an oral presentation.
- A grade of "C" or better in all courses that are counted towards the minor requirement.

By successfully completing all requirements indicated above, students will receive a "Minor in Global Engineering Studies" upon graduation with their bachelor degrees.

Table 1: Schedule for engineering students at Purdue University participating in the undergraduate GEARE program.

<table>
<tr><th>1st Semester</th><th>2nd Semester</th><th>1st Summer</th><th>3rd Semester</th><th>4th Semester</th><th>2nd Summer</th><th>5th Semester</th><th>6th Sem.</th><th>3rd Sum.</th><th>7th Semester</th><th>8th Semester</th></tr>
<tr><td rowspan="4">Regular Freshman Sem.</td><td rowspan="4">Regular Fresh-man Sem.

Student Selection</td><td rowspan="4">May-mester course (recom.)

Foreign Lang. & Culture 1</td><td rowspan="4">Regular Sopho-more Sem.

Foreign Lang. & Culture 2</td><td rowspan="4">Regular Sopho-more Sem.

Foreign Lang. & Culture 3</td><td rowspan="4">Domestic Internship with Strategic Global Industry or Org. Partner</td><td rowspan="4">Regular Junior Sem.

Foreign Lang. & Culture 4

Orienta-tion Program</td><td colspan="2" rowspan="4">International Internship with Strategic Global Industry or Org. Partner

Study Abroad Semester at Strategic Global University Partner

1st Semester of Global Design Team Project</td><td rowspan="3">Regular Senior Sem.</td><td rowspan="3">Regular Senior Sem.</td></tr>
<tr></tr>
<tr></tr>
<tr><td colspan="2">2nd Semester of Global Design Team Project</td></tr>
</table>

Program Participation and Outcomes

The first class of undergraduate Purdue University GEARE students was made up of six students, who went abroad to the University of Karlsruhe in 2003. Since then, 74 Purdue University students have gone abroad or are slated to go abroad in 2008. In addition, 77 students from strategic partner university students have come to the U.S. or are slated to come in 2008 to participate in the program. Table 2 shows a listing of the number of students and their home universities by year. Each year from 2004 to 2006, one more strategic partner university was brought on-line in the following order: Shanghai Jiao Tong University, IIT Bombay, and Tec de Monterrey. It can be seen from Table 2 that after having student participation numbers in the low teens for the last three years, 21 Purdue University students are slated to go abroad in 2008.

Table 2: Number of engineering students at Purdue University and partner universities participating in the undergraduate GEARE program

	Universität Karlsruhe	Shanghai Jiao Tong University	IIT Bombay, Mumbai	Tec de Monterrey	Total
2003	6 Purdue 9 Karlsruhe				6 Purdue 9 Partners
2004	9 Purdue 8 Karlsruhe	1 Purdue 1 SJTU			10 Purdue 9 Partners
2005	7 Purdue 9 Karlsruhe	5 Purdue 5 SJTU	1 Purdue 0 IITB		13 Purdue 14 Partners
2006	4 Purdue 4 Karlsruhe	5 Purdue 5 SJTU	2 Purdue 2 IITB	1 Purdue 0 MT	12 Purdue 11 Partners
2007	6 Purdue 6 Karlsruhe	4 Purdue 6 SJTU	1 Purdue 1 IITB	1 Purdue 0 MT	12 Purdue 14 Partners
2008	11 Purdue[1] 11 Karlsruhe[2]	3 Purdue[1] 3 SJTU[2]	4 Purdue[1] 4 IITB[2]	3 Purdue[1] 3 MT[2]	21 Purdue[1] 21 Partners[2]
Total	43 Purdue 47 Karlsruhe	18 Purdue 20 SJTU	8 Purdue 7 IITB	5 Purdue 3 MT	74 Purdue 77 Partners

Notes: [1]Students currently accepted to go abroad in 2008. Student participation is depending on meeting academic requirements.
[2]Currrent estimates. Final selection will be made by partner universities by the end of 2007 or beginning of 2008.

Table 3 provides a listing of the number of female students participating in the undergraduate GEARE program. It can be seen that total of 17 female students from Purdue University have gone or will be going abroad in 2008, which equals a 23% participation rate. This is almost double the percentage of female students in the Mechanical Engineering program at Purdue University, which is currently at approximately 12%. However, the number of female students participating from the partner universities is significantly lower at 12.5%.

The undergraduate GEARE program has instituted an assessment procedure to more fully understand the personal gains derived from the international learning and work experiences and of global teamwork experiences. This assessment is made of each GEARE cohort during the last month of the program at a time when the students are completing their common semester of

study at Purdue. Data for the assessment is collected from individual written responses to a survey questionnaire and from interviews with cohort members within a "focus group" format. The interviews are conducted on both the cohort as a single group and on segmented cohort groups based on common-language criteria. Detailed assessment results of the 2004-2005 cohort are reported in [10]. The reoccurring findings of the yearly assessment of the undergraduate GEARE program students are summarized below:

- Student groups reported that cultural differences had significant impact on their interactions during all phases of the undergraduate GEARE program. Groups clearly indicated that their ability to accommodate to changes in a foreign environment improved with experience and that, as they became more confident in their new environment, their productivity increased.
- Foreign students reported that they were likely to adapt more readily to cultural differences due to their familiarity with the American culture through the mass media. U.S. students, in contrast, emphasized that they felt a much greater personal change due to their adaptations to the cultural differences.
- English was reported by all groups to be the language of last resort in communications between members of the groups. However, U.S. students indicated that their foreign language skills improved considerably in both social and business settings throughout the program.
- Students were impressed with the success of the student design team projects. They attributed the success to the integration of the combination of a wide variety of skill sets that they developed based on their different educational systems.
- The development of communication skills was considered to be the best outcome of the program.

The assessment process of the undergraduate GEARE program will see continual evolution throughout the years to come in order to better understand the impact of this program on the development of global engineering competencies of its participants.

Table 3: Number of female engineering students at Purdue University and partner universities participating in the undergraduate GEARE program

	2003	2004	2005	2006	2007	2008	Total
Purdue University	2	1	4	1	3	6	17 (23%)
Partner Universities	0	1	1	3	2	n/a	7 (12.5%)

Other GEARE Related Programs

Initially, the GEARE partners focused on developing the undergraduate program component. However, other international programs and exchanges where quickly added to the portfolio to strengthen the collaborations between partners and to provide additional opportunities to the students.

Faculty Exchanges

Faculty exchanges are an integral part of the strategic partnerships developed between the participating universities in order to help sustain faculty interest and student participation in the program. In addition, in order for the GEARE network to be successful over the long term there must be a substantive research collaboration component. Furthermore, given the complexities

and challenges of curriculum articulation and credit transfer, and of having a significant number of students studying abroad as a group, having faculty exchanges through leaves and sabbaticals is crucial to the long-term success of the program. Purdue University had an ME faculty member on site for the first three years at the University of Karlsruhe (2003, 2004, and 2005) and for two years at Shanghai Jiao Tong University (2005 and 2007). Purdue faculty resident directors at University of Karlsruhe and IIT Bombay have also been identified for 2008. The first faculty visitors from the University of Karlsruhe and IIT Bombay were at Purdue University in 2004 and 2005, respectively. The bilateral nature of the faculty exchange will be continued in the future. One facet of the faculty exchange is to provide continuity in the two-semester design projects, e.g., the Purdue University resident faculty at the University of Karlsruhe in 200x was the instructor of the 2nd semester of the design project at Purdue University in 200x+1.

Short-term Courses Abroad

While working with this first group of U.S. students participating in the undergraduate GEARE program, a new program component was developed. In order to recruit freshman students into the undergraduate GEARE program, a short on-site "study-tour" was offered to students in their second semester at Purdue. To make the course viable, more students than the ones eventually joining GEARE were allowed to participate in this international experience. In addition, the entire program had to fit into the frame of one week to allow for flexible scheduling and offer the courses at reasonable costs. These "short courses" were available either during spring break in the middle of the semester or during a "Maymester" intensive period just after the close of the regular semester. These schedules have proven attractive, permitting students to complete the course and still have time available for summer commitments and employment, including co-op work sessions. Students who participate in these short courses are assisted by discussion of relevant readings and orientation sessions. They are also introduced to further opportunities that offer more substantial international experience. While the syllabi of these short courses vary, all include visits to industrial sites and cultural centers, as well as sessions set aside for classroom work and interactions with partner university students. Classroom discussions are based on observations and readings concerning cultural differences, intercultural communications, and presentations on culturally specific matters, as well as foreign and local history. Perhaps of most significance are the interactions with on-site GEARE program participants who are working on their design projects and eager to share their work in progress with the newcomers. Interactions are not just "on task" but include social occasions. The short courses include several excursions, typically to local GEARE partner companies, as well as train rides and sight seeing tours.

The benefit of the program development is that instructional materials once assembled and "field tested" as part of the short course can be used effectively in a range of additional venues, including that of preparing U.S. students without international experience for a substantial period of work, study and team design abroad. One particular benefit is the relatively small class size that is typical of these short courses, approximately 15 students with two instructors. This instructor-student ratio allowed for good exchange and feedback and the course really became a laboratory for exploring possibilities of what works for engineering students who are often encountering the broad issues of cultural diversity and global markets for the first time. These short courses proved to be an excellent recruitment tool for the undergraduate GEARE program with approximately 20% of the short course participants subsequently enrolling.

Graduate GEARE Program

Funding was received from German Ministry for Business and Work to establish a team oriented diploma student/master student exchange program between the mechanical engineering departments at the University of Karlsruhe and Purdue University. The basic idea of the program is to team up one Karlsruhe diploma student with one Purdue master student for a six-month uninterrupted and course-free research project. The program goal is to have nine students participate from each university per year. The start of the program was fall 2005. Funding was received to support up to six research assistantships (RA) for six months plus travel stipends from each university per year for a total of three years. After three years, it is envisioned that the program is self-supporting through funding from industry projects that are the basis for the six-month research projects. The objectives of the graduate GEARE program are:

- To develop engineering understanding of the German culture, German language, and Germany as a whole.
- To supporting interactions/meetings between German and U.S. American people, especially young people and future leaders in business and society.
- To provide a forum for the exchange of opinions of current and upcoming engineering topics.
- To support the development of research relationships among faculty.
- To install new initiatives of transatlantic relationships.

Three types of student exchange teams are being implemented within the graduate GEARE program:

1. The one-on-one student team will work full time at the University of Karlsruhe. In this case, a Purdue master student will study at the University of Karlsruhe for a six-month time period and is teamed up with a local diploma student. The student team is advised by a faculty at the University of Karlsruhe. The Purdue student selects the project and partner from a slate of possible projects at the University of Karlsruhe.
2. The one-on-one student team will work full time at Purdue University. In this case, a Karlsruhe diploma student will study at Purdue University for a six-month time period and is teamed up with a local master student. The student team is advised by a faculty at Purdue University. The Karlsruhe student selects the project and partner from a slate of possible projects at Purdue University.
3. The one-on-one student team is formed in cyber-space. Students conduct their research work at their home universities and communicated through the internet, phone conferencing and other electronic media. Students are advised by one or a team of faculty from both universities. Students select the project and partner from a slate of possible projects at either one of the universities. The program provides a travel stipend for the Purdue student to go to Karlsruhe for one week at the beginning of the project to get to know each other. It also provides a travel stipend for the Karlsruhe student to go to Purdue for one week at the end of the project to present the work.

The program started with the academic year 2005/2006 with one Purdue MS student studying at the University of Karlsruhe and two Karlsruhe students studying at Purdue. During the academic year 2006/2007, these numbers increased to three students from each university studying abroad. In addition, the first one long-distance team project was started using a regular video conferencing approach. For the academic year 2007/2008, four students from each university

will study abroad and two long-distance team projects are planned, resulting in 10 students participating from each university, which exceeds the original goal of nine students each.

Summary

The administration of the undergraduate GEARE program with its domestic and international internships, one-semester study abroad and two-semester global design project is a time consuming task. It is important to have dedicated staff members at each partner university to coordinate the activities of the program including chairing the selection committee for participants, the arrangement of internship positions for both domestic and foreign students, and the coordination of the foreign languages studies and orientations as part of the program. In addition, the role of the in-resident Purdue faculty member during the study abroad phase for the Purdue students has proven critical to the success of the program. The Purdue faculty member teaches one or two courses at the partner university during the semester when Purdue students study there. The faculty member usually lives in the same housing unit as the students providing counsel and support. Having the faculty member present has also helped in resolving minor problems that have arisen in the coordination of the program. Overall, the international industry, educational and design experiences offered by the undergraduate GEARE program have become invaluable experiences for Purdue University students who participate.

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