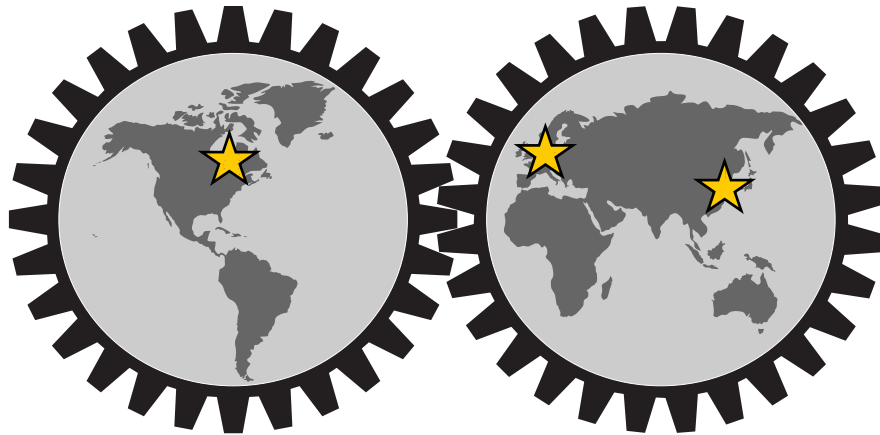


## GEARE: A Comprehensive Program for Globalizing Engineering Education

E. D. Hirleman<sup>1</sup>, D. Atkinson<sup>1</sup>, E. A. Groll<sup>1</sup>, J. Matthews<sup>1</sup>, L. Xu<sup>1</sup>, B. Allert<sup>2</sup>,  
W. Hong<sup>2</sup>, A. Albers<sup>3</sup>, S. L. K. Wittig<sup>4</sup>, Z. Q. Lin<sup>5</sup>, and L. F. Xi<sup>5</sup>

<sup>1</sup>School of Mechanical Engineering, Purdue University / <sup>2</sup>Department of Foreign Languages and Literature, Purdue University / <sup>3</sup>Institut für Maschinenkonstruktionslehre und Kraftfahrzeugbau, Universität. Univ. Karlsruhe / <sup>4</sup>German Aerospace Center (DLR), Köln / <sup>5</sup>School of Mechanical Engineering, Shanghai Jiao Tong University



## GLOBAL ENGINEERING ALLIANCE FOR RESEARCH AND EDUCATION (GEARE)

### Abstract

The Global Engineering Alliance for Research and Education (GEARE) increases the effectiveness of undergraduate engineering education in preparing engineers for careers in the global technical economy. The unique 18 month program developed at Purdue in partnership with Karlsruhe and Shanghai Jiao Tong Universities integrates: language education; cultural orientation; three month domestic and three month international internships at the same partner firm; study abroad; and a two semester face-to-face-, multinational design team project, with one semester abroad and one at home. The program is bilateral, with nominally equal numbers of students from each university participating in the paired exchanges. Curriculum articulation is such that courses are transferable and offered so that there is no negative impact on time to

graduation. Faculty exchanges are also an integral part of the strategic partnerships developed between the participating universities in order to help sustain faculty interest and participation in the program over the long term. Global industry partners are crucial to the success of the program as they provide the integrated domestic and international internship opportunities for students from all partner universities. The Purdue-Karlsruhe element is nearing the end of its first cycle, with six Purdue ME students having spent seven months in Germany and nine Karlsruhe students having completed their international (US) internship postings during the fall 2003. This international cohort is at Purdue during the spring semester 2004 at which time they will complete the 2<sup>nd</sup> semester of the design project course. The next two classes of Purdue GEARE students have nine and seven students for Karlsruhe, and one and five students for Shanghai, respectively. The percentage of female students in the Purdue program is about twice that of the overall ME student body. Our preliminary assessment based on feedback from industry and students indicates that the program is meeting its goals.

## I. Background:

It is clear that the engineering profession is undergoing major changes as national borders become less relevant. Most of the key industrial partners of universities with large engineering programs, such as Purdue, Karlsruhe, and Shanghai Jiao Tong, have substantial global presence. Major employers of engineers and scientists are reconfiguring the ways they do business to take advantage of engineering talent located in other countries, for example IBM recently announced that it would outsource about 4,700 high-paying programming jobs to India and China<sup>1</sup>. The US automobile manufacturers continue to set up major operations in Shanghai. GE has established major research labs in India and China.

The careers that our engineering graduates from today will enjoy will be quite different from those as recently as a decade or so ago. For that reason, engineering education should change as well to prepare our graduates for success in the global technical workforce. Instilling a global perspective in US students of science and engineering requires efforts early in the educational process, as supported by an NSF Workshop Report which states: “*Current programs do not reach students early enough in their careers. Opportunities tend to focus at the graduate level (with some notable exceptions). It is important that undergraduates be provided opportunities for international experiences as it is in this point in their career when they are most flexible*” (emphasis added)<sup>2</sup>. Global experience cannot be an add-on, but rather should be viewed as part of the mainstream. We are convinced that an extended *engineering-related* experience in a country where one’s first language is not that of the host country, combined with a multiple-semester face-to-face multinational design team experience, is critical to making a significant impact on undergraduates<sup>3</sup>. Further, we believe an integrated, two-session (one domestic, one international with the same firm) internship experience in the global workplace is also critical to making a substantial impact on the abilities of fresh-out engineers to contribute from the very beginning of their careers.

The fraction of US science and engineering students who have a substantial international career-related experience before receiving the BS is rather small, probably in the range of a few percent. Among Purdue Mechanical Engineering graduates the number having had a substantial international engineering experience (defined here as a semester of university-level education with an engineering component or 3 or more months of engineering internship experience in a country where English is not the first language) upon graduation is between 1 and 2%. For all of

the Schools of Engineering at Purdue, which encompasses nearly 6,500 undergraduates, the data are similar.

In order to assess the reasons for the low participation of Purdue engineering students in international experience opportunities, the incoming sophomore ME students have been surveyed as part of their required ME 290 introductory course by the ME Office of Industrial Experience since 2000. The students listed the following barriers in order of importance: 1) separation from familiar surroundings, family, and friends (community); 2) cost; and 3) possible delay of graduation date. The more recent DAAD (German Academic Exchange Service) study identified several key barriers for Americans to study and/or take internship assignments in Germany, including: German language capability; difficulty in affording airfare and extra program costs; difficulty in foregoing work during break periods; difficulties associated with mutual recognition of coursework between German and American Institutions; lack of flexibility in engineering curriculum; incompatibilities in German and American academic calendars; and the fact that American engineering students do not often appreciate the value of global experiences<sup>4</sup>. Further, that study indicates that only a small number of US science and engineering students per year have internships in Germany, surprising given the similarity of the types of industries in Germany and the US and the relatively similar (western) cultures.

## II. The Challenge:

The long-term goal of the School of Mechanical Engineering at Purdue University is to have 20% of the graduating BSME seniors having had a “substantial” international engineering experience during their undergraduate years. Since the primary “customers” of any international experience we might design are these Purdue students, the challenge is to design programs that effectively deal with those issues that are barriers in the minds of the students. Whether these barriers are real or perceived is irrelevant, for a program to be successful it must effectively mitigate each barrier while providing significant perceived advantages for the students. The Purdue ME student body is about 50% in-state students, with the majority of the out-of-state students coming from the surrounding Midwestern states.

At the same time, for a program to be an integral part of the educational experience, there must be support from a large number of faculty who to first order split their time equally between research and education. In other words, the challenge is to design a program that is consistent with appropriate career goals of engineering faculty and presents a compelling value proposition to approximately 50 out of 250 predominately-midwestern Purdue ME students per class.

## III. The Design Solution – GEARE:

The Global Engineering Alliance for Research and Education (GEARE) model is based on comprehensive, strategic partnerships between a few similar international institutions. It involves student and faculty exchange programs, curriculum integration, and collaborative research. While we present it here in the context of globalizing undergraduate engineering education, significant intellectual involvement on the part of faculty is imperative. At research universities like Purdue, Karlsruhe, and Shanghai Jiao Tong, there then must be a substantial, value-adding research component to the partnership or the program will not be sustained.



- Increased study and work abroad participation by students.
- Increased exchange of first-rate US, Chinese, and German engineering students.
- Graduates of engineering programs at all partner schools who are better prepared to:
  - function in a global technical environment and relate productively to the challenges of a global marketplace
  - transcend cultural issues to collaborate effectively in diverse, international teams
  - incorporate best practices from global technical experience and a range of engineering and company cultures
- Development and demonstration of the GEARE model that can be adopted by other engineering and science departments at various universities, whereby multiple GEARE networks between different groups of partner Schools could be created.

#### IV. Elements of the GEARE Student Experience:

*Candidate Selection.* The GEARE program is targeted to the very best students. It is a competitive program and acceptance includes an application process as well as an interview. The application includes an essay on why the students want to participate and two letters of recommendation. The Selection Committee screens applications and interviews and selects the applicants. The Selection Committee at Purdue is composed of two German and one Chinese Language and Literature faculty, 2-3 Mechanical Engineering faculty, and 2 Mechanical Engineering staff. The criteria used for selection include: 1) academic qualifications; 2) language skills or strong interest to learn; 3) knowledge of host country; 4) written and verbal communication skills; 5) evaluation of impression applicant will make abroad as a citizen/student representing the sending universities; 6) leadership skills; 7) evaluation of ability to work as a team member; 8) relevant engineering work experience; and 9) evidence of maturity, motivation, and adaptability to a different cultural environment. Because of the extent of the commitment, and the challenge of taking on international assignments and study abroad, there is some natural self-selection on the part of students for high academic achievement, leadership, and risk-taking. The students who have been accepted into the program to date have certainly been among the top students. For example in Karlsruhe, more than 40 students applied for the six openings in the first Karlsruhe-Purdue GEARE class.

For the Purdue participants we currently have a minimum 3.0 GPA requirement to apply, but in practice the GEARE students have considerably higher performance. For example, of the 12 Purdue sophomore students selected for the Karlsruhe and Shanghai programs to start with domestic internships in summer 2004 there are three 3.8 GPAs, two 3.9s, and a 4.0. One is one of 60 Purdue freshman (from class of 7,144) in Mauzy Emerging Leaders Program, and another is one of only 30 Purdue Freshman in the Purdue President's Student Leadership Program. Of those going to Karlsruhe, three have lived in Germany for more than 6 months, one in France for 5 years, and two were in the People to People Ambassador Program. Three are taking German minors, two fluent in French, and the group will have an average of 4.5 semesters of university-

level German courses by the time they study abroad. Four of the twelve (33%) are women, compared with 13% overall in Purdue Mechanical Engineering.

*Domestic Internship:* The GEARE students have a domestic internship with one of our partner firms during the summer after their 2<sup>nd</sup> year (see Fig. 1). The process of matching students with companies is similar to that we use for the Cooperative Engineering Education Programs at Purdue, whereby students first prioritize their preferred assignments. After some balancing of needs and preferences, the companies are provided access to a couple more students than they have slots, and the companies and students make the final decision on offers and acceptances.

*International Internship:* Since the goal is for the domestic and international internships to be integrated, GEARE students and companies are actually agreeing to two work assignments during the selection process that occurs in the middle of the students' 2<sup>nd</sup> year. The timing for a decision is not too different than what occurs for co-op programs, and for recruiting of top students for traditional domestic internship assignments. Ideally, the Purdue students would work with the same group/area, or even on the continuation of the same project, both in the US and then during their international assignments in Germany or China. The GEARE partner firms (Behr GmbH and Co., Cummins Corp., John Deere and Co., and Siemens Corp.) have supported the program and provided assignments for Purdue-Karlsruhe students in about a half-dozen different cities across Germany. GM, Daimler-Chrysler, and LUK provided an internship in the start-up phase as well.

The preferred language capability for the Purdue students in the GEARE program is equivalent to four semesters of university German. Several of the participants have been fluent, but in order to reach our goal of 20% of Purdue students it is not feasible to require fluency in German or Chinese. Therefore the internships are conducted primarily with English as the working language, though our students very quickly become self-motivated to improve their communication skills in the host country language in order to perform better in their internships. Certainly fluency would make for a better and more productive experience for both the students and their employers, but at the present time it really comes down to a trade-off of numbers vs. language skills. Some programs, such as the International Engineering Program (IEP) at Rhode Island University require fluency. After the GEARE program has been operated for a few years, there should be adequate data to assess the relative effectiveness of the two models.

*Semester abroad:* As reported above, one of the barriers to US student participation in comprehensive international experiences is that of a delay in graduation. While a case can certainly be made that a semester or so delay for a GEARE-like experience is well worth it in the big picture of one's career, the data show that is not a compelling argument to most US engineering students and their parents. Similarly, while ideally these students would be fully immersed in the university culture abroad and be able to take courses from that university for grades in the host country language, that too is a barrier to many US students who must be convinced to participate if we are to reach our goal of 20% participation in Purdue ME. For that reason, in choosing partners for Purdue it was necessary to select universities where transferable (in the prerequisite-chain sense) courses are available in English. That puts very strong demands on the level of cooperation between the GEARE university partners for curriculum articulation. Also, it means that ME curricula must also be offered in English at partner Schools. Admittedly

this aspect of the GEARE program is not uniform and bilateral, since obviously Purdue does not offer courses in German or Chinese. But it is consistent with global trends in engineering education, and in fact Karlsruhe (through the International Department) and Shanghai Jiao Tong both offer enough ME courses in English to accomplish the GEARE model.

GEARE students participants generally take their 6<sup>th</sup> semester abroad, and hence for Purdue students ABET-equivalent courses that are required in that semester must be available. For Purdue students at Karlsruhe, those courses are: Mechanical Design (MKL) III plus tutorial; Thermodynamics II - (Prof. Mass); Methods of Product Development (KLA) A; Materials Science II; a Global/Culture Awareness or Language General Studies Elective; the first semester of the multinational design team project; and in some cases a technical elective course typically taught by resident director from the Purdue faculty. Students from Karlsruhe and Shanghai Jiao Tong have somewhat more flexibility and take junior level classes at Purdue.

*Multinational Design Team Project:* One of the most important and compelling aspects of the GEARE model is the opportunity to participate in a two-semester design team project, working face-to-face on a team with two Purdue students and two Karlsruhe or Shanghai students. In the Karlsruhe model, the first term of this course is taught by Prof. A. Albers at Karlsruhe in the spring/summer semester. In 2003, the project involved design of a personal carousel. Prof. E. Groll of Purdue ME who was the resident director at Karlsruhe in 2003, will be the instructor of the 2<sup>nd</sup> semester of that project in the spring 2004 when the Purdue and Karlsruhe GEARE students are enrolled at Purdue. The 2<sup>nd</sup> semester will involve the fabrication/validation aspects of the project.

The first group of Karlsruhe students traveled to the U.S after their “Vor-Diplom” examination period in mid September and had U.S. internship assignments from October through December 2003 at Cummins, John Deere, LUK, and Siemens. At the beginning of January, the Karlsruhe students moved to West Lafayette to attend classes at Purdue during the Spring Semester 2004. The Karlsruhe students will return to Karlsruhe at the beginning of May for the Karlsruhe summer semester.

*Preparation of Participants:* After the selection process is completed, a number of orientation activities are conducted to prepare the students for their work and study in Germany and China. A Foreign Languages and Literature faculty member meets with each selected student to further evaluate language and culture skills. An individual plan of action is developed to ensure the student has a working knowledge of the target language prior to departure. Some students are also asked to prepare a 20-minute presentation in German or Chinese about their own background to introduce themselves to an international audience. Students selected for the Program are required to continue to attend regular German or Chinese classes at the appropriate level with emphasis on the Scientific and Science/Engineering courses offered in the Language Department. There are also some other opportunities for GEARE students, including attending appropriate lectures given both in English and German or Chinese, attend the weekly German *Kaffeestunde* or Chinese Tea Hour, and participating in events offered by the various language clubs.

## V. Other Aspects of GEARE Program

*Student recruitment:* To date, student recruitment has been targeted primarily at sophomore students in the School of Mechanical Engineering. Class presentations and seminars, information sessions, and industry speakers from GEARE partner firms have accomplished promotion of the GEARE Program. At Purdue the sophomore professional seminar (ME 290), required for all students in the School, is used. In the context of professional communications, a segment on the challenges of “intercultural” communications has been introduced, incorporating such case study materials as the Daimler-Chrysler merger. One class is titled *International Opportunities in Mechanical Engineering* and industry speakers consistently emphasize the need and demand for engineers with cross-cultural and bilingual skills.

In addition, at Purdue we are using one-week intensive courses (1 credit hour) offered on site in Karlsruhe and Shanghai to recruit freshman engineering students into the pipeline. In Spring 2004 the course *Introduction to Cross-cultural Teamwork* will be offered in Shanghai over spring break and in Karlsruhe during Maymester (the week immediately following the spring semester). These courses are team-taught by instructors from both the Foreign Language and Literature Department and Mechanical Engineering, with participation and support from faculty at Karlsruhe and Shanghai Jiao Tong. The course involves some team projects where these freshman are paired with the GEARE students who are abroad, as well as industry speakers and visits to local industry sites.

*Faculty Exchange:* In order for a GEARE network to be successful there must be a substantive research collaboration component. Further, given the complexities and challenges of curriculum articulation and of having tens of students studying abroad as a group, having faculty exchanges through leaves and sabbaticals is crucial to program success, certainly in the start-up phase. Purdue has an ME faculty member on site for two years at U. Karlsruhe and at Shanghai Jiao Tong. Purdue faculty resident directors for those two partner universities have also been identified for the next two years. The first Karlsruhe visitor is at Purdue in 2004, and the bilateral nature of the faculty exchange will be continued for a few years until the program is established.

One facet of the faculty exchange is to provide continuity in the two-semester design projects, the Purdue resident faculty at Karlsruhe in 2003 is the instructor for the 2<sup>nd</sup> semester of the design project at Purdue in 2004.

*Assessment:* For more than a decade Purdue ME has assessed the 1) importance, and 2) the effectiveness of fourteen *program objectives* established for our undergraduate program. The feedback we use in our assessment and continuous improvement process is obtained from five *program constituencies*: students (senior exit survey), faculty, alumni, employers, and the ME Industry Advisory Council. Two relevant *program objectives* impacted by the GEARE experience are: 3c) an appreciation of the impact of engineering solution in a *global* and *societal context* (ABET program outcome h), and 3d) sensitivity to *world affairs* and *cultures* (ABET program outcome j). In the 1994 survey for ABET accreditation our alumni (of one- and five-year past BSME graduation) the importance of 3c and 3d were evaluated just slightly above 1.0 on a 0-4 scale. Only six years later, in the 2000 program assessment, our alumni rated these close to 3.0 out of 4.0, while our perceived effectiveness in delivering on those two program



objectives increased only about half a point on the 4.0 scale, and remained lower than our performance on two of the other twelve program objectives. As stated earlier this was, in fact, a large part of the rationale for establishing the GEARE program. In the future we will be able to track our performance on these, including on a student-by-student basis for GEARE participants. We also expect a very positive impact on our program objective 2b - the ability to function effectively on a team and with peers. We are convinced that a two-semester, face-to-face, multinational design team experience will have a dramatic impact on this objective.

In addition we have our students do assessments of their work experiences (some 90% of our students have had 3-month or more engineering work experience, either internship or co-ops, upon graduation). We have made some modifications to that instrument anticipating special considerations related to the integrated domestic and international internship experiences.

## VI. Summary:

The GEARE program integrates important components of the engineering curriculum: industry experience through domestic and international internship placement, design experience through the team project across two academic semesters, and academic coursework and credit towards the BSME. Furthermore, these program objectives are achieved while students are immersed in an international context, learning to negotiate at the intersection of two cultures, acquiring not just second language skills but also strategies for anticipating and resolving difficulties related to diverse cultural environments. The program is well underway, with six and nine Purdue ME students at the University of Karlsruhe in the first two years, and nine Karlsruhe students at Purdue in the first year. At this time seven have been selected for next year. The Shanghai Jiao Tong University partnership is piloting with one student this year and five selected for next year.

Finally, we have observed that international opportunities, such as those created by this program, are particularly attractive to women and therefore could play a significant role in increasing the number of women pursuing engineering degrees. In GEARE's first year at Purdue, we had 33% participation by women, whereas the overall enrollment of women in Mechanical Engineering is about 13%. In another program, the International Engineering Program (IEP) from Rhode Island University, women represent only 16% of the undergraduate engineering students but 32% of the students participating in the international program. Thus, combined with our plans for recruiting and outreach to high schools and Purdue freshman, this program should increase the number of women in engineering at Purdue. Further, with this compounded concentration of women in the GEARE program, partner companies will have preferential access to a larger pool of most-talented Purdue women engineers.

## VII. Acknowledgements:

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