From Ad Hoc to Systematic Study Abroad

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Abstract
The recent acceleration in the globalization of the world economies is impacting the focus of engineering education. Universities are increasingly looking to internationalize their educational programs to meet the challenges imposed by this changing environment. Virginia Tech and its College of Engineering, which is one of the largest producers of engineers in the USA, is responding to this challenge by aiming to increase its students' study-abroad participation from approximately 1.7% to 15% by year 2011. This paper will describe how the Department of Mechanical Engineering plans to implement its share of this plan, including senior year abroad programs, dual masters programs, joint doctoral programs, and joint research and teaching activities in collaboration with overseas partners—all while maintaining a strong focus on quality assurance and continuous improvement.

Introduction

The concept of a study-abroad experience has for more than 50 years been recognized as a valuable addition to the conventional university programs. Most universities facilitate the transfer of academic credits earned for a semester or two elsewhere at some point between matriculation and commencement, and especially during the sophomore and junior undergraduate years; hence, the use of the decades old term "junior year abroad." At the graduate level it is likewise acceptable to temporarily conduct research at another institution. Still, even after all these years of accepting the concept of study abroad, it remains an infrequent experience for students in the field of engineering. For instance, at Virginia Tech, which is one of the largest engineering universities in the USA, only about 30 engineering students venture abroad each year, with the result that only 1.7% of its engineering students ever participate in a study-abroad experience.

In the meantime, the global economy has changed the engineering profession forever. The ability to quickly and inexpensively ship finished and unfinished products worldwide has enabled the shift of manufacturing from local high-cost sites to distant low-cost sites. This shift was further expanded with the widespread deployment of high-bandwidth computer networking starting in the late 1990's. Data can now be easily shipped within seconds from one country to another. This has enabled the location of back-office functions in overseas, low-cost locations. Hence, today it is common that insurance claims, radiology assessments, computer programming, and engineering analyses are processed overseas. Indeed, large multinational corporations have increasingly over the past several years established research and development centers abroad to reduce their overall cost of engineering—drawn in large part by the promise of vast numbers of engineers being educated abroad and readily available at a much lower cost than engineers in the USA or Western Europe.

While this availability of employable engineers overseas has been questioned [1,2,3,4], the trend to shift and grow engineering capacity abroad has not gone unnoticed in Western European and US academia, and it is now increasingly recognized that a complete engineering education must include global aspects. The Accreditation Board for Engineering and Technology (ABET), which is the principal accreditation agency for undergraduate engineering programs in the USA, has set the stage by placing increased emphasis on educating engineers who are socially aware and who can communicate and function well in multi-disciplinary teams. The US National Science Foundation (NSF) has taken this one step further by placing a strategic emphasis on educating engineers that are globally engaged and competitive. Many US universities have established engineering programs and even campuses abroad to

offer their degree programs in these overseas markets, and many overseas universities have established masters degree programs specifically to attract students from the USA. Also, many universities outside of the USA are seeking accreditation through ABET, which is now offering full accreditation to these institutions.

Innovative programs have been established that enable students to study with students from other countries, both online and at location, and at times combined with domestic and international internships [5,6,7,8,9]. Though these international programs currently tend to be relatively small in volume compared to the overall student body, they have decisively set the direction towards increased presence of global experiences in university programs. This includes Virginia Tech, where the College of Engineering in October 2005 established a series of strategic goals to be reached by year 2011:

- The overall engineering student study-abroad participation will be increased from 1.7% to 15%. Study-abroad participation is here defined as educational activities that include a stay of at least one month abroad.
- All the *undergraduate* engineering programs will have at least one pre-approved study abroad option that enables students to study abroad for at least one semester or summer without delayed graduation.
- 50% of the *graduate* engineering programs will have at least one pre-approved study abroad option that enables students to study abroad for at least one semester or summer without delayed graduation.
- All departments will have at least one international research exchange partnership.
- The College will identify partnership universities, and each department is expected to have at least one well-established international program and substantial relationships with one or more of these sister colleges throughout the world.

To reach these goals, the college will have to depend on the Department of Mechanical Engineering to do its share. This department, which has the third largest BSME program in the USA, will therefore have to transition from an ad hoc system supporting less than a handful of students each year studying abroad, to a systematic process and portfolio of programs that will successfully engage at least 45 students per in year in study-abroad experiences. This paper will examine how such a transformation can be achieved by year 2011.

Strategic Alliances and Quality Assurance

It is important for a research university such as Virginia Tech to maintain its quality and credibility as it internationalizes its curricula and research programs. The university and college strategic plans therefore call for identifying a small, strategic portfolio of trusted overseas partners with whom to build its core foundation of international partnerships and programs. The identification of these key partners, while still in its infancy, is strongly leaning towards framing this selection such that there is a strong multilateral recognition and commitment to quality assurance among all the partners. In the case of partnerships with European universities, an important factor for consideration will therefore be their alignment with the Conference of European Schools for Advanced Engineering Education and Research (CESAER) [10], the Consortium Linking Universities of Science and Technology for Education and Research (CLUSTER) [11], and the Top Industrial Manager for Europe (TIME) [12]. Three strong candidates for this portfolio of partner universities in Europe include the Eidgenössische Technische Hochschule Zürich (Switzerland), Politecnico di Milano (Italy), and the Technische Universität Darmstadt (Germany).

From within this group of partnership universities, the Department of Mechanical Engineering at Virginia Tech has chosen to work closely with its sister department at the Technische Universität Darmstadt to develop a strong and comprehensive portfolio of undergraduate and graduate curricular programs and research activities. The department's strategy is to initially focus on a single partner university with which to build a successful partnership that subsequently can be replicated with other universities. These subsequent expansions will take place with the other partnership universities identified by the college and the university so as to continue to take advantage of a common student recruiting and program preparation and management infrastructure.

Programs in Place: Senior Year and Dual Masters Degree

The departments of mechanical engineering at Virginia Tech and the Technische Universität Darmstadt have developed a bilateral senior year abroad and a dual masters degree program [13,14,15]. In the senior year abroad programs, the students merely attend courses at the other university and transfer the credits back to their home institution. They do not matriculate at the other university. Hence the approval of each program rests fully with the corresponding home institution. The host institution only guarantees that courses will be delivered as promised.

The two bilateral exchange programs were both designed around a full academic year abroad instead of only a semester abroad. This longer length of study is necessitated by the fact that the semester schedules at the two universities do not readily facilitate a one-semester experience without a significant loss of time. The Fall and Spring semesters at Virginia Tech run August-December and January-May, respectively; while the Winter and Summer semesters at the Technische Universität Darmstadt run October-February and April-July, respectively. The two pre-approved study-abroad programs are therefore planned around an August-May visit to the USA and an October-July visit to Germany.

Undergraduate study-abroad programs are usually scheduled during the junior year. Indeed, Virginia Tech, like many other universities in the USA, requires that the majority of the senior-year courses are taken at home and not transferred from another university. The intention is to ensure that these last advanced courses come together to form the signature experience associated with a degree from the home university. However, the requirement that a study abroad take place during the junior year is impractical for most engineering programs because of the tight coupling between the core engineering courses during the sophomore and junior years. The composition of these core courses—though they as a portfolio essentially cover the same material at most engineering universities—are not easily transferable on an individual basis because the course sub-modules tend to be distributed uniquely across the curriculum at each university. Although rules must be revised to permit study abroad during the senior year, the fact is that the senior year tends to be filled with technical electives that can easily be taken elsewhere once the common core has been completed. The same situation exists at the Technische Universität Darmstadt, where the Diplom-Ingenieur degree was recently replaced with a three-year BS degree and a two-year MS degree, following the British BS/MS model per the Bologna process [16]. Hence, the conventional junior year abroad was abandoned and, by special exception, replaced with the senior year abroad. The result are two bilateral programs in which about half the courses are matched and credited on a one-to-one basis, while the other half of the courses are selected from one or more lists of topical electives.

The two senior year abroad programs are designed to be more or less cost-neutral to the students relative to the option of not studying abroad. In each case the students only pay tuition and fees to their home institution, which then uses these funds to finance the cost of a reciprocating visiting student. Tuition and fees at Virginia Tech (2005-2006) are approximately US$3,200 (€2,700) and US$8,900 (€7,400) per semester for Virginia and non-Virginia students, respectively; while tuition at Technische Universität Darmstadt is expected to be approximately €500 (US$600) per semester starting in October 2006 (which will be the first time it charges tuition). This difference in tuition levels necessitates a balanced exchange in the number of students between the two universities. The subsequent section on student recruiting will discuss the challenge of maintaining this balance.

The second academic program in place between the departments of mechanical engineering at Virginia Tech and at the Technische Universität Darmstadt is a dual masters of science in mechanical engineering (MSME) program. This program differs from the senior year programs in that the student is simultaneously enrolled at both universities and pursues a degree at each university. It also differs from most other dual degree programs in that it is fully symmetric [7,12]. In most dual degree programs, the majority of the courses are completed at the home institution, while the minority of the courses are completed at the host institution. In contrast, in this program the student will study one year at each university, in the order selected by the student, while completing a research-based thesis during a large part of the second year. Because of this inherent program symmetry, and because tuition and fees are paid to the institution of residence, the program has no concept of a home or host institution, nor is there a need to balance the number of students exchanges.

In the dual MSME program, the students must satisfy all the degree requirements for both the MSME degrees. This includes course credits, internships, and examination procedures. Where possible, the course credits are applied simultaneously to both degrees to reduce the total number of credits

required to earn the two degrees. The result is a dual MSME degree program that requires 58-59 semester credit hours [116-118 credit points (CP)], divided into 41-42 semester hour credits [82-84 CP] of course work and 17 semester credit hours [34 CP] of research, plus a six-week (approximately 240 hour), pre-approved industry internship. For symmetry and to satisfy the requirements of both degree programs, the thesis examination committee includes a co-chair and a member from each department.

The design of the dual MSME program is far more complex than the design of the two senior year programs. Capturing the respective standard operating procedures and traditions and devising a plausible and agreeable combination of courses while maintaining the program symmetry requires significant effort. The same will be the case for the ongoing maintenance of the program in response to even the smallest changes to either of the two underlying degree programs. Future expansions of similar programs to other universities will therefore be a slow process that will only be pursued subject to strong demand for such programs. The Department of Mechanical Engineering is therefore unlikely to have more than at most two dual MSME programs in place before year 2011, though it is reasonable to expect that several more senior year abroad programs will be established during the same period. The priority for establishing these senior year abroad programs will follow the priorities of the college and emphasize the distribution across major language groups and strategic geographic regions. In particular, it is anticipated that one senior year abroad program in mechanical engineering will be established in each of the following locations by year 2011:

LANGUAGE GROUPS	**POTENTIAL PARTNERS**
SPANISH ITESM	Monterrey (Mexico)
ITALIAN	Politecnico di Milano (Italy)
ENGLISH (1)	British Isles
ENGLISH (2)	Australia or New Zealand
FRENCH	France
MANDARIN	China
JAPANESE	Japan

The senior year abroad programs will most likely be established approximately in the order shown here, through changes may take place in response to opportunities that arise in the interim. The Spanish and Italian language locations are near certain because of existing relationships and a strong, existing infrastructure at Virginia Tech to support the necessary language training. The two English language locations will be important to make study-abroad experiences more available to students not prepared to study in another language, and to help push up the overall study-abroad participation so as to more quickly establish a strong culture and tradition of study abroad among Virginia Tech engineering students.

Programs in Development: Joint Doctoral Degree

The traditional doctoral programs at Virginia Tech and the Technische Universität Darmstadt differ in several aspects. At Virginia Tech, the Ph.D. builds on the BS degree, with the MS degree representing an interim result. Specifically, the Ph.D. requires 90 semester credit hours [180 CP] of courses work and research beyond the BS degree. This course work is typically distributed with 21 semester credit hours [42 CP] during the MS studies and 15-21 semester credit hours [30-42 CP] during the post-MS studies, for a total of 36-42 semester credit hours [72-84 CP]. At the Technische Universität Darmstadt, the 82-84 CP [41-42 semester credit hours] of post-BS course work is entirely contained within the MS degree such that the doctoral program only contains research. Hence, the natural combination of the two departments' graduate programs is therefore to design the dual MSME degree, the way it was done, such that it satisfies all the course work and course residency requirements for both the departments' doctoral programs, and such that only research remains for a student pursuing a doctorate in either department.

A second difference between the two doctoral programs is that the Dr.-Ing. degree enjoys a particularly strong legal protection in Germany, which the Ph.D. degree lacks. Hence, German students are hesitant to pursue a Ph.D. in place of a Dr.-Ing. degree. A dual Ph.D./Dr.-Ing. degree program would address this concern. The disadvantage of a dual degree, as has been observed with the dual MSME degree program, is that either university may unilaterally change the parameters for its own underlying

degree, which complicates the dual degree program administration. A cleaner approach is to pursue a joint degree program. The parameters of a joint degree cannot be changed unilaterally; the two university logos on a single degree diploma better symbolized the strong, mutual commitment in the partnership; and, because it is a single degree, it is immune to the discussion that a dual degree program occasionally faces: How much effort should a dual degree program require compared to the sum of the separate efforts of the two underlying degrees if pursued individually? Must the effort in a dual degree program significantly exceed the effort of either of the underlying programs to justify the receipt of two degrees?

These questions will be addressed and answered in the planned development of a joint Dr.-Ing. degree in Mechanical Engineering between Virginia Tech and the Technische Universität Darmstadt will be pursued during the 2006-2007 academic year, for possible initial deployment during Fall 2007 and full deployment during Fall 2008. Beyond this one joint doctoral degree program degree, any subsequent program will only be pursued if there is sufficient demand, both from students interested in studying abroad and from research sponsors interested in supporting research projects across multiple sites.

Joint Courses and Research Activities: building an infrastructure

Formalizing the curricula as described above is essential to support a comprehensive study abroad participation, but it is in itself insufficient to generate a substantial study-abroad participation at a research university, especially at the graduate level where the students are closely associated with sponsored research projects. The departments of mechanical engineering at Virginia Tech and the Technische Universität Darmstadt are therefore also pursuing infrastructures that will facilitate and support joint research and the exchange of research personnel. The following illustrate a few of the ongoing initiatives:

- An NSF Research Experiences for Undergraduates (REU) program in the area of automotive technologies will be established jointly at Virginia Tech and the Technische Universität Darmstadt, starting in summer 2007. Students from across the USA will be able to pursue research at both locations, including transitioning their work from one location to the other over a period of two summers or a summer and an adjacent semester.

- A joint research center in the area of unmanned vehicles is under development, leveraging the hardware research at Virginia Tech and the software research at Technische Universität Darmstadt. An estimated 14 doctoral students will be funded over a period of nine years. These students will be prime candidates for the proposed joint Dr.-Ing. degree program.

- A joint research center in the area of global collaborative engineering and product data management is under development to specifically address the needs of US-German multinational corporations as they expand their global operations.

Joint courses will not necessarily satisfy the targets set by the College of Engineering, but will help expose students to global engineering and should stimulate an interest in participating in one or more of the study-abroad programs. Examples of such courses already in existence include:

- A course on global collaborative engineering design that is team-taught by faculty at Virginia Tech, the Technische Universität Darmstadt, Howard University (Washington, DC, USA), ITESM Monterrey, and, starting in Fall 2006, Shanghai Jiao Tong University (China). In this course the students work in multi-national teams to redesign a production vehicle for various geographic markets, using the latest communications and collaboration technologies [17,18,19,20].

- A senior capstone design project with more than 150 mechanical and industrial design students in Australia, Brazil, Canada, China, Mexico, South Korea, Sweden, and the USA that are working with General Motors designers, engineers, and managers to develop a new line of automotive vehicles. The student teams are organized by university as part suppliers, and they use the latest communications and collaboration technologies [20,21]. Approximately 18 Virginia Tech students are participating on this project during the 2005-2006 academic year.

Work is also in progress to repackage selected courses at the Technische Universität Darmstadt such that they are offered in English by Technische Universität Darmstadt faculty to visiting Virginia Tech

students during the Virginia Tech Summer I semester (approximately May 22 – July 1). These courses will generate study-abroad participants that can be counted towards the strategic targets; they will generate tuition waivers that can be used to fund Technische Universität Darmstadt students attending Virginia Tech; and they will provide Virginia Tech students with course options that are not available at Virginia Tech and during a time of year when upper and graduate level courses are generally not offered at Virginia Tech. These courses will also provide a sampling of student life in Darmstadt and thus hopefully stimulate subsequent yearlong study-abroad activities.

Faculty and Student Recruitment

It is essential to study and work in the native language of the surrounding environment in order to realize the full potential that a study-abroad experience can offer. A program that is based on English, though surely valuable, will only enable the student to attain a much more limited experience, exposure, insight, and understanding of engineering in a global context.

The challenge for US students studying abroad in is that language studies receive a relatively low priority in the USA. For instance, only 2.5% of US high school students study German for at least three years. Hence, programs such as the senior year abroad and the dual MSME must incorporate German language training. The students in the senior year abroad program must attend lectures, read textbooks, and take written exams in German. This corresponds to the UNIcert Level III skill set [22], or receiving the grade "B" after 18 semester credit hours [36 CP] of university level German language studies. At Virginia Tech, this corresponds to the course GER 3106. Note that three years of high school German language instruction, if present, counts for the first six semester credit hours [12 CP]. The students in the dual MSME program must attend lectures in German, but most of the textbooks are in English and the exams are oral and in English. This corresponds to UNIcert Level II skill set [22], or receiving the grade "B+" after 12 semester credit hours [24 CP] of university level German language studies (the course GER 2106 at Virginia Tech). For the doctoral program and for research activities in Germany, the work language is English; though, of course, German language skills would be useful for improved social interactions and access to German language documents. Similar issues are expected for the study-abroad programs based on Spanish, Italian, French, Mandarin, and Japanese.

This sets the stage for how students must be recruited to the various study-abroad programs and trained in the German language (and the other languages as appropriate). The senior year abroad and dual MSME programs have been designed to incorporate German language instruction into the overall plan of study. Unfortunately, most students do not plan sufficiently to incorporate the necessary German language training without causing graduation delays. The Department of Mechanical Engineering at Virginia Tech is therefore working closely with the German language faculty to recruit and train students in time for participating the various study-abroad programs. The introductory German language courses are being offered in Summer II at Virginia Tech (July 3 – August 12) to enable both prospective and current students to study German, and incoming students are encouraged to attend these courses following high school but before their first year of university studies begins. Additional German language and cultural training offered during the five-week Technische Universität Darmstadt Summer School program.

The following illustrates the anticipated distribution and participation by the mechanical engineering students at Virginia Tech in the various study-abroad programs by year 2011. These estimates are reasonably conservative to account for those students that participate in multiple study abroad activities:

TARGET: NEW ENTRIES EACH YEAR BY 2011

- 10 TUD summer school (German language & culture; design project with German students)
- 10 Senior year abroad at TUD (US students)
- 10 Dual MSME with TUD (both US and German students)
- 4 Joint Dr.-Ing. with TUD (both US and German students)
- 4 Other graduate students visiting TUD for summer and/or semester research
- 15 Attending VT Summer I courses offered at TUD by TUD faculty
- 5 VT undergraduate students attending NSF REU site at TUD (US students)

58 TOTAL STUDY ABROAD AT TUD (19% participation)
15 Senior year abroad elsewhere
5 Graduate students visiting elsewhere for summer research
5 Other summer programs (ad hoc)
83 TOAL STUDY ABROAD AT ALL LOCATIONS (28% participation)
15 VT students in global team courses team-taught with faculty and co-students abroad
15 VT seniors in capstone design projects involving global student teams
113 STUDENTS EXPOSED TO GLOBAL ENGINEERING (38% participation)

Another important element of a successful student study-abroad program is strong faculty participation and support. Faculty must see their participation as advantageous to their own career. Hence, just like the pre-approved study plan for the senior year abroad and the dual MSME programs make it easy for the students to include a study-abroad experience, so must the support infrastructure be designed to facilitate easy migration of faculty and scientific staff between the partner universities. This includes creating a cost-neutral, "turn-key" environment that addresses the professional and personal needs of the faculty and their families during the extended stays abroad. Examples include the availability of furnished guest housing and high-quality assistance to address transportation and family relocation and adjustment needs. Without this infrastructure, the faculty will be hesitant to participate. The Department of Mechanical Engineering at Virginia Tech will therefore work to identify and establish the services that are needed to create such an environment.

Conclusions

The Department of Mechanical Engineering at Virginia Tech has embarked on an ambitious plan to meet and significantly exceed the strategic objectives set by the College of Engineering at Virginia Tech by year 2011. The majority of the infrastructure components in this plan has been already deployed or will be deployed within the year. The challenge that remains will be to populate this infrastructure with students to reach the participation targets. Continuous improvement will be applied to identify and overcome the inhibiting factors.

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