2006-1619: STUDY ABROAD PROGRAMS IN MECHANICAL ENGINEERING

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Study Abroad Programs in Mechanical Engineering

Abstract

The Technische Universität Darmstadt (Germany) and Virginia Tech (USA) view the bilateral exchange of students with their respective academic programs, both at the undergraduate and graduate levels, to be the cornerstone and foundation needed to support successful and sustainable joint-research activities. They also view such programs as a prime opportunity to benchmark each other's academic programs, thus providing a thorough, global benchmark to complement their respective portfolios of domestic benchmark partners. It is in this context that these two research universities have developed a bilateral senior year abroad program and a dual Master of Science degree program in Mechanical Engineering, both in which the students study in the language of the host university and graduate on schedule. This paper describes the design of these two programs.

Keywords: International education; Study abroad; Dual degree program

Introduction

The objectives of engineering education are evolving and becoming ever more challenging to meet. As the frontiers and complexities of engineering grow and increase, there is pressure to include increasingly more technical content into the curriculum. At the same time, there is strong pressure to improve the on-schedule graduation rate by reducing the number of credits required for graduation. Engineering programs have furthermore been challenged over the past several years to produce graduates that are articulate and that can function well on multidisciplinary teams; in essence, the quintessential renaissance engineer capable of mastering just about any challenge coming his or her way. A recent addition to this mix is the need to produce engineering graduates that are globally competitive and poised to succeed in the global engineering market place.

It is difficult to learn and understand another culture without experiencing it first hand. Universities have long since realized this and offered their students the opportunity to study abroad. The concept of junior year abroad in liberal arts is well established; with students taking courses abroad and transferring the credits earned back into what for engineers are incredibly flexible curricula. In contrast, the typical solution for engineering students has been to increase the duration of their studies in order to accommodate a study abroad experience. Hence, the study abroad participation rate among engineering students has significantly trailed that of liberal arts students. For instance, at Virginia Tech, which is one of the largest producers of undergraduate engineers in the USA, only 1.7% of its engineering students study abroad, compared to 15% its of non-engineers.

There are several reasons for why study abroad is more common in liberal art programs than in engineering programs. Language- and culture-studies have their home in liberal arts, and study abroad constitutes a natural field study experience for these students, just as hand-on design projects do in engineering. Hence, liberal art students have long been encouraged to study abroad, whereas until recently study abroad for engineers has been regarded as an unnecessary novelty. Liberal arts programs are also much less structured than engineering programs. In liberal arts, the number of required courses is fewer, their courses carry fewer prerequisites, and the number of elective courses is much higher, specifically to allow for study programs that are customized to each individual student. In contrast, engineering courses are tightly coupled and students cannot easily take their core-engineering courses out of sequence. Furthermore, while the total content of these core-engineering courses as a group is fairly common among engineering universities, the location of the various modules within these courses varies highly from one university to another. Hence it is generally difficult to transfer credits for a singular core-engineering course taken at another university because of the lack of one-to-one match between the two universities' courses. Most transfer of credits in engineering—and in liberal arts—therefore take place among the elective courses, which tend to be scarce in engineering. Finally, liberal arts programs generally require less course credits for graduation than engineering programs. For instance, in the USA, most liberal arts programs require 120-124 semester credit hours for a bachelor degree, whereas most undergraduate engineering programs require 128-136 semester credit hours. Recent pressures to reduce the average time-to-graduation in engineering have generally been solved by eliminating electives while keeping the number of engineering credits intact, and recent pressures to ensure minimum competencies in specific topics (e.g., history, geography, economics, writing) have been solved by further restricting the scope of the elective credits. Taken together, while liberal arts can still easily accommodate the "junior year abroad," such endeavors are becoming increasingly difficulty within engineering.

For most engineering students, the consequence of a conventional one- or two-semester study-abroad experience is to increase the time to graduation. The students might reduce this time by accumulating credits prior to their studies (e.g., advanced placement credits), by overloading on credits during their regular semesters, or by taking additional courses between their regular semesters (e.g., during summer semesters). However, in most cases, these study abroad experiences are simply accommodated by postponing the original date of graduation.

Given these challenges that face engineering students studying abroad, it is unreasonable to expect that the number of engineering students studying abroad will increase noticeably without accommodating programs being put into place. In Europe, the response has been to pursue what is known as the Bologna process [1]. The essence of this process, which was launched with a common declaration on June 19, 1999, and which now has been committed to by more than 40 European countries, is to standardize on a common higher education structure that facilitates transparent, international mobility of students, researchers, and faculty, with full quality assurance and mutual academic and professional recognition of qualifications. The result has since been a flurry of activities across Europe to reconfigure their academic programs in the context of a bachelor/masters/doctorate sequence, and to demonstrate the quality of this reconfiguration via the international mobility of their students. The Technische Universität Darmstadt has been one of the very first universities to pursue this reconfiguration process, with

it Department of Mechanical Engineering leading the way. This academically top-ranked department, which graduates about 220 bachelor students each year, has completely replaced its Diplom-Ingenieur degree with a new bachelor and masters degree sequence, and it is demonstrating its students' international mobility by having more than 60% of them studying one or more semesters abroad. Their goal is to exceed 80% study abroad participation within the next few years.

By any measure, the efforts to increase the study-abroad participation in the USA are far less coordinated, and, in most cases, they are also far less ambitious. Consider, for instance, two of the largest undergraduate engineering programs in the USA: Virginia Tech has a six-year goal of increasing the study-abroad participation among its engineering students from 1.7% to 15%, while Purdue University has a goal of 20% participation. In both cases, there will be a massive need to develop systematic programs to facilitate such increased levels of study abroad participation. The current systems of ad hoc study-abroad programs will simply not suffice.

Systematic programs to facilitate study-abroad participation among engineering students in the USA are few and far between. The following examples illustrate some current approaches:

- Milwaukee School of Engineering (MSOE) has established junior year abroad programs in electrical and mechanical engineering at Fachhochschule Lübeck (Germany) [2]. This is a two-semester program with custom courses offered in English that are designed to match the MSOE curriculum. The MSOE students graduate on time. Some of the German students attending these courses in English attend MSOE the following year.

- University of Connecticut offers a five-year program, known as EUROTECH [3], in which the engineering students earn a bachelor degree in engineering and a bachelor degree in German. The study-abroad component consists of a six-month industry internship in Germany. No prior German language skills are required.

- University of Rhode Island (URI) and the Technische Universität Braunschweig (TUB) offer a dual-degree program in which the students earn a masters degree in engineering from URI and a Diplomingenieur degree from TUB [4]. For both universities, the final year, including the thesis, is completed abroad. The courses at URI are in English and the courses at TUB are in German.

- Purdue University's School of Mechanical Engineering is a participant of the Global Engineering Alliance for Research and Education (GEARE) [5]. The core of this program is a junior-year spring/summer semester study-abroad in Germany, India, or China. The courses abroad are in English and transfer back to Purdue so there is no delay in graduation. Concurrently, the students also participate in a two-semester industry-inspired project with students from the other countries and in a two-part industry internship; in both cases, one half of the project and internship is at home, and the other is abroad.

The Technische Universität Darmstadt and Virginia Tech have similarly seen the need to pursue a systematic approach to study abroad programs. In February 2003, these two research

universities embarked on a strategic partnership that was spawned by their mutual membership in the Partners for the Advancement of Collaborative Engineering Education (PACE) [6] and their many commonalities: They both share similar educational and research missions, and they both are state universities pursuing increased autonomy. From the very start, it was recognized that in order to sustain any significant research collaborations, it would be necessary to have a comprehensive portfolio of joint academic programs in place to facilitate the ongoing and systematic exchange of research personnel—most of which would be graduate students. A seamless, multi-level academic program was thus envisioned to help recruit and move students through the system, and to create a robust culture and tradition of study abroad at each others universities:

- Language courses at the home institution to prepare students for study abroad;
- Summer school programs and summer internships at the other university to provide an opportunity to explore and sample that university prior to committing to a longer study abroad experience;
- Semester or year-long study abroad experience in which the student attends courses at the other university, in the language of that university, and in which the course credits earned abroad are transferred back to the home university towards the degree program there;
- Dual degree programs in which the student studies at both universities, completes all the requirements for both degrees, and receives the two degrees simultaneously;
- Joint degree programs in which the student receives a single degree issued jointly by both universities; and
- Research exchanges as appropriate to thesis or dissertation research activities.

The following sections describe the two first joint academic programs that were be developed between the Technische Universität Darmstadt and Virginia Tech; namely, the bilateral senior year abroad program and the fully symmetric dual Master of Science program in mechanical engineering. This is then followed by a brief outline of future plans.

Senior year abroad program

The first joint academic program that was developed between the Technische Universität Darmstadt and Virginia Tech was a bilateral senior year abroad program. The development of the program was based on two premises. The first premise was that the program would involve the customary cost-neutral exchange of tuition. That is, there would be a one-to-one exchange of students over time, with the Virginia Tech students paying Virginia Tech tuition while studying at the Technische Universität Darmstadt, and with the Technische Universität Darmstadt students paying the Technische Universität Darmstadt tuition while studying at Virginia Tech (German universities are broadly expected to implement a tuition system during 2006). The second premise was that the studies would take place in the language of the host university using existing courses at that university. Though this would make it a challenge to recruit Virginia Tech students to the program (only 2.5% of high school students in the USA study German), it is

felt that the full value of the study abroad experience can only be realized with the full native immersion, and that available resources should therefore be directed towards improved student recruiting and preparation rather than on creating an insulated study abroad experience.

This second premise therefore became a driving factor towards situating the program in the senior year. To acquire the German language skills necessary to attend classes in German at the Technische Universität Darmstadt, Virginia Tech students need to complete six semesters of German language instruction, with three years of high school German language instruction counting as two semesters. Since most universities in the USA, including Virginia Tech, do not offer third through sixth semester German language instruction during its summer semesters, it therefore became a practical necessity to situate the study abroad experience in the senior year.

A second reason for situating the study abroad experience in the senior year is that the senior year in mechanical engineering at both the Technische Universität Darmstadt and Virginia Tech is heavily loaded with electives and relatively few core-engineering courses. Hence it is relatively easy to identify topical clusters of courses at the host university for the students to choose among. This approach simplifies the student advising and program management in that the unavailability of a course would not leave the student abandoned, since the student would then simply choose another available course within the cluster.

Indeed, the concept of clusters was used whenever there was not a one-to-one match between core courses that are required and thus guaranteed regularly available at both universities. Examples of courses with a one-to-one match, both in content and in credits, include fluid mechanics, vibrations, controls, heat and mass transfer, and senior capstone design. For instance, the unique, required course at Virginia Tech on applied fluid mechanics and heat transfer design, was replaced with a cluster of non-required but regularly offered portfolio of lecture and laboratory courses at the Technische Universität Darmstadt, that taken together, covers the material of the required Virginia Tech course, with the surplus credits being applied towards the Virginia Tech technical elective requirements; thus no credits earned abroad remain unused once transferred home.

The students from the Technische Universität Darmstadt do not need to rearrange their standard study plan in order attend their senior year at Virginia Tech. The courses scheduled for their senior year can, as a portfolio, be completed entirely at Virginia Tech. Experience has also shown that the German students are sufficiently proficient in English to the extent that they do not require additional language training prior to attending classes at Virginia Tech.

The students from Virginia Tech, however, do need to prepare for their senior year at the Technische Universität Darmstadt several years in advance of departure. The vast majority of these students must schedule time for a sequence of six German language courses prior to departure. These are courses that the students do not receive credit for towards their Bachelors degree in mechanical engineering. In most cases, these students must rearrange their schedules and attend three summer semesters (there are two summer semesters per summer). Students with three years of German language instruction in high school (2.5% of population) may reduce this to two summer semesters, and students with advanced placement (AP) credits may even avoid summer semesters all together subject to the number of AP credits they have. However, in either

case, the students must plan ahead and rearrange their standard study schedule by the end of their freshman year at the very latest. This rearrangement must not only accommodate the German language courses, but also a key difference between the four-year Bachelors degree in the USA and the new three-year Bachelors degree being deployed via the Bologna process throughout Europe. The new European Bachelors degree is based on the British model of three year with all-technical coursework. In contrast, the US Bachelors degree is a four-year degree that covers the same technical material in addition to a year of liberal arts that is embedded throughout the four-year program. Obviously, the study abroad program for Virginia Tech students must also satisfy these liberal arts requirements. For instance, in the regular Virginia Tech senior year program, a student would take three courses on humanities, social science, and "critical issues in a global context" in addition to the technical courses. Gaining and maintaining the approval for the transfer of such courses from the Technische Universität Darmstadt would be an ongoing bureaucratic challenge. The standard study program for Virginia Tech students studying abroad has therefore been modified such that these liberal arts courses are completed prior to departure by moving select mechanical engineering courses from the junior year into the senior year. The results are two bilateral senior year abroad programs that are controlled exclusively by their respective mechanical engineering department [7].

Finally, it is appropriate to address the duration of the senior year study abroad activity. The timing of the academic semesters at the Technische Universität Darmstadt and Virginia Tech are quite different: At the Technische Universität Darmstadt, the Winter semester runs from mid-October through mid-February, and the Summer semester runs from early-April through mid-July, with the academic year thus running from mid-October through mid-July. In contrast, at Virginia Tech, the Fall semester runs from late-August through mid-December, and the Spring semester runs from mid-January through early-May, with the academic year thus running from late-August through early-May. Because the Winter semester overlaps with both the Fall and Spring semesters, it is impractical for Technische Universität Darmstadt students to attend a single semester at Virginia Tech; though it is feasible for Virginia Tech students to replace a Spring semester at Virginia Tech with a Summer semester at the Technische Universität Darmstadt. Still, for programmatic symmetry, for ease of management, and to provide a functional, pre-approved starting point for students planning to study abroad, the two programs were designed to match the two universities' regular academic years.

Figures 1 and 2 illustrate what the senior year abroad programs might look like from the Technische Universität Darmstadt and Virginia Tech students' perspectives, respectively.

Dual Master of Science degree program

The design of a dual degree program is more complicated than an exchange program. In the exchange program, such as the bilateral senior year abroad program described above, the students studying abroad are not matriculated at the host university, and the academic program are fully owned and controlled by the home university. For instance, the ultimate decision with regards to transfer of credits is made exclusively by the home institution.

In the case of a joint- or dual-degree program, the students are simultaneously enrolled at both universities. Hence the concept of a home- and host-university becomes irrelevant. Instead, all

THE TECHNISCHE UNIVERSITÄT DARMSTADT SENIOR YEAR AT VIRGINIA TECH

This program would complete the required 31 semester credit hours (62 CP) in two semesters. The dates shown reflect the 2005-2006 academic year.

Fall Semester (August 22 – December 15)				
ME	3404	Fluid Mechanics		3 credits (6 CP)
ME	4504	Dynamic Systems – Controls Engineering I		3 credits (6 CP)
ME	4015	Engineering Design and Project I		3 credits (6 CP)
ME	4204	Internal Combustion Engines	*Tech elective 1*	3 credits (6 CP)
ME	4554	Advanced Technology Motor Vehicles	*Tech elective 2*	3 credits (6 CP)
TOTAL				**15 credits (30 CP)**
Spring Semester (January 17 – May 10)				
ME	3504	Dynamic Systems – Vibrations		3 credits (6 CP)
ME	3304	Heat and Mass Transfer		3 credits (6 CP)
ME	4016	Engineering Design and Project II		3 credits (6 CP)
ME	4534	Land Vehicle Dynamics	*Tech elective 3*	3 credits (6 CP)
AOE	4404	Applied Numerical Methods	*Math elective*	3 credits (6 CP)
TA	2024	Introduction to Acting	*Non-ME elective*	3 credits (6 CP)
TOTAL				**18 credits (36 CP)**

Figure 1 Sample study program for a senior pursuing the Bachelor of Science in Mechanical Engineering at the Technische Universität Darmstadt while at Virginia Tech

VIRGINIA TECH SENIOR YEAR AT THE TECHNISCHE UNIVERSITÄT DARMSTADT

This program would complete the required 30 semester credit hours (60 CP) in two semesters. The dates shown reflect the 2005-2006 academic year.

Winter Semester (October 24 – February 17)		
Maschinendynamik I *(structural dynamics; vibrations)*		6 CP (3 credits)
Fluidtechnische Antriebe *(fundamentals of fluid power)*		4 CP (2 credits)
Ölhydraulik und fluidtechnische Antriebe *(fluid powered drives laboratory)*		4 CP (2 credits)
Produktentwicklung I *(product development)*	*Tech elective 1*	4 CP (2 credits)
Turbomaschinen I *(turbomachinery)*	*Tech elective 2*	8 CP (4 credits)
Umformtechnik I *(deformations)*	*Tech elective 3*	4 CP (2 credits)
TOTAL		**30 CP (15 credits)**
Summer Semester (April 4 – July 21)		
Praktikum Aktoren für mechatronische Systeme *(laboratory on mechatronics)*		6 CP (4 credits)
Bachelor-Thesis *(senior capstone design project)*		12 CP (6 credits)
Produktentwicklung II *(product development)*	*Tech elective 4*	4 CP (2 credits)
Turbomaschinen II *(turbomachinery)*	*Tech elective 5*	4 CP (2 credits)
Umformtechnik II *(deformations)*	*Tech elective 6*	4 CP (2 credits)
TOTAL		**30 CP (15 credits)**

Figure 2 Sample study program for a senior pursuing the Bachelor of Science in Mechanical Engineering at Virginia Tech while at the Technische Universität Darmstadt

aspects of the program are jointly owned between the two departments and must be managed accordingly. As will be described in this Section, this entail a significant amount of coordination between the two departments, both to establish and maintain the program as a whole.

The decision was made to design a dual degree program based on the two universities' existing Master of Science in Mechanical Engineering degree programs. In essence, upon satisfying all

the requirements for both the existing programs, the student would be awarded both Master of Science in Mechanical Engineering degrees; that is, one from each university. Wherever the requirements are the same, the effort is counted towards both degrees. Hence, to put this effort in context, from a student's point of view, the dual degree requires approximately 20% more effort than either of the individual degrees. The motivation for the students to take on this extra effort is, of course, both the intrinsic value of studying abroad, and the added market value of graduating from two excellent universities in two different countries.

The two underlying Masters degree programs are reasonably similar in structure and duration. The Masters degree at the Technische Universität Darmstadt is a two-year program that typically consists of three semesters of coursework, followed by up to six months of full-time thesis research (the upper time limit prevents the project from dragging on). During this time, the student must also complete a pre-approved industry internship. At Virginia Tech, the students take on average 23 months to complete their Masters degree. During this time, they pursue both coursework and thesis research, and they are frequently engaged in part-time research or teaching employment (up to 50% effort is permitted).

The main differences between the two programs are as follows:

- Industry internship:
  - The Technische Universität Darmstadt requires an industry internship
  - Virginia Tech has no such requirement
- Part-time employment:
  - Virginia Tech expects most of its Masters and doctoral students to be employed as part-time researchers and/or teachers during their studies (up to 50% effort)
  - The Technische Universität Darmstadt does not employ Masters students; it only employs doctoral students (up to 100% effort)
- Coursework:
  - The Technische Universität Darmstadt concentrates all the graduate coursework in the Masters degree program such that the doctoral program consists entirely of research (41-42 semester credit hours [82-84 CP] in the Masters program and 0 semester credit hours in the doctoral program)
  - Virginia Tech distributes the graduate coursework across both the Masters and doctoral program (approximately 21 semester credit hours [42 CP] in the Masters program and 15-21 semester credit hours [30-42 CP] in the doctoral program, for a total of 36-42 semester credit hours [72-84 CP])

In addition, both the Technische Universität Darmstadt and Virginia Tech have several specific course requirements that differ. For instance, the Technische Universität Darmstadt requires a course on project management, while Virginia Tech requires a course in mathematics or statistics. In the case of the dual degree program, the students must satisfy all these requirements.

An interesting side effect of having to satisfy all the Technische Universität Darmstadt coursework requirements is that, with minimal additional effort, the students can simultaneously satisfy all the Virginia Tech doctoral requirements as well. At Virginia Tech, the doctoral coursework count includes those courses that were completed towards the Masters degree. Hence, any excess coursework towards the Masters degree can be applied towards the doctoral degree. The course selection within the dual degree program was therefore further restricted such that it would satisfy both the Virginia Tech Masters and doctoral program in Mechanical Engineering. In particular, the maximum number of undergraduate courses was reduced, and the minimum number of graduate level courses and the number of mathematics and statistics courses were increased. The result is a dual degree program in which its graduates only need to pursue research should they later choose to pursue a doctorate at Virginia Tech. This, of course, increases the compatibility between the two universities' doctoral programs, and thus paves the way for a research-only dual- or joint-doctorate degree in the future.

Most degree programs have a residency requirement. That is, the students must spend a minimum amount of time at a university in order to receive a degree from that university. In the case of this two-year dual-degree program, it therefore is natural to require that the students spend at least one year at each university. Hence, given the timing of the academic semesters at the Technische Universität Darmstadt and Virginia Tech (see dates listed in Figures 1 and 2), it is therefore most practical to design the standard study program around the students distributing their two residencies using the two universities' respective academic years; i.e., Winter/Summer at the Technische Universität Darmstadt, and Fall/Spring at Virginia Tech. It was further decided to create a fully symmetric program in which the students can choose the order of their two residencies. This symmetry further emphasizes the erasure of the concept of a home- or a host-university, in that the dual degree program is fully self-contained and does make any assumption as to the student's nationality or undergraduate alma mater. Once a student is admitted into the dual degree program, the student is simultaneously a student of both the Technische Universität Darmstadt and Virginia Tech.

Because the Technische Universität Darmstadt has a standard, suggested course-sequence, while Virginia Tech does not suggest a particular order of its courses, the course symmetry was designed around the courses suggested at the Technische Universität Darmstadt for a given year. That is, for each year in the Technische Universität Darmstadt Masters degree program, an equivalent portfolio of courses was identified at Virginia Tech. The particular Virginia Tech program requirements, such as mathematics and statistics courses, were integrated into the two versions of the Virginia Tech residency. In general, this equivalency and integration was managed by creating a number of topical course-clusters at each university from which the students could choose. The Technische Universität Darmstadt also has several particular requirements that reflect the traditional signature of their Masters program. This includes an extensive industry internship, and a self-directed, 80-hour, non-thesis, team design project. The parameters and spirit of these requirements were captured and restated in the context of being offered during the Virginia Tech residency for the cases where it is impractical to satisfy these requirements within the Technische Universität Darmstadt residency.

Students participating in this dual degree program must be able to attend the courses during both their residencies. The issue of language skills preparation for this program thus becomes similar

to that of the senior year abroad program, with the exception that the level of German language skills required is lower than for the undergraduate program. The reason is that in the undergraduate program the students must be prepared to complete written exams in German. Only exceptionally can they expect that the German professor will provide an exam translated into English. In contrast, in the graduate program, while most of the lectures are still in German, much of the reference material is in English, and all the exams are oral. Hence, with the commitment of the faculty in Mechanical Engineering at the Technische Universität Darmstadt, the students will have the option to take these oral exams in English. The students entering the dual Masters degree program must therefore demonstrate UNIcert Level II language proficiency (or the equivalent), as compared to the more demanding UNIcert Level III language proficiency that is required for the senior year abroad program [9]. The German language faculty at Virginia Tech estimate that a student earning the grade "B+" in GER 2106 at Virginia Tech should be able to pass the UNIcert Level II exam. This corresponds to 12 semester credit hours [24 CP] of German language instruction. In the case of the UNIcert Level III exam, it is estimated that the grade "B" in GER 3106 at Virginia Tech should suffice (18 semester credit hours [36 CP] of German language instruction). These correlations will be monitored to assist students in planning their entry into the dual Masters degree program without first having participated in the senior year abroad program.

Finally, it is appropriate to address the maintenance and operation of the dual degree program. Every university has developed its own policies, procedures, and traditions; some which are written down, and many that are not. In most cases, these policies, procedures, and traditions are complied with by using corporate memory and a common understanding of the system. In the case of a dual degree program, and especially one in which the two faculty generally have limited first-hand knowledge of the finer details of each others' policies, procedures, and traditions, and where language is often a serious barrier, it is particularly important that a minimum, common understanding of policies, procedures, and traditions is created, given that the program must comply with two sets of these simultaneously. An integral component of the design of the dual Masters degree program was therefore to capture and summarize these policies, procedures, and traditions so they can easily be shared among the participating faculty, staff, and students. This summary was reviewed and refined a multitude of times, both formally and informally, with regards to past policies, procedures, and traditions, and with regards to where these two degree-programs are most likely heading. Indeed this experience quickly highlighted the maintenance challenge associated with a dual degree program. In this case it was the Technische Universität Darmstadt that made a few minor changes to its Masters degree program. Ordinarily, this would have been an internal matter, but because their program is now linked with the Masters degree program at Virginia Tech, it becomes important that these changes get communicated efficiently to Virginia Tech. Hence two observations can be made from this experience: First, the process for program changes within one underlying program must include efficient communication links with the university; and second, it becomes exponentially challenging to link a degree program to more than one other degree program due to the ripple effect between the programs. Indeed, this challenge highlights an important advantage of a joint degree program over a dual degree program: In a dual degree program the underlying programs can be modified independently of each other and without communications; that is, communications is not necessarily assured. In contrast, in a joint degree program, all changes must be jointly approved for them to take effect; hence communications is assured.

Furthermore, the standards and procedures for a joint degree can be maintained separately from the two local degrees. That is, each of the three degrees can be maintained separately without the need for ongoing, detailed coordination.

Future plans

The two mechanical engineering senior year abroad programs have been approved at their respective universities, and the first student from the Technische Universität Darmstadt is currently attending Virginia Tech (2005-2006 academic year). Thus far the experience has been successful, including the completion of two written Technische Universität Darmstadt examinations while at Virginia Tech. The first student from Virginia Tech to attend the Technische Universität Darmstadt is expected during the 2006-2007 academic year.

The dual Master of Science in Mechanical Engineering program was approved at the Technische Universität Darmstadt in June 2005 and at Virginia Tech in February 2006. The first students in this program are expected to enroll for the 2006-2007 academic year. The program is currently undergoing minor adjustments to reflect recent adjustments to the Master of Science in Mechanical Engineering program at the Technische Universität Darmstadt. The result will be a dual degree program that consists of 58-59 semester credit hours [116-118 CP], divided into 41-42 semester credit hours [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.

The next step will be to develop a dual- or joint-degree doctoral program. This should be greatly facilitated by the dual Masters degree satisfying all the Virginia Tech course work and course residency requirements. Hence, the doctoral program should become an all-research, no-coursework degree. One approach is to pursue a dual degree that utilizes the existing Dr.-Ing. degree at the Technische Universität Darmstadt and the existing Ph.D. degree at Virginia Tech. Its implementation would be a relatively quick to achieve. The alternative would be to pursue a joint doctoral degree. Currently, the benefits and implementation issues of a joint doctoral degree are being investigated. This includes the legal status of various doctoral degree names in Germany and in the USA, and the differences in doctoral degree operating procedures and traditions at the two universities. The approach to be pursued will be decided upon in 2006.

Conclusions

The Technische Universität Darmstadt and Virginia Tech have recently established a bilateral senior year abroad program and a fully symmetric dual Master of Science degree program in the area of mechanical engineering. A joint doctoral program in mechanical engineering is planned, as are similar programs in other fields of engineering. The goal is to create a comprehensive portfolio of academic programs that come together to support large numbers of students participating in studies abroad and a multitude of joint research activities. In the future, once a sufficient student throughput is achieved, these programs will also enable quality benchmarking, control, and improvement on a global scale.

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