Introduction to German Engineering. A Transatlantic Experience

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Abstract

Numerous universities provide semester- or year-long overseas educational experiences for undergraduate students. However, few provide intensive short experiences focused on introducing engineering students to the differences in process design, industry, and culture. This paper presents a unique opportunity for US students to participate in an award-winning introductory engineering design process course in Germany. First, the US rising sophomore engineering students joined second-semester freshman German engineering students in a week-long design project in Germany. American students learned that the German design method is a well defined procedure, leading to the best engineered product or process. While the American method generally tends to be more rapid to market, frequently with improvements made after production begins. Then the US students toured ACHEMA 2012 in Frankfurt, Germany, as well as numerous large industrial facilities to explore commonalities and differences between the two countries' industries and traditions. Finally, the US students participated in guided tours of German historical and cultural sites. The initial offering of this short-term introduction to German Engineering was very well received by the US engineering students, and is providing a spring-board for these students to pursue subsequent longer and more in-depth experiences abroad.

Background and Overview

The Mechanical Engineering departments at Virginia Tech (VT; Blacksburg, VA, USA) and the Technical University Darmstadt (TUD; Darmstadt, Germany) have since 2007 offered a transatlantic dual-BSME degree program in which the German students spend their senior year (3rd year) at VT while the US students spend their senior year (4th year) at TUD. Upon successful completion, the students earn both a US and a German BSME degree. Thus far, 24 US and 22 German students have participated in this program, and 17 more students are expected to exchange during 2013-2014.

The South Dakota School of Mines (SDSMT; Rapid City, SD, USA) offers its students a European Project Semester (EPS; Kiel, Germany; Copenhagen, Denmark; and Trondheim, Norway) with a focus on engineering product design.

As a way to introduce US students to differences in engineering process and product design, and to encourage increased numbers of students to consider pursuing an extended overseas experience, the authors collaborated on a shorter, intensive experience. The cornerstone of this three-week exposure abroad is an award-winning multi-disciplinary one-week design course offered within the Mechanical Engineering Department at TUD. This one-week TUD design

course, led by one of the authors, has recently been expanded to involve nearly all of the different disciplines within the TUD, thus making it a truly multidisciplinary experience. Another objective of this course was to provide an opportunity for USA engineering students sample what it would be like to study abroad, through a short experience. The premise is that this experience will encourage students to seriously pursue longer term studies abroad, who might not have otherwise considered overseas educational opportunities. The student participants (both German and American) in last year's, and this coming summer's course, will be tracked longitudinally for study abroad experiences, while contrasting this with their class peers, who did not participate.

In June 2012, six American engineering students from two engineering universities and one American professor crossed the Atlantic to take part in an intercultural experience with German first-year engineering students, faculty, industry, and history. The participating students included 5 Mechanical Engineering students and 1 Materials Engineering student. Their approximate three week stay was well-received and developed into a rich intercultural experience, not only for the American students, but also the German student team members.

Students arrived on a Sunday and settled into youth hostel accommodations. The next morning the design project was introduced to both German and American students. Teams were formed and each group spent the entire week working to develop a solution to the design problem. It should be noted that the American student's spring semester was already over, but the German student's summer semester was still in session, requiring the German engineering students to basically take a week away from their lecture course work. At the end of the week, each team presented their solution to the rest of the class members and a team of industrial and academic judges.

During the second week, the American students and selected German students were given guided tours of the ACHEMA 2012 exhibition in Frankfurt, Germany. Access was generously provided by the DECHEMA organization. At the end of the week, students traveled to München to tour the BMW world headquarters.

The final week included industrial tours of Audi in Ingolstadt and the former Hoechst site near Frankfurt. During the weekends, interspersed throughout the three weeks, and during some of the evenings, the American students were exposed to the cultural and historical side of Germany.

Design Project

For more than a decade the Mechanical Engineering Department at the TUD has held a week long introductory freshman design project. At times, only mechanical engineering (ME) students participated. At other times multidisciplinary teams, including students studying chemistry, biology, social science, and political science, were assigned to solve the problem. This course provided the freshman German Mechanical Engineers with an exposure to the concept of engineering design, and sometimes the necessity to work with other disciplines. Example projects included: "Heavy Transport with a Flexible Airship Transportation System"; "Construction of a Modular Coffee Machine System for Restaurants of Various Sizes"; Design of a Very Large Bar-B-Que Grill (the winning design was actually constructed and used

successfully); “The Use of Water Absorption on Zeolites for Cooling”; “An Automatic Hair Cleaning Apparatus”; “Continuous Preparation of French Fries”; and “An Un-Manned System for Destruction of Illegal Poppy Plants”.

Based on the successful experiences, the idea was developed to create a transatlantic course that would expose American engineering students to the differences in the approach to a process/product design. An open-ended design task was crafted and titled: “Design a Process and a Product that Makes Use of the Leftover Forest Biomass from Logging Operations.” This project was written into a problem statement that provided sufficient background information to constrain it to a 1-week timeframe, while remaining open-ended in nature.

The project course began with an interactive presentation of the problem background and the specific project statement. During the entire week long course, English was the language of instruction and work. While this was a necessity for all of the American students, it was excellent practice for technical language skills of the German students. The six American students were then teamed up with approximately 30 German first-year students; forming teams of 12 students with two Americans on each team. The teams were then released and taken to separate dedicated rooms, which they would use full-time for their project design work over the next 5 days. Student teams were closely supervised by a tutor from the TUD Mechanical Engineering department for technical assistance (to keep the teams on task, provide basic guidance, and keep each team on a path that would allow completion within the 1 week timeframe) and issues and a TUD graduate student from the Psychology Department for team collaboration coaching and issues. The atmosphere in the team mimicked the German way of conducting engineering design and teamwork. The engineering tutors and faculty coached the team on the German design technique, pointing out differences between the typical German and American design processes. German engineering design is characterized by a very structured approach, first analyzing a problem on a functional level. After having identified the functions of the new design, principles from physics and chemistry are identified that might serve to fulfill the functions. Always a variety of solutions should be suggested. A meticulous evaluation of the variants will identify the physical and chemical effects that seem to be best suited for the subsequent design on the construction level. Again, several design proposals are required and the best one will be selected after a careful evaluation. The German students learned from the American students that besides design there is also a time-to-market principle that governs commercial success dramatically.

At midweek, short (15-20 minute) meetings between each team and the German and American supervising professors were arranged. During their meeting time, each team was allowed to have three team representatives ask technical questions of the “experts”. The teams were expected to have a well prepared set of questions and the meeting times were held to a rigid schedule. It was

found that prior to the meetings, most teams were still exploring broad concept solutions, but afterwards they refined their work to focus on one or two solution paths.

Each team was given the task of preparing a 20 – 25 minute slide presentation in English of their final process. Three of the team members were chosen by the team to present their solution to the entire class. Only one of the American students was allowed to be on the presentation team. A panel of judges, consisting of engineering professors and industrial engineers, was also in the audience. After one week of hard work, the student teams were able to present an array of surprising solutions, and a winning team was identified. The winning team was presented an award of a chance to race on the Hemsbach Superkart track, where Sebastian Vettel, the current world Formula 1 champion, learned racing. The week concluded with catered sandwiches and a time for teams, tutors, industrial engineers, and faculty to mingle and reflect on the past week.

The American engineering education experiences at both Virgina Tech and SDSMT are evaluated by ABET. The German design project course experience dovetails nicely with a number of the ABET a-k outcomes. While the TUD Mechanical Engineering Department is not subject to ABET (they have their own accreditation procedures through the Bologna Process), the education of engineers on both continents have similar outcomes. In both the German education system, and in particular this Introduction to German Engineering course, the ABET a-k outcomes that were touched on include demonstrating:

a) the ability to apply math, science and engineering principles;
c) the ability to design a system or process to meet a desired goal;
d) the ability to function on multidisciplinary teams;
e) the ability to identify, formulate, and solve an engineering problem;
f) understanding of professional and ethical responsibility;
g) the ability to communicate effectively;
h) the understanding of the impact of engineering solutions in a global and societal context;
i) the need for an ability to engage in life-long learning;
j) knowledge of contemporary issues;
k) the ability to use techniques, skills, and modern engineering tools for engineering practice.

Industrial Exposure

Week two began with a train and subway ride to the Frankfurt Messe (fairgrounds), where the triennial ACHEMA exhibition was occurring. ACHEMA is arguably the world's largest exhibition of equipment for the chemical and process industries; including exhibits of analytical and laboratory equipment and components, process technology and equipment, instrumentation, automation and control techniques, environmental technology, materials technology and testing,

biotechnology equipment, and pharmaceutical equipment and technology. Approximately 167,000 people participated, viewing more than 3700 exhibitions from 56 countries.

The American students, accompanied by some of their German team members and tutors, visited ACHEMA for three days. During this time they were given guided instructional tours by the professors and special detailed guided presentations from a number of exhibitors, such as Siemens, Sulzer, Lurgi, and others. Many exhibitors create near-full sized examples of process equipment including absorption and distillation columns, heat exchangers, filters, pumps, liquid-liquid mixer-settlers, fermenters, or sterilizers. Within the acres of the Frankfurt Messe, students were able to view and touch state-of-the-art industrial equipment constructed of a variety of material types, common to industry. Much of the equipment they have been, or will be, learning about over the course of their academic studies was on display. Clearly, three days was not sufficient time to visit the entire ACHEMA exhibit. However, students commented that they learned a lot and appreciated the opportunity to see actual equipment that they had only seen in pictures previously, or not at all.

Three other industrial tours were organized by the TUD. These included two automobile manufacturing facilities and one large scale chemical processing and manufacturing site. The two automobile factories were BMW in München and Audi in Ingolstadt. At BMW, students

were introduced to the virtual world of luxury car design in the München R&D computer automatic virtual environment (CAVE). Next, a guided tour through the factory floor followed the creation of a new BMW from stacks of sheet metal to the final function test on rollers, just prior to shipping. Beginning week three, the Audi factory tour was similar, yet astonishingly, quite different. One of the significant differences was that the BMW facility is constrained by the city of München and could only expand the factory assembly line vertically. Whereas, students discovered that Audi has a nearly 2 km long single level factory assembly line. At both facilities the students observed the integration of automation and hand assembly of a modern factory, the role materials science and engineering takes part in manufacturing, and how just-in-time assembly functions to produce custom-built vehicles. Of course every student was hoping for “samples” at the end of each tour, but that will likely have to wait until graduation and their first paycheck.

The last tour during week three was hosted by Infraserv, the holding company into which Hoechst AG was spun off and converted. InfraServe now is the operator of the Höchst Industrial Park, which once was the site of largest chemical company in the world. The facility is a modern profitable production site for many small- and medium-sized companies. The tour began with a brief history of the Hoechst chemical company, followed by a visit to the technical administration building; designed by famed German architect Peter Behrens, complete with a functioning Paternoster (continuous elevator). Driving through the site with an Infraserv guide (a former Hoechst employee) the students were able to learn and see how the equipment they viewed at ACHEMA can be assembled into numerous chemical processes to manufacture intermediate and fine chemicals and pharmaceuticals for use world-wide.

By exposing students to process design first, followed by industrial tours, they were able to begin to make connections to what they are studying and how it ties into manufacturing.

Cultural Exposure

One of the goals of the 3 week course was an intensive immersion for the students into the German culture, the German education system, and German industry. For all but one of the American students, this was their first time visiting Germany. And likewise only one student had studied any German language. Thus, as with visiting any foreign country with a different language, the lack of knowledge of the native language is an immediate "cultural" shock. Of course most German people are able to speak excellent English and do so with a friendly smile.

Through integration of both German and American students into teams, each was able to learn about the similarities and differences in their educational institutions and engineering curriculum. Even in the short time frame of the design course many friendships and connections between the students developed. The German team members were gracious hosts; frequently inviting the American students to after-hour events and gatherings. The UEFA Euro Cup 2012 soccer tournament had just started when the students arrived from America. Public viewing, and the inevitable fan enthusiasm, was a definite high point for the students, who went with their German teammates.

The American students were exposed to the excellent public transportation system, the German autobahn, stores, restaurants, and the fact that stores are not always open, like in America. They learned that driving and parking spaces in the USA is something all Americans take for granted. Also, that a 12 passenger van (called a bus in Germany) will not fit into a 2 m parking garage, thus, requiring a lot more walking.

During the weekends students were taken on guided tours to visit cultural sites. The first weekend included visiting German historical sites, such as a castle that has been owned by the same family for over 800 years and the site on the river Rhein were General Blücher walked across on New Year's night (1813-1814) in pursuit of Napoleon. Interestingly, the students also visited the Blücher company in ACHEMA, which is still owned by the same family Blücher. The first weekend also included a visit to the foundational remains of a Roman bath and troop fort, located on a part of the old Roman Limes, (circa 100 AD; border marking the boundaries of the Roman Empire) in the Odenwald near Darmstadt.

The second weekend was devoted to visiting sights around the city of München. The Nazi concentration camp located in Dachau was the first stop. This site has been preserved as a reminder of the past, which can never be repeated by any country. This remarkable site triggered many insightful questions about the societal responsibility of engineers in non-democratic environments.

Students also learned about the many technological contributions by German engineers and scientists through a visit to the Deutsches Museum (a German national museum, akin to the American Smithsonian).

Outcomes and Lessons learned

The three week time frame allowed the USA students the chance for an intense immersion into German education, engineering, and culture. In this short time the American students learned: the differences in the German and American university system; the similarities and differences of the engineering curriculum; how the German design process differs from the USA; that there are many global issues facing engineers; there is a rich history of technology development in Germany; and that the Euro Cup isn't a beverage cup at all. Even in this short time, many friendships and connections developed between the students from both continents.

The assessment of the course, by both the American and German students, has been extremely positive, and it is therefore likely that it will be repeated in future years. Updated information from the 2013 offering of this course will be reported in the June oral presentation. Students considering studying abroad, if even for a short three-week period should be encouraged to learn a little of the local language. While English is the predominate technical language in the world, one can miss the beauty and richness of reading or learning about something in the native language. Overall this intensive immersion into overseas engineering education and industrial manufacturing has been successful in exposing American engineering students to study abroad. Many of the students are already planning for longer experiences abroad.