AC 2012-5255: LESSONS LEARNED WITH TRANSATLANTIC UNDERGRADUATE ENGINEERING DUAL DEGREE PROGRAM

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Lessons Learned with Transatlantic Undergraduate Engineering Dual Degree Program

Abstract

The departments of mechanical engineering at Virginia Tech (USA) and Technische Universität Darmstadt (Germany) have developed an education abroad program with a full year of engineering coursework abroad in a foreign language, culminating with the students simultaneously earning two bachelor of science degrees in the field of mechanical engineering; one from each university. This program has been steadily growing since the first students graduated in 2009, and 35-45 students are expected to spend their 2013-2014 senior year abroad. The program has been designed to be near cost-neutral for the students so as to not necessitate scholarships or subsidizes. The US students can commence learning German as late as their second semester junior year without adding time to graduation. This paper discusses lessons learned while developing and evolving this dual degree program. In particular, it notes the importance of curricular redesign for conforming to the Bologna process so as to enable international dual degree compatibility.

Introduction

The engineering economy is growing increasingly global. Future engineers can expect to routinely be called upon to work effectively with colleagues abroad that define and approach problems differently from how they do. Yet, only 1.3% of US undergraduate students have a credit-bearing education abroad experience in a given year\(^1,2\), and most of these students earn these credits during a brief excursion abroad while guided by a US professor.

Critics of such short-term projects suspect that they do not amount to much more than academic tourism, in part because the students do not immerse into the local environment but remain segregated with their fellow travelers from home. Advocates argue that these excursions remain important because they introduce the students to the concept of a world beyond our borders, and that this initial experience will stimulate subsequent more substantial education abroad exposure. This latter argument is usually based on singular anecdotal evidence, but a casual examination of education abroad data does not support such claims. For instance, students at Virginia Tech (enrollment 30,000+) annually complete more than 900 short-term excursions abroad but less than 300 semesters abroad\(^3\). There is no data on the fraction of these short-term excursions that were followed by a semester abroad experience.

Short-term excursions abroad can be designed to add value and deliver a transformative effect. Fry and Paige, surveying more than 6000 students from 22 US colleges, universities, and education abroad providers over a period of nearly five decades, maintain that the key is to ensure that the experience abroad has a strong academic grounding\(^4\). Cobert and Bøhn\(^5\) reduce this inherent variability by quantifying the relative transformation for US mechanical
engineering students going to Germany for a summer research internship in English, versus US mechanical engineers going to the same location for two semesters of engineering coursework in German. Their benchmark population is US mechanical engineering students engaged in summer research internships in the US: Working abroad one summer in Germany is sufficient to significantly grow the awareness of differences in US and German cultural images, and the awareness of US cultural tendencies. Extending this experience to a year does not measurably increase this growth. The summer abroad significantly increases the factual knowledge of Germany and the awareness of German cultural tendencies, and extending this experience to a year significantly continues this growth. The summer abroad does not measurably impact the factual knowledge of the US, but extending the experience abroad to a full year does significantly increases this knowledge. The factual knowledge of Germany for students that spent a year in Germany is approximately equal to the factual knowledge of the US for students that have never left the US. This demonstrates the transformational value of substantial education abroad programs.

A few progressive universities such as Purdue University and the University of Rhode Island enable their engineering students to spend two semesters abroad: one semester of coursework using a foreign language, and one semester of industry internship.

Within the University of Rhode Island (URI) International Engineering Program (IEP), students can pursue a double major, earning both a BA in a foreign language and a BS in an engineering discipline. The BA degree adds one year of study. A popular combination is a BA in German (30 semester credit hours) with a BS in Mechanical Engineering (122 semester credit hours, including 3 semester credit hours of free electives). In this program, the students learn foreign language together with their engineering courses during their first three years. They then go abroad for their entire fourth year. This year consists of one semester of foreign language, culture, and engineering courses, followed by an industry internship abroad. The students then return to URI for their fifth and final year of engineering courses.

Within the Purdue University Global Engineering Alliance for Research and Education (GEARE) program, students complete 12 semester credit hours of foreign language over five semesters before spending a semester and a summer abroad just prior to their senior year. Hence the students are able to complete their BS program in 8 semesters without adding time to graduation. A popular combination is to visit Germany as part of a BS in Mechanical Engineering (128 semester credit hours, including 3 semester credit hours of free electives). Where suitable, such as in Germany, the students complete their course work abroad in the local language. In other countries where it takes significantly longer time to achieve the same level of language proficiency, such as in China, the coursework abroad is conducted in English.

The departments of mechanical engineering at Virginia Tech (VT) (USA) and Technische Universität Darmstadt (TUD) (Germany) have taken this concept of full immersion one step further with a full year of engineering coursework abroad in a foreign language, culminating with the students simultaneously earning two bachelor of science degrees in the field of mechanical engineering; one from each university. In this dual degree program, the students
complete all the VT (130 semester credit hours with no free electives) and TUD course requirements (180 CP ECTS with no free electives). The German students complete all these requirements in four semesters at TUD followed by two semesters and two summer sessions at VT. The US students do the same in six semesters at VT followed by two semesters at TUD. The VT Bachelor of Science in the field of Mechanical Engineering (BSME) degree program and the TUD Bachelor of Science in the field of Mechanical and Process Engineering (BSMPE) degree program were accredited with these dual degree program variations by ABET and ZEvA, respectively, in 2008.

While most German engineering students are sufficiently proficient in English to study in the US, the same cannot be said of US students looking to study in Germany. Only 2.5% of US high school students study German, and, according to a 2008 internal study of VT first-year students, approximately 60% of these must start over. The dual BSME degree curriculum and course offering was therefore designed from the outset to enable the US students to acquire all the necessary German language skills prior to taking engineering courses at TUD in German\textsuperscript{10,11}.

The VT-TUD dual BSME degree program has been growing fast since the first students graduated in 2009, and approximately 35-45 students are expected to spend their 2013-2014 senior year abroad. Given the significant language acquisition effort, the recruitment of US participants drives the program growth. Thus far recruitment has been limited to junior and senior high school students that visit the annual Virginia Tech College of Engineering open house, VT freshmen general engineering students looking to choose a major, and VT sophomore students taking their first mechanical engineering course. At each of these three opportunities, the students are exposed to a 5-10 minute presentation on the VT-TUD dual BSME degree program. All subsequent recruitment is by e-mail reminders once per semester. The US students must have a 3.0 in-major or overall grade point average (GPA) on a 4.0 scale, thus making the program available to approximately 70% of VT BSME students (VT general engineering students must have a 2.5 GPA to transfer into mechanical engineering after their freshmen year). It is interesting to note that as these high school students become mechanical engineering sophomores and juniors, an increasingly larger number of students claim that they specifically chose Virginia Tech and mechanical engineering because of this program. We are also increasingly seeing that these students are influencing their friends to join this program, and we have not yet seen any indication that this growing interest is leveling off. Indeed, if we achieve a participation rate similar to that at URI, TUD will rank as a top-10 producer of BSME degrees in the US!

We believe the success and growth of this program is largely due to two factors: First, we are delivering a quality program with tangible credentials. The students become bilingual and they graduate with both a US and a German BSME degree as credentials. Second, the program is near cost-neutral to the students, and the program does not require scholarships or subsidies for it to operate and grow. For both the German and US students, the added cost of spending the BSME senior year abroad instead of at home is approximately US$3,400 — which includes the cost of two transatlantic round-trip tickets!
The standard study plans for US and German students are shown in Appendices A and B, respectively. In the case of the US student, it assumes no advance placement credits, transfer credits, or prior German language instruction. It also assumes that the student waits until his or her 6th semester to start learning German, which is that last opportunity to do so. In this case, the student must pay for summer school tuition, which is clearly not a cost-neutral situation. However, this summer tuition, living expenses, and lost income, can be avoided all together if the student begins learning German their freshman year—or sophomore year following three years of high school German. And increasingly we are seeing that the students are taking such steps to reduce their cost of education.

While we are excited with the success of this program and with how quickly it is growing in size, we believe that now is a good time to take assessment and analyze why this particular effort succeeded while a parallel effort with another university partner failed. This paper will therefore next discuss lessons learned while developing and evolving this dual degree program. In particular, we will note the importance of curricular redesign for conforming to the Bologna process so as to enable international dual degree compatibility.

**The Bologna Process**

The emergence of the European Union (EU), from its 1957 birth as a customs union known as the European Economic Community (EEC), through its formal establishment in 1993, has been paralleled by an increasing desire to facilitate not only the uninhibited movement of goods within the union, but also the mobility of its workforce. While people were free to move between the western European countries, the barriers of academic credentials remained a problem. Each country had its own educational system and traditions, and their equivalencies were poorly understood across Europe. Hence jobseekers were challenged to demonstrate their qualifications when seeking employment in another European country. An early effort to overcome this problem was the development of the European Engineer title. Each national engineering society was responsible for issuing this title based on a combination of education from that country and certain years of practice—very similar to the concept of an international driver’s license. However, this only covered engineering, and it has never been widely accepted even there.

Discussions on how to harmonize European higher education accelerated in 1997 with a French instance that Europe move towards the British system of a three-year technical (no general education) bachelors degree followed by a two-year technical masters degree. This concept stuck, and on June 19, 1999 the ministers in charge of higher education in 29 European countries signed the Bologna Declaration that started the ongoing process to harmonize European higher education. Every few years since, these ministries, now spanning 47 countries, have committed their universities to a steadily growing set of directives and standards to facilitate increased harmonization. The overarching objective is to facilitate student mobility and subsequent worker mobility across Europe.
The EU-US ATLANTIS Program

Now that Europe had supposedly conformed to a standard two-cycle Bachelors-Masters educational system, could this student mobility be extended to the US? Assuming that this was now possible, the US Department of Education and the European Commission established the EU-US ATLANTIS grant program. The objective was for sets of one US and two European universities to establish pairs of transatlantic dual degree programs. One of the first grants went to Virginia Tech, Technische Universität Darmstadt, and Kungliga Tekniska högskolan (KTH) in Sweden in 2006. The plan was to establish two sets of dual BSME degree programs: a VT ⇨ TUD pair and a VT ⇨ KTH pair, in which the students would also spend a semester at the other European university taking courses that included the local language and culture. We were able to implement the VT ⇨ TUD pair, and we have had 16 students graduate on time— including with a semester of engineering, Swedish language, and Swedish culture courses at KTH. However, the KTH semester was not financially sustainable without extensive scholarship subsidy to the students (i.e., US$18,000 per student), and we were never able to identify a plausible VT ⇨ KTH dual BSME degree solution.

The KTH semester was not financially sustainable because the US students made no academic progress towards their VT BSME or TUD BSMPE degree program while at KTH. That is, the students had to shoulder the cost of tuition, cost of living, travel, and lost income, while the course credits that were available could not be applied towards their degrees. The primary reason for this was the limited availability of courses at KTH that our students could take. Most of the courses during the KTH fall and spring semesters are in Swedish, and there is no capacity at VT to teach the students Swedish prior to arriving at KTH. Hence, the US students visited KTH during the summer for beginning Swedish and undergraduate research, but these credits were already satisfied by the German language courses at VT and several required courses at TUD that transfer as technical electives to VT. Hence, the US students could not make use of their credits earned at KTH.

Lack of Compliance with the Bologna Process

While the ministers for higher education across Europe have endorsed the Bologna process and committed their universities to comply with its directives and standards within set deadlines, it is clear that universities across Europe more often than not are resisting these changes. Resistive responses, partial compliance, relabeling of existing programs with new terms without making changes, and waiting until the last possible deadline in hopes that the directive will be reversed, are the norm. As we discovered, KTH fell into this category: Like the old German Diplom Ingenieur degree program, the Swedish Civilingenjör degree program is a five-year program. In their English literature, KTH simply identified the first three years as the BS program and the last two years as the MS program, and thus declared that they were in compliance with the Bologna process. Their Swedish literature did not change, and they continued to issue Civilingenjör degrees to their students. After all, they could not imagine the need to issue a BS degree after three years since all their students would stay for five. In particular, they had no intention to enable students to exit after three years with a BS degree, though this is a specific
expectation of the Bologna process, namely, that the BS degree is the first professional degree, and that students should be able to move to another university for their MS degree if they so desire.

Even if KTH were to start issuing BS degrees after three years of study, they would have found that their program was incomplete as a first professional degree. The reason is that the inherent structure of the German Diplom Ingenieur degree program and the Swedish Civilingenjör degree program is a two-year fundamentals program followed by a three-year upper level program, and with the capstone experience only taking place towards the end of this latter program.

KTH has since made a transition to the Bologna 3+2 structure, and the third year now finishes with a capstone experience. Their students now have the option to apply for a Kandidatexamen degree upon completion of their third year, thus creating the Bologna exit point after three years. However, KTH still does not use the term “bachelor” in their Swedish literature.

The residuals from the old 2+3 structure persist in the KTH curriculum. Under the old structure, the students would enroll in one of 12 tracks starting in their third year. Thus students coming from abroad for the last two years had to have appropriate specialty courses as prerequisites. This continues to be the case, and the students must choose their elective in their third year depending on which track they want to pursue in their fourth and fifth years.

In their transition to the Bologna 3+2 structure, KTH has also recently revised their first and second year curriculum significantly. The plausibility for it to support a VT ⇅ KTH dual BSME degree solution without adding significant time to graduation has not been reevaluated in detail. However, a preliminary review of the new KTH curriculum indicates that there is now a potential for a KTH ⇆ VT dual degree program, starting two years at KTH, followed by a VT Summer II session (6 weeks starting in early-July), followed by a VT Fall and Spring semester, and then followed by a VT Summer I session (6 weeks ending in late-June). Similarly, the new curriculum appear to have a potential for VT ⇆ KTH dual degree program as well without adding time to graduation. The basis for these positive assessments is that the fundamentals of engineering is completed largely during the first two years, and the third year consists exclusively of courses that have a direct and equally-weighted counterpart at VT.

This last point is important when considering a dual degree program. One challenge with KTH, relative to TUD, has been the large number of credits that are associated with many KTH courses. For instance, if a student is missing 30% of an 11 semester credit hour course (22.5 CP ECTS), then this cannot be ignored—but at the same time, this represents a significant amount of repeat material for the student, which is not desirable either. At TUD and VT, this is less of an issue since their course modules are generally much smaller, so there is less material missed and there is less material that needs to be repeated.

This only leaves the issue of Swedish language instruction for the US students. This could be solved by having the US student spend the three months between their junior and senior year attending intense Swedish-as-a-second-language training in Stockholm. This would be non-
curricular and the tuition fee would be nominal. Additional Swedish language training could be taken at KTH during the Fall semester as part of the VT → KTH dual degree curriculum (i.e., free elective for the KTH BSME degree and a technical elective for the VT BSME degree).

**Curricular Redesign at TUD**

The above example illustrates a slow conformance to the Bologna process. The mechanical engineering program at TUD, however, approached the same situation very differently\(^\text{12}\). By the late 1990’s, the TUD mechanical engineering faculty had come to the realization that a significant overhaul of their curriculum was needed. It was time to replace drafting tables with CAD, it was time to integrate electrical engineering into machine elements in the form of mechatronics, and it was time to introduce teamwork into the curriculum. The old German Diplom Ingenieur degree program was in need of renovation. As was the norm across Germany, this five-year program started with a two-year of science fundamentals taught by other departments. Students were disengaged and could not see how this material was related to their future careers, and the dropout rate routinely exceeded 50% during that phase. If they survived these first two years, they faced a sequence of three annual individual efforts: a 200+ hour design paper in the third year, a 200+ hour research paper in the fourth year, and a three-month Diplom thesis at the end of the fifth year. And there was no opportunity for experiencing teamwork or project management in the curriculum.

The faculty wanted to change all this, and when the Bologna process arrived in 1999, the migration to from a 2+3 to a 3+2 program made it all come together. Here are some of the many changes that were made:

- The BS and MS degree programs were each assigned a significant team design project midway through the program and an individual thesis as a capstone at the end.
- Student advising was shifted from doctoral candidates, whose main responsibility is research, to an office of advising professionals. These professionals also assumed responsibilities for record keeping and program assessments.
- The courses were assigned credits to signify their workload, and learning outcomes were documented for every course.
- Introductory science and engineering courses were still taught by faculty in those fields, but the material was specified and synchronized across the curriculum specifically for mechanical engineering.
- Approximately one month into the first semester, all first-year classes are now cancelled for one week (remember, mechanical engineering now “owns” these courses). The first-year students are organized into 10-person teams and are given this one week to design and prototype a solution to an engineering problem. Each team is assigned to mechanical engineering graduate student as a technical coach and a psychology graduate student as a...
teamwork coach. The entire mechanical engineering faculty then holds open office hours for three hours the first Wednesday morning to serve as consultants. The students prototype and present their work as a team.

- All 800+ applicants to the BSME program are interviewed by a faculty member as a two-way selection process: for the candidate to discover if mechanical engineering is the right field for him or her; and for the faculty member to determine if the candidate is ready for mechanical engineering.

The outcome of these changes has been a dramatically reduced dropout rate during the first few years. Students became dramatically more motivated and focused, and they developed a robust understanding of how the curriculum comes together to support their future profession.

German society, however, does not take kindly to change, especially a change to their revered Diplom Ingenieur degree program, no matter what the Bologna process dictates. Hence, from a strategic point of view, this major curricular overhaul was designed from the ground up as a Bologna 3+2 program, but was released as a minor adjustment to the existing five-year Diplom Ingenieur degree program (Figure 1, left-hand side), and was offered as such for the following

Figure 1. The radically revised 3-year BSMPE + 2-year MSMPE degree program combination (right) was initially presented as a minor adjustment to the existing 5-year Diplom Ingenieur degree program (left).
five years so as to not ruffle feathers. The reality, however, was that the TUD mechanical engineering faculty had thus in fact made the switch to the Bologna process—and subsequently they were the first in Germany to retire the five-year Diplom Ingenieur degree program (Figure 1, right-hand side).

**Observations**

Research shows that long-term, full immersion education abroad experiences have a measurably stronger impact on participants than short-term excursions. Yet a declining number (-640) and share (3.9%) of US students study abroad for a year¹. The year-long and growing programs abroad in engineering at URI, Purdue, and VT demonstrate that it is possible to have a significant share of US engineering students study engineering abroad for a year using the local language.

The Bologna process has been an important enabler for transfer of academic credit in transatlantic student exchanges, and even the establishment of transatlantic dual degree programs. The challenge thus far has been the at times strong resistance among European universities to conform to Bologna directives and standards. As this resistance fades and the conformity to Bologna increases, one should expect an ongoing increase in transatlantic student mobility.

**Conclusions**

The Bologna process has had a major impact on student and worker mobility across Europe. Degree program can now be compared. The process has also aligned the European educational systems to make them more compatible with the US educational system, enabling US students to attend European universities with similar ease that they can attend other US universities; and in reverse for the European students. The extreme demonstration of this new transatlantic compatibility is the successful implementation of a VT ⇔ TUD dual BSME degree program.

**Acknowledgements**

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References


Appendix A

Class of 2013 standard course sequence as seen by the students in the VT BSME → TUD BSMPE dual degree program; the items in yellow highlight the German language training:

**VT Freshman year, Fall semester (15 credits)**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
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<tbody>
<tr>
<td>ENGL 1105</td>
<td>Freshman English I</td>
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<tr>
<td>MATH 1205</td>
<td>Calculus I</td>
<td>3</td>
</tr>
<tr>
<td>MATH 1114</td>
<td>Elementary Linear Algebra</td>
<td>2</td>
</tr>
<tr>
<td>ENGE 1024</td>
<td>Engineering Exploration</td>
<td>2</td>
</tr>
<tr>
<td>CHEM 1045</td>
<td>General Chemistry Laboratory</td>
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</tr>
<tr>
<td>CHEM 1035</td>
<td>General Chemistry</td>
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<tr>
<td>AREA 6 – Creativity and Aesthetic Experience</td>
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**VT Freshman year, Spring semester (17 credits)**

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<td>PHYS 2305</td>
<td>Foundations of Physics I</td>
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</tr>
<tr>
<td>ENGL 1106</td>
<td>Freshman English II</td>
<td>3</td>
</tr>
<tr>
<td>MATH 1224</td>
<td>Vector Geometry</td>
<td>2</td>
</tr>
<tr>
<td>MATH 1206</td>
<td>Calculus II</td>
<td>3</td>
</tr>
<tr>
<td>ENGE 1114</td>
<td>Exploring Engineering Design</td>
<td>2</td>
</tr>
<tr>
<td>AREA 2 – Ideas, Cultural Traditions, and Values</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

**VT Sophomore year, Fall semester (16 credits)**

<table>
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<tr>
<td>PHYS 2306</td>
<td>Foundations of Physics II</td>
<td>4</td>
</tr>
<tr>
<td>MATH 2224</td>
<td>Multivariable Calculus</td>
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</tr>
<tr>
<td>ESM 2104</td>
<td>Statics</td>
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</tr>
<tr>
<td>ENGE 2314</td>
<td>Engineering Problem Solving with C++</td>
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</tr>
<tr>
<td>ISE 2214</td>
<td>Manufacturing Processes Laboratory</td>
<td>1</td>
</tr>
<tr>
<td>ME 2024</td>
<td>Introduction to Engineering Design &amp; Economics</td>
<td>3</td>
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**VT Sophomore year, Spring semester (16 credits)**

<table>
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<th>Course Code</th>
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<td>Applied Electrical Theory</td>
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<tr>
<td>STAT 3704</td>
<td>Statistics for Engineering Applications</td>
<td>2</td>
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<tr>
<td>ESM 2304</td>
<td>Dynamics</td>
<td>3</td>
</tr>
<tr>
<td>ESM 2204</td>
<td>Mechanics of Deformable Bodies</td>
<td>3</td>
</tr>
<tr>
<td>ME 2124</td>
<td>Introduction to Thermal &amp; Fluid Engineering</td>
<td>2</td>
</tr>
<tr>
<td>MATH 2214</td>
<td>Introduction to Differential Equations</td>
<td>3</td>
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**VT Junior year, Fall semester (18 credits)**

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<td>Industrial Electronics</td>
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<td>ME 3514</td>
<td>System Dynamics</td>
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<tr>
<td>ME 3614</td>
<td>Mechanical Design I</td>
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<td>ME 3404</td>
<td>Fluid Mechanics</td>
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<td>ME 3124</td>
<td>Thermodynamics</td>
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<tr>
<td>STS 2054</td>
<td>Engineering Cultures (AREA 2, 7)</td>
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### VT Junior year, Spring semester (18 credits)

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<td>ME 4005</td>
<td>Mechanical Engineering Laboratory I</td>
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<tr>
<td>ME 3304</td>
<td>Heat &amp; Mass Transfer</td>
<td>3</td>
</tr>
<tr>
<td>MSE 2034</td>
<td>Elements of Materials Engineering</td>
<td>3</td>
</tr>
<tr>
<td>GER 1114</td>
<td>Accelerated Elementary German</td>
<td>6</td>
</tr>
<tr>
<td>AREA 3</td>
<td>Society and Human Behavior</td>
<td>3</td>
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(Equivalent to GER 1105-1106 course sequence)

### VT Summer I Session (6 weeks)

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<tr>
<th>Course Code</th>
<th>Course Title</th>
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<tbody>
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<td>GER 2114</td>
<td>Accelerated Intermediate German</td>
<td>6</td>
</tr>
</tbody>
</table>

(Equivalent to GER 2105-2106 course sequence)

### VT Summer II Session at TUD (6 weeks)

Entry: “B+” or better in GER 2106 or GER 2114

German language bridge-course for VT students going to TUD

This summer session is optional for students with a “B” or better in GER 3106

### Early-Fall session at TUD (6 weeks)

*First day:* Take German language placement exam

German as a Second Language (standard course depending on placement results)

*Last day:* Take UNIcert German language exam

### TUD Senior year, Winter semester (28 CP)

<table>
<thead>
<tr>
<th>Course Title</th>
<th>Credits</th>
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</tr>
<tr>
<td>Systemtheorie und Regelungstechnik</td>
<td>6</td>
</tr>
<tr>
<td>Tutorium Pneumatik I</td>
<td>4</td>
</tr>
<tr>
<td>Aerodynamik I (6CP) or Grundlagen der Flugantriebe (8CP)</td>
<td>6-8</td>
</tr>
<tr>
<td>VT BSME / TUD BSMPE technical electives</td>
<td>6-4</td>
</tr>
</tbody>
</table>

Audit a German as a second language course

Attend weekly engineering homework session in German for VT students

### TUD Senior year, Summer semester (34 CP)

<table>
<thead>
<tr>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bachelor-Thesis</td>
<td>12</td>
</tr>
<tr>
<td>Numerische Mathematik</td>
<td>4</td>
</tr>
<tr>
<td>Numerische Berechnungsverfahren</td>
<td>4</td>
</tr>
<tr>
<td>Grundlagen der Turbosystemen und Fluidsystemen</td>
<td>8</td>
</tr>
<tr>
<td>AREA 3 – Society and Human Behavior</td>
<td>6</td>
</tr>
</tbody>
</table>

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### VT BSME degree = 130 semester credit hours (minimum 33 semester credit hours at VT)

- 99 semester credit hours (76.2%) earned at VT
- 31 semester credit hours (23.8%) transferred from TUD

### TUD BSMPE degree = 180 CP ECTS (minimum 60 CP ECTS at TUD)

- 124 CP ECTS (67.4%) transferred from VT
- 60 CP ECTS (32.6%) earned at TUD (includes 4CP ECTS free electives)
Appendix B

Class of 2013 standard course sequence as seen by the students in the TUD BSMPE → VT BSME dual degree program:

**TUD Winter Semester Year 1**
- Arbeitstechniken .................................................. 1 CP
- Einführung in den Maschinenbau ................................ 1 CP
- Grundlagen der Datenverarbeitung ............................... 4 CP
- Mathematik I für Maschinenbauer ............................... 8 CP
- Naturwissenschaften I ............................................... 4 CP
- Technische Mechanik I (Statik) .................................. 6 CP
- Technologie der Fertigungsverfahren ............................ 6 CP

**TUD Summer Semester Year 1**
- Einführung in das rechnergestützte Konstruieren ............ 4 CP
- Einführung in die Elektrotechnik ................................ 6 CP
- Naturwissenschaften II ............................................. 4 CP
- Mathematik II für Maschinenbauer ............................... 8 CP
- Technische Mechanik II (Festigkeitslehre) .................... 4 CP
- Werkstoffkunde und –prüfung .................................... 4 CP

**TUD Winter Semester Year 2**
- Naturwissenschaften III ........................................... 4 CP
- Maschinenelemente und Mechatronik I ......................... 8 CP
- Mathematik III für Maschinenbauer ............................. 4 CP
- Technische Mechanik III (Dynamik) ............................ 6 CP
- Technische Thermodynamik I .................................... 6 CP
- Werkstoff- und Bauteilfestigkeit ................................. 4 CP
- General Chemistry Laboratory .................................... 2 CP  *VT course at TUD*

**TUD Summer Semester Year 2**
- Maschinenelemente und Mechatronik II ......................... 8 CP
- Numerische Mathematik ........................................... 4 CP
- Physikalisches Grundpraktikum für Maschinenbauer ........ 2 CP
- Product Design Project ............................................. 4 CP
- Technische Strömungslehre ........................................ 6 CP
- Technische Thermodynamik II ................................... 2 CP
VT Fall Semester (18 credits)
ENGL 1105  Freshman English I ........................................3 credits
ME 4006  Mechanical Engineering Laboratory II .......3 credits
ME 4015  Engineering Design and Project I ............3 credits
ME 4124  Fluid Machinery – Heat Transfer Design ....3 credits
ME 4504  Dynamic Systems – Controls ....................3 credits
AREA 3 – Society and Human Behavior ..................3 credits

Distance learning delivered from TUD; exam taken during VT Spring semester at VT
Messtechnik für Maschinenbauer .................................. 4 CP

VT Spring Semester (19 credits)
ENGL 1106  Freshman English II ........................................3 credits
ME 3304  Heat and Mass Transfer ...........................3 credits
ME 3504  Dynamic Systems – Vibrations ................3 credits
ME 4016  Engineering Design and Project II ............3 credits
AOE 4404  Applied Numerical Methods ..................3 credits
or
AOE 4024  Introduction to Finite Elements ..............3 credits
Technical Elective (see TUD BSMPE at VT list) ..........3 credits
AREA 6 – Creativity and Aesthetic Experience ..........1 credit

VT Summer I Session (6 credits)
AREA 2 – Ideas, Cultural Traditions, and Values ..........3 credits
AREA 7 – Critical Issues in a Global Context ............3 credits

VT Summer I Session (6 credits)
AREA 2 – Ideas, Cultural Traditions, and Values ..........3 credits
AREA 3 – Society and Human Behavior ..................3 credits

VT BSME degree = 130 semester credit hours (minimum 33 semester credit hours at VT)
  81 semester credit hours (62.3%) transferred from TUD
  49 semester credit hours (37.7%) earned at VT

TUD BSMPE degree = 180 CP ECTS (minimum 60 CP ECTS at TUD)
  120 CP ECTS (66.7%) earned at TUD
  60 CP ECTS (33.3%) transferred from VT