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INTRODUCTION

In recent years many universities have responded to the growing insight that a technical advantage of their graduates entering the global market place is gained by collaborating across borders and cultures worldwide (Grandin/Hedderich 2009, 363). Developing a “collaborative advantage” is what will help U.S. research institutes remain a center of innovation while competing with centers emerging across the globe (Lynn/Salzman, 2006). This is true for the science and engineering side of competitiveness, as well as the linguistic and cultural competence (e.g. Alan Parkinson’s thirteen dimensions of global competence, 2009). On the science and technology side, an overview of the *National Science Board* entitled *Science and Engineering Indicators 2010* is quite telling. It reports that collaborative international research is becoming the norm and is steadily growing, as indicated by the increasing co-authorship of journal articles. The rate of international collaborations in the United States is similar to China and Japan, but lower than Europe, where EU policies and incentives push for higher inter-European collaborations (0-10f.)

Corporations are also getting the word out to the academic engineering community. What skills and experiences will today's engineering students need to develop while in school and throughout their careers to successfully compete in today's global workplace? This question is the focus for a group of corporations affiliated with the American Society for Engineering Education (ASEE) Corporate Member Council, who released an online survey aimed at enhancing the preparation, performance and employability of engineering graduates living and working in an increasingly global context. The survey is available in twelve different languages.

On the language and culture side, it is noteworthy that the Department of Education now calls foreign language education in this country a high-stakes issue. It advocates for a shift in perspective, a shift from relying on other cultures learning English, to recognizing the centrality of teaching foreign languages in our own schools and universities. In his December 8 remarks at a foreign language summit, notably convened by CIA director Leon Panetta at the University of Maryland, secretary Arne Duncan states

> *To prosper economically and to improve relations with other countries, Americans need to read, speak and understand other languages.*
>
> *It is absolutely essential for the citizens of the United States to become fluent in other languages—and schools, colleges and universities must include producing bilingual students as a central part of their mission. Nelson Mandela has said, "If you talk to a man in a language he understands, that goes to his head. If you talk to him in his own language, that goes to his heart.” (Duncan, 2010)*

It seems that our students are already beginning to take this insight to heart. Enrollment in study abroad programs has risen and the effect of globalization on study abroad patterns has become measurable. According to the *Open Doors Report on International Educational Exchange* (2009) there seems to be noted growth in the numbers of US students studying abroad, even if the percentage of engineering students is still only at 3.2 percent, and that of those US students going abroad for an entire year it still hovers at a little over 4%. Great Britain is the #1 destination, and Germany ranks after its more popular European neighbors like France, and Italy at #8. These numbers might still rise once our academic leadership recognizes that second language gain across linguistic skills is strongly correlated with longer-duration immersion programs (Davidson 2010, 6). Results like these recent data debunk the myth that language skills can somehow be absorbed abroad no matter how long

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the exposure is and point at a year-long stay as a priority if "advanced mid", "advanced high" or "superior level" language skills are the goal.

Recognizing the need to equip their graduates with the right skills to stay globally competitive, a number of universities have developed effective internationalization strategies (Berka, 2009) and various models to increase the percentage of engineering students going abroad as well as the percentage of international engineering students they are receiving. They have also developed models to train students before going abroad and to assess their learning outcomes. In many cases institutions with study or work abroad programs aimed at engineering students, whose students participate in international exchanges, internships or dual degree arrangements, use various assessment tools to measure the impact the stay abroad has had on their students. They include Georgia Institute of Technology, Massachusetts Institute of Technology, Purdue University, Worcester Polytechnic Institute, Rensselaer Polytechnic Institute, and the University of Rhode Island. Some conduct pre- and post study abroad surveys or Oral Proficiency Interviews (OPIs) to assess the gained linguistic skills, or use tools like the IDI (Intercultural Development Index) or the M-GUDS (Miville-Guzman Universality-Diversity Scale) to assess intercultural skills of the students going abroad. These institutions, in collaboration with members of the private sector, have published and distributed a "Call for Action", the "Newport Declaration," which recommends a set of strategies designed to move the globalization of engineering education forward to implement changes in U.S. Higher Education (Grandin, Hirleman, 2009).

The general trends mentioned above provide the context within which this paper is situated. It takes a closer look at an area of international graduate level education and collaboration that has not been very well researched so far: the impact of study abroad experience on graduate engineering students. First attempts at systemization have been made: In their analysis of the impact of the NSF funded IREE program, which is designed to educate a globally minded work force, colleagues from Purdue University summarize the impact of international research and collaboration as a three-partite domain, the "technical", "professional" and "global/transcultural" dimension (Chang, Atkinson, Hirleman 2009). In February 2011, NSF sponsored a workshop entitled "Investigating the International Experience in STEM Graduate Education and Beyond: An NSF Workshop to Develop a Research Agenda." The workshop was led by Maresi Nerad, Director of the Center for Innovation and Research in Graduate Education (CIRGE) at the University of Washington in Seattle who has published on the internationalization of graduate education (Nerad, 2008, 2010) and who sees the need to systematize our anecdotal evidence about the students' gains. At the workshop, Daniel Denecke from the Council of Graduate Schools (CGS), reported that in 2008, CGS received a grant from NSF to identify policies and practices that foster, or inhibit, successful international collaborations in graduate education, including informal research and formal (e.g., joint and dual) degree collaborations. As one of the biggest barriers to developing successful and strategic international collaborations in US graduate education Denecke mentions the lack of comparative and formative metrics for assessing the outcomes of international collaborations. He points out the need to develop "well-defined metrics of success and models for assessing graduate international experiences" (Denecke 2011). In addition, Darla Deardorff, who has been instrumental in developing assessment tools of intercultural competence, suggested an outcomes oriented "program logic model for international programs and initiatives" which looks at four categories to measure the long-term impact of internationalization (inputs/resources; activities/components of internationalization; outputs of internationalization; outcomes of internationalization). Using this model as a starting point for the specific assessment needs of STEM international graduate education, a workshop discussion group developed an adapted logic model which challenged STEM outcome assessment to include outcomes related to intercultural skills, knowledge of engineering cultures, technical and scientific skills, and called for longitudinal impact studies (Maresi, Blumenberg 2011, p.33). What became very clear for workshop participants, was the need to be creative, to go beyond existing approaches of assessment and to develop a tool-set which reflects the unique experience of engineering students abroad.

In Deardorff' words it is crucial to go beyond surveys and self report instruments and "to provide a more thorough picture of outcomes achievement which is difficult to obtain through any single instrument" (Deardorff 2005, 30). Her call for a multi-method assessment approach is echoed by the "mixed methods approach" consisting of a qualitative electronic survey and in-depth qualitative interviews used to determine the transformative power of study abroad (Fry, Paige et.al. 2009) which focuses on the long-term impact study abroad has on participants' lives in terms of their careers, knowledge and skill development as well as changes in values and world views. Gary Downey's emphasis on the need to include "story-telling" in engineering education to arrive at a more complete picture of what happens in students' and educators' international experiences goes even further in trying to grasp a holistic picture of outcomes. Downey portraits "personal geographies" of international educators which "contrast with survey results, summaries of structured interviews, and content analysis of texts" and succeed in making a person's "implicit knowledge" of their experience explicit (Downey, 2010, 10f).

Taking the above discussion as a frame of reference, this paper sets out to examine four concrete cases of learning outcomes of engineering graduate students enrolled in the University of Rhode Island's dual degree program with the Technical University of Braunschweig. While the International Engineering Program has done various quantitative student and alumni surveys, both short-term and longitudinal, drawing from a large student population which goes back to international exchange in 1987, it seemed more promising to choose a qualitative methodology in determining the added value of a dual degree program on the graduate level which has had a limited number of participants. Finding out what sort of learning outcomes the program offers for its students is approached by a blend between story-telling and case study, yet the paper goes beyond anecdotal evidence in determining program outcomes. It proposes the following guiding questions:

Are there any technical skills or additional research methods gained by students involved in the University of Rhode Island/Technical University of Braunschweig dual degree graduate program? To what extent does such a research intense program have an impact on broadening research perspectives and opportunities for its participants? How does such an international dual degree program, which requires students to conduct research in at least two institutions (one of them abroad) leverage the advancement of science and engineering for its participants and for the world? According to findings in cross-cultural and international education research (e.g. Bennett, Janet M. 2009; Vande Berg and Paige, Michael R., 2009), there is a clear value in the internationalization of education, of student mobility, and the development of cross-cultural as well as linguistic competence in our graduates. In this respect, a dual degree program is a great model to prepare them for the challenges of the global market place. But what can be gained by going abroad for the very research outcomes of students participating in such an international dual degree arrangement?

The National Science Foundation has addressed the challenge of remaining globally competitive by creating grant programs that foster international educational research collaboration like its PIRE, IRES, IREE and IGERT programs. One such funded initiative is the University of Rhode Island's dual masters and dual Ph.D. program with the Technical University of Braunschweig, both supported by an NSF PIRE grant, as well as by funding from the Max Kade Foundation in New York.

After two decades of ground-breaking work in the field of undergraduate International Engineering Education, the University of Rhode Island (URI) has become a pioneering institution in developing an interdisciplinary graduate dual degree program whose goal is to prepare students for global (research) careers (Grandin 2006). It received a 2.4 million NSF PIRE grant to support educational and research initiatives in collaboration with its long-standing academic and new corporate partners in Germany. Building on its existing relationship with the Technical University of Braunschweig (TUBS) in the area of microfluidics technology and its dual degree master's program in Mechanical Engineering, this new project has developed research opportunities from the undergraduate through the graduate level, culminating in a new International Ph.D. The NSF funding supports graduate students, all of whom are spending part of their programs in Germany.

Conducting research in two countries involves different approaches and equipment, including university institute research and applications in industry. All of this being accomplished in a foreign culture and language, helps to tackle grand challenges like engineering better medicines or providing a safer environment from various angles and thus adds enormous value to the outcome. The project's technical goals are focused on two applications:

- Design of a system to detect the early response to pathogen infection using a microfluidic "lab-on-a-chip."
- Use of microfluidic technology to study the generation of fluid pressures in sediments due to seismic loading and lead to a better understanding of the triggering of tsunamis.

A key element of the project is the international collaboration with scientists and students at the German partner university, which has the complementary technical infrastructure and expertise necessary to pursue this program of research. The University of Rhode Island is a leader in training engineers for the global marketplace through its renowned International Engineering Program. It has partnered with the German partner on engineering education for undergraduates for over 15 years, and has exchanged over 500 students during that period.

This international dual degree master's program was launched in 2004. The purpose of the program was to allow students of each university to acquire both a *Master of Science* degree from URI and a *Diplom* from the Technical University of Braunschweig. Starting in 2010, this model has been adapted to a master/master dual degree program due to the reform of Higher Education and the introduction of the Bachelor/Master system in Europe. This is accomplished through a formal exchange program in which students from each university will conduct program coursework and thesis/project activities at both institutions. Because of the credit transfer agreements and modified requirements established between both institutions, the students will be able to complete the work for both degrees in less time required than if pursued separately (Grandin 2009). This arrangement makes it possible for them to hone their language skills while working towards their engineering degrees. They do not need to put their degree on hold when integrating engineering with language studies, and they can fully benefit from what Davidson calls "the challenges of self-managed learning, self-conscious strategy selection, and formative self-diagnosis – all qualities they will need for life-long learning in general" (Davidson 2010, 10).

It is expected that URI students spend their first year of the Master's program at URI and the second year at TUBS. TUBS students have a choice: they can spend their first year at TU-BS and the second at URI or vice versa. Students who have earned their Bachelor's degrees at other universities must spend their first year of studies in the school where they were first admitted for the Master's program. Further, students must take graduate level courses at both universities and do research at both. A detailed addendum to the 2004 dual degree agreement is currently being finalized by both sides; various presentations and procedures documents were established to gauge the course requirements on both sides and the credit transfer in detail (Scholl, Mayer, 2011; Anagnostopoulos/Sadd et al. 2011). As an integral part of the degree requirements and the study program, the TUBS master's degree requires a minimum of 20 weeks industrial internship. For graduates of URI's International Engineering Program (IEP) this is satisfied by the IEP internship. An equivalent industrial experience of program participants may also satisfy this requirement. For a Master of Science degree URI requires a minimum of 30 credits (not counting the credits for the weekly graduate seminars) for graduation, and TUBS requires a minimum of 120 ECTS.

A joint doctoral level program followed along the same of the dual master program lines in 2008. Faculty and graduate students in the dual degree programs are supported by an NSF/PIRE grant as well as by the Max Kade Foundation. They come from a multitude of disciplines in the US: Mechanical Engineering, Chemical Engineering, Entomology, Ocean Engineering, Civil Engineering, and additional disciplines in Germany: Microtechnology, Biochemistry and Biotechnology, Computer Applications in Civil Engineering, Hydrology, Pharmaceutical Chemistry, Chemical and Thermal Process Engineering. In addition, industry partners in Germany, e.g. Bayer, Boehringer Ingelheim Microparts and Siemens, provide internships in the area of expertise.

What can be gained by this kind of international research initiative? What is the added value of the students' interdisciplinary and multi-institutional research approaches? It is helpful to look at a few of the microfluidics research areas. NSF PIRE interdisciplinary and international research in the microfluidics/lab-on-chip technology area brings together several science and engineering disciplines to tackle research problems in the area of point-of-care medicine. The key to the success of the dual degree masters' and Ph.D. is the candidates' research in multiple locations: at their home institution and abroad. This allows the *complementarity* or *synergy* of research topics and methods. Students learning outcomes benefit from a broader perspective brought into the game by an expanded faculty force, different approaches to research questions due to distinct engineering cultures, a wider range of equipment, differences in education systems which require flexibility and inquisitiveness from the candidates, and, of course, from broadening their cultural and linguistics skills. To exemplify the concept of *complementarity*, let's examine four students' research areas more closely.

Case I

The research of a dual master's degree University of Rhode Island/TU-Braunschweig candidate in biology is about the following:

> *Lyme Borreliosis, caused by the microorganism Borrelia burgdorferi, is a disease which is endemic in North America. Left untreated, it can have serious impacts on the health of infected individuals. This microorganism is transmitted most commonly through the vector Ixodes Scapularis, commonly known as the deer tick. The challenges today in diagnosing this disease are the unreliability of some testing methods and/or the inability of some patients to report contact with the most common vector of this disease, which can lead to misdiagnosis. The student researched the detection of active biomarkers as an indication of tick contact. Using blood from patients who have tested positive for Lyme Borreliosis, he was able to generate a library of antibodies which can be screened against various tick antigens. This allows for the isolation of tick-specific antibodies for characterization as diagnostic tools in reliable, cost-effective indicators of vector contact and confirmation of infection. These antibodies are also applicable to future research in the interaction of B. burgdorferi with its vector and how this relates to pathogen transmission.*

His thesis topic has evolved abroad and combines the University of Rhode Island's scientific strength in the area of epidemiology with a unique method in the area of Antibody Engineering, developed at URI's academic partner institution abroad. The thesis topic is "The production of antibodies to tick saliva borne pathogens using phage display technology."

At the University of Rhode Island, the student's mentor is renowned for his expertise in tick biology, ecology, and control. Specific research goals are among others to:

- identify factors determining human tick-borne epidemiology
- formulate novel vaccination strategies to prevent tick-transmitted infections
- develop biomolecular assays for tick-borne pathogens
- gain greater understanding of tick immune mechanisms.

At TU Braunschweig, the student has been working in the Biotechnology Institute which provides the exact *design complement* to the University of Rhode Island "tick" science research by focusing on Antibody Engineering. In analogy to the engineering of machines, antibodies and other protein domains are designed, assembled at the molecular level and utilized to achieve specific functions in biological systems. Research is being done among others in the following areas:

- Generation and selection of recombinant antibodies by phage display
- Novel production methods for recombinant antibodies
- Antibody fusion proteins: adding new functions to antigen binding regions

In the TUBS biotechnology institute the research team relied not so much upon engineering in the sense of mechanical or chemical engineering, but more in the sense that they were able to use bacteria to build different versions of proteins they used in their research: human antibody genes as a template for building antibody fragments. Rather than using whole antibodies, they designed fragments instead because they are much easier to produce and can be made much more specific for their binding antigens once selection is completed. They put them into expression vectors capable of producing the antibody genes as proteins in a variety of ways (attached recombinantly to M13 phage or merely as soluble antibody fragments). Most of the vectors for phage display were built by institute researchers themselves. Phage display and the fragments the team has been producing can be considered as a type of "protein engineering".

> *"The antibodies built may have used human genes as templates, but they are newly designed proteins that don't exist naturally and were built specifically for the purpose of being used as biomarkers for tick salivary gland homogenates (SGH) and for this purpose only. They have no other applications, and to our knowledge no other research lab has ever produced them." (Email B.L. to author August 4, 2011)*

Thus in designing his own interdisciplinary research topic, the student took advantage of the two distinct research clusters of each institution involved in the dual degree program. He could not have come up with a thesis topic which crosses so elegantly between the disciplines of tick research and antibody engineering had he stayed at his home university. Getting a dual degree seems to be less a 1+1 calculation; instead it seems to propel research into unknown territories and creates innovative areas exponentially!

Case II

Another example of uniquely adding value to one's education is a dual degree masters' candidate in Mechanical Engineering's research on the "Development of a Lab-on-Chip Fluorescent Imaging System and its applications to the Detection of Alzheimer's Disease Biomarkers."

Equipped with a bachelor's degree in Physics, the student was attracted to the University of Rhode Island/ TU Braunschweig dual masters degree because she believed that, in her words,

> *…the world is continually being made smaller through advances in technology and an increased need for nations to work together toward common goals—such as global health and the protection of our environment. In order to be a successful contributor to the fields of science and engineering today, one must not only understand what work is being done in their own nation, but also what is being done around the world. (Email to the author 7/18/2010).*

The student sees it as "an incredible preparation for her future professional pursuits. My goals include being a multi-lingual engineer and researcher with not only scientific talents, but also the ability to make connections and exchange ideas with people all over the world" (Email to the author 8/20/2010).

This student began research for her master's thesis at the University of Rhode Island and was able to continue this work at the Institute for Microtechnology in Braunschweig working on "Development of a Lab-on-Chip Fluorescent Imaging System and its applications to the Detection of Alzheimer's Disease Biomarkers," a topic crossing the disciplines of health and microtechnology. University of Rhode Island faculty created the initial idea and set-up for this PIRE funded project. They combine expertise in computational fluid dynamics as well as in fluid flow and heat transfer in micro scale devices. Over a period of four years, the URI team provided the multi-disciplinary training program needed for a diverse group to succeed:

> *Development of microfluidic chips for detecting infectious agents and infection biomarkers is a multidisciplinary undertaking. A critical task in this project is developing a multi-disciplinary training plan that will allow young scientists, including graduate and undergraduate students in biology, mechanical engineering, and chemistry to work effectively together in solving a common, complex bioengineering problem; in particular, these students must be able to work side by side and integrate their specific expertise towards development of unique biosensors. This requires that all involved have at least some basic understanding about the specific tasks in each discipline. This training program takes advantage of research cores found among the PIRE collaborators" (Faghri, 2009).*

Building on the ground-breaking work done by the PIRE team at the University of Rhode Island (Biomedical News Today, 2010), the Institute of Microtechnology at TU Braunschweig provided the student with the needed specialized expertise in LEDs, CCDs and other devices. Through this fruitful cross-fertilization, her research goal accordingly shifted more specifically to assess the plausibility of fabricating a portable device that would use a naked CCD light sensor without optical lenses to detect amyloids in a microfluidic channel through fiber optic fluorescent excitation.

During the continuation of this research begun at URI in Germany, the student was able to get new opinions on ways to approach the difficulties she was having with her experiments, new equipment like an epifluorescence microscope and the suggestions she received from the experienced researchers there made it possible for her project to advance much more rapidly. In addition, supplemental class offerings at TU Braunschweig allowed the candidate to deepen her technical knowledge, such as the course on "Microfluidics" in Braunschweig, which is not offered at the University of Rhode Island.

Another added value in this dual degree arrangement is the large corporate network the students can tap into. Dual master students in Mechanical Engineering have to fulfill the internship requirement by doing a 26 week internship in a German company. URI's award winning undergraduate International Engineering Program (IEP), which includes a mandatory year abroad with one semester spent studying at a university and one semester interning in industry, has developed an extensive corporate research network. The IEP was able to identify three companies which work on lab-on-chip technology pertinent to the student's research (Bayer, Boehringer Ingelheim Microparts and Siemens), and she was placed with Siemens in Munich in the Sensor Systems and Applications department where she was able to apply the combined power of her theoretical and experimental research gained in two complementary Mechanical Engineering programs and found out about the possible applications of her research for a globally operating company. She was subsequently offered to write her master thesis with Siemens, and successfully defended her dual master thesis in November 2011.

In addition to the interdisciplinary expertise that this Mechanical Engineering graduate student is developing in her major field, she is now also fully bilingual, having first profited from a year of course work and an additional summer immersion program at the University of Rhode Island. The curriculum offered content based courses such as "German for Engineers" or "Technical German" which were especially designed for the integrated International Engineering Program (see von Reinhart, W. (2001) and Rarick, D. (2010). Then she continued with an intensive German course at TU Braunschweig followed by full immersion in the country itself.

Case III

An example from a different research area representing the international dual degree doctoral program, is a Ph.D. candidate in Ocean Engineering (University of Rhode Island)/Civil Engineering (TU Braunschweig). She is studying the role of the water pressure build-up in sediment that causes liquefaction of soils and using a Fluid Structure Interaction (FSI) Computational Fluid Dynamic (CFD) code. Her Ph.D. thesis is on "The role of pore pressure on the triggering of underwater tsunamogenic landslides:

> *Underwater landslides may be triggered by the reduction in soil strength caused by excess inter-granular pore pressures, such as resulting from seismic loading. This research project aims at acquiring a better understanding of the micro-mechanical processes responsible for this excess pore pressure build up, in ideal soils, during earthquake by mean of numerical simulations. A computational fluid dynamic (CFD) solver is developed and implemented based on the lattice Boltzmann method (LBM) coupled with a rigid body interactions solver (PhysicsEngine - PE) to model flows in ideal saturated sediment consisting in rigid spheres of varying radii. A series of validation test cases with a small number of spheres is presented to demonstrate the ability of the solver to model rigid body dynamics within a fluid, showing good agreement with analytical solutions. Modeling of idealized experiments performed at MGL (Marine Geomechanics Laboratory - Department of Ocean Engineering, URI) a soil composed of up to 10,000 spheres packed in a pipe with cyclic pressure loading applied at the pipe extremities are modeled and a parameter study is performed to determine in which cases this cyclic loading in the sediment yields soil liquefaction.*

The Ph.D. candidate's example shows again how international research activities can complement each other and lead to tackling one of the world's great challenges: the analysis and hopefully soon predictability and prevention of catastrophes caused by tsunamis. Complementing the modeling of idealized experiments done at the University of Rhode Island and benefiting from its expertise in the numerical modeling of long wave propagation, her studies abroad allowed her to take advantage of the expertise developed at the *Institute for Computational Modeling* in Civil Engineering (iRMB) at the Technical University of Braunschweig. There she is using a very specific code based on the Lattice Boltzmann method. Moreover, the TU Braunschweig has a very good computer infrastructure, a brand new cluster with over a 1000 processors, which is vital for her research as she is running parallel simulations using a lot of computational resources.

Case IV

A fellow dual degree master's student who will graduate in fall 2011 with a master in Ocean Engineering from the University of Rhode Island and a master in Civil Engineering from TU Braunschweig has mentors at his home university who specialize in slope stability and liquefaction assessments for deepwater silt and sand locations. At TU Braunschweig he has conducted research in *Leichtweiß Institute of Hydromechanics and Coastal Engineering*. The student's research is on "The Effect of Wave-Induced Pore Pressure on Scour Development around a Slender Pile:"

> *This study is an experimental investigation on a scale model monopile foundation in order to better understand the processes behind scour development and to determine if bed pore pressure development plays a role in scour development. The monopile is in the so-called slender pile flow regime which is a function of the pile size in regards to the flow characteristics. Around the pile the fluid flow induced by currents and waves create turbulence which causes erosion of the sediment in the vicinity of the monopile and local scour. Besides the obvious effects of the resulting turbulence on scour generation around the pile, an additional important boundary condition at the sediment-water interface is the reaction of the pore pressures in the sediment due to wave loading. The scour dimensions and the pore pressure response in the sediment are functions of the wave climate, the average sediment grain size diameter, the relative density of the sediment and the internal friction angle. In his study, the fluid flow and scour development with time is measured in parallel to the sediment pore pressure response.*

Due to the nature of the global challenges posed by climate change and the highly non linear, dynamic, stochastic and complex nature of the processes and interactions in coastal zones, the *Leichtweiß Institute for Hydraulic Engineering and Water Resources* spearheads many interdisciplinary collaborations with national and international partners to satisfy the increasing need for diverse more challenging methods, modeling tools and measuring techniques. The institute's research topics include "Sea waves and design of coastal structures", "Offshore structures", " Sediment transport and coastal morphodynamics", and "Shore protection against tsunami." These topics provide a valuable synergy with those spearheaded by the Department of Ocean Engineering at the University of Rhode Island. Here, the graduate student's faculty advisors are involved in research on Ground Impovement, Stability of Submarine Slopes, Evaluation of Composite Piles in Marine Environment, In Situ testing and Site Characterization Techniques and Dynamics Behavior of Rhode Island Silts.

Thus the student benefited not only from the synergies between his home ocean front campus and TU Braunschweig's *Leichtweiß Institute*, but also from facilities in Braunschweig in coastal protection and ocean engineering that simply do not exist in the US on the East coast. It is true, he writes in an email, that "some West coasts universities and institutes like Scripts and Oregon State could have also sufficed or had similar research opportunities in a slightly different research direction, but those are just as far away as Europe and there are less incentives for inter-US exchange programs and less secondary benefits" (Email to the author 8/1/2010). He could not have written a thesis on his geotechnical topic without large scale model tests. The facilities and funding simply do not exist at the University of Rhode Island or in the North East. In contrast, at TU Braunschweig he was able to join an existing project.

In particular, the Ocean/Civil Engineering master student took advantage of a piece of infrastructure that both universities have, but which is much larger in size in Germany: the TU Braunschweig has access to the large wave channel of the German Coastal Research Centre in Hannover. It has a length of 309 meters, a breadth of 5 and a depth of 7 meters! He took full advantage of the infrastructure in carrying out his research investigating scour around a vertical slender pile.

When asked about the value of pursuing this international dual degree program, the graduate student summarized what he calls its "secondary" benefits:

> *The added values have been experiencing new viewpoints and ideas on the various research material, working with people I typically would not have had the chance to, and the university classes are often taught in a different style than in the US so it is good to learn similar material but from a different approach to better understand how people are developing their ideas and opinions in an international sense (Email to author 8/1/2010).*

Conclusion

The four examples portraying engineering students enrolled in the University of Rhode Island/TU Braunschweig's dual degree graduate program show the effectiveness of research oriented international dual degree programs which are designed to complement each other. Assessing the learning outcomes of these four candidates by looking at their stories and synergies in their research methodologies at home and abroad, the study revealed that the impacts of engaging in interdisciplinary international research go way beyond "secondary benefits" and include primary scientific gains. Thus the findings of this STEM related study echo more general findings about the specificity of graduate international research outcomes: that the gained competencies are more directly career related than those by undergraduates, for whom personal development is in the foreground (Gullahorn & Gullahorn, 1996).

These findings underscore the necessity to keep sending engineering graduate students abroad to broaden their perspective and to encounter different ways of approaching problem solving. This is a key finding, especially in the current political and congressional climate where budget cuts for international educational initiatives such as the Atlantis/FIPSE grant, the Business International Education (BIE) grant and others have been approved despite evidence that those initiatives greatly improve U.S. innovation power and competitiveness. This paper is a beginning, but more outcomes assessment of international STEM graduate programs is needed. As the University of Rhode Island/ TU Braunschweig case shows, students enrolled in international dual degree graduate programs significantly broaden the scope of their "national" education and cross-fertilize their learning by going abroad. While broadening the scope of learning is also true for international undergraduate programs, when assessing the specific added values the international study, research and work experience provided each of the four graduate students examined in this paper, the following ten "added" learning outcomes can be derived. The first five are particularly relevant for STEM graduate students, the remaining five can be extended to undergraduate populations as well.

- **Broadened scope of research skills or methods**: doing research in a different university system and culture of knowledge opens up flexibility in methods pursued to tackle problems.
- **Encountering different engineering cultures**: the ways in which research related problems are solved depend on the "engineering culture" of a country (Gary Downey, in *Global Hub*), e.g. a more math based approach in French research labs versus a more experimental one in U.S. labs; more freedom, responsibility on the doctoral level in Germany which demands better time management skills versus more direct professorial influence, feedback and supervision a Ph.D. student in the U.S. system enjoys.
- **Leveraging gains abroad for engineering success at home**: students on the PIRE team have contributed to the PIRE success story, e.g. the development of a portable device for point-of-care diagnostics.
- **Continued international student/faculty collaboration**: initial doctoral research at partner universities abroad can lead to post-doc/faculty cooperation on the same topic in the home university, e.g. hiring of a TUBS Postdoctoral candidate specializing in the Lattice-Boltzmann method at URI or submitting joint research proposals.
- **Being prepared for the global work place:** by interning in companies with R&D related to the university thesis. The German master degree requires such an industry internship and it is often directly related to or sponsors the student's academic research.
- **Gaining more depth and breadth by benefitting from complementary offerings**: a well designed dual degree program allows its students to take advantage of additional course or research offerings abroad that are not available at home; of deepening a specification abroad after a general education at home; of complementing a science angle to the research with an engineering edge and thus allowing to accelerate the research, thinking outside the box, and gaining novel perspectives that would otherwise be lost.
- **Raising one's linguistic proficiency skills**: students staying abroad for an entire year have the advantage of returning at a higher linguistic level than those only staying for a summer or semester and usually bring back a level of advanced low to high, some become fully bi-lingual.
- **Developing intercultural competence**: international dual degree students learn to navigate diverse cultures, are more likely to be open towards other cultures more tolerant towards diversity, and they become savvy for careers in the global market place.
- **Strengthening self-efficacy:** being persistent despite obstacles encountered through differences in languages, cultures, engineering cultures and being engaged in

project-based learning in institutes and internships leads to significant gains in self-efficacy.

- **Growing as a person**: studying abroad and thus experiencing different life styles, world views and philosophies are fulfilling and empowering experiences correlated with transformational change in attitude, and life-long learning.

As John Grandin has pointed out, in addition to these advantages for the participants involved in international dual degree programs, there is also an added value to the institution and its faculty. Dual degree programs increase enrollment in both engineering and the languages and "both language and engineering faculty have 'profited' from their common programs" by attracting especially bright and successful students (Grandin, 2006, 5).

If we look at reports on global competitiveness and see how the U.S. is falling behind with regards to other countries (e.g. in the recent rankings from the Geneva-based World Economic Forum, in *Manufacturing.Net*, Sept. 9/2010), one can only strongly recommend a shift in graduate education, one which institutionalizes modules of international learning and allows students to reach out to the ways in which knowledge is created in other countries. Given the opportunity to participate in international dual degree programs, students will benefit from the spill-over effect of transferring knowledge gained abroad back home and vice versa. At the same time they will become the world-savvy citizens needed to tackle global problems of the future, and be prepared for career and life choices world-wide.

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