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A Step towards Global Engineering Education: The U.S.–Brazil Engineering Exchange Partnership

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1. Introduction

Several world events have been fueling the development of the "globalization of engineering." In Parkinson[1], the author discusses technological, political and economic world events leading to globalization. Among them, the advances in communications and computers, the breakup of the Soviet Union creating more free-market economies, the formation of the European Union, the market economies' openness to foreign investments by China and India, and the large influence of multi-national companies. As a result, engineering education must be tailored to the needs of the current globalized world. Industry has begun to respond to the transformation by redefining business strategies and expecting new skills for engineers. According to the literature[1-13], engineering students who have international study experience are more likely to be hired and prepared for the global market place. Engineering graduates will be integrally involved with the globalization of engineering during the course of their careers by working in multinational companies, often having foreign-born coworkers, working with international suppliers, providing services to international product markets, and/or developing products that have an appeal on the international market[14].

The need to prepare students to contribute to the global workplace has been recognized by academic, industry, and government institutions. Criteria 3H from ABET Inc., the accreditation agency for programs in engineering and technology, states that "engineering programs must demonstrate that their students attain the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context." Therefore, engineering students need to have a new set of skills, referred to as "global competence." The list of competences for engineers might include more attributes besides the technical knowledge typically required for each major[2, 8, 14, 15]. This list of attributes includes: an engineer must understand and accept diversity; be creative in the solution of problems impacting a wider and more diverse population; be able to communicate and socialize with people from different cultures; be knowledgeable of other languages; be able to use the technology to exchange ideas, solve problems and present solutions in a global context; be a leader; a team member; and an ambassador, among others[2, 8, 14, 15]. However, preparing engineering students for these additional competencies with all of the previously required attributes is no small task given that engineering programs are already overloaded with credits, content, and other demands. In Parkinson *et al.* [15], the authors proposed 13 attributes of global competence, and present the results of a survey which gathered feedback from people in academia and industry on the relative importance of these 13 attributes. Based on the results of this survey, the five most important attributes of global competences are that engineering graduates:

1. Can appreciate other cultures;
2. Are proficient working in or directing a team of ethnic and cultural diversity;
3. Are able to communicate across cultures;
4. Have had a chance to practice engineering in a global context, whether through an international internship, a service-learning opportunity; a virtual global engineering project or some other form of experience;
5. Can effectively deal with ethical issues arising from cultural or national differences.

In addition, the industry respondents of the survey indicated the importance of global competence for engineering graduates to be between "highly desirable" and "essential."

In 2004 and 2005, the U.S. National Academy of Engineering published two reports, *The Engineer of* 2020[4], and *Educating the Engineer of* 2020[5]. Both reports stress the impact of globalization on the practice of engineering and the need for U.S. engineers to focus on innovation and creative aspects of the profession to be globally competitive. The need to educate engineers with these skills clearly requires academic programs to offer engineering students the opportunity for international experiences where the students can obtain the global competency skills and therefore become more prepared for the global market place[3, 9, 16, 17].

The challenges and opportunities in forming global engineers for the Americas were also discussed in a recent workshop sponsored by the National Science Foundation (NSF) and the Latin American and Caribbean Consortium of Engineering Institutions (LACCEI). The outcomes and recommendations based on this workshop were reported by Esparragoza *et al.*[9]. Brito *et al.*[7] made a comparative analysis based upon recent international conferences on engineering education held in Brazil to demonstrate the role of international cooperation in the dissemination of new approaches in engineering education worldwide. This series of conferences reflects the effort of Brazilian educators, educational organizations, and government agencies in attracting recognized international organizations and institutions for mutually beneficial cooperation. In October 2006, representatives of 31 organizations in 10 countries gathered in Brazil to launch the International Federation of Engineering Education Societies (IFEES), recognizing the need for well-trained and culturally sensitive engineers[13,18]. IFEES mission is to establish effective and high quality engineering education processes to assure a global supply of well prepared engineering graduates[18].

While the importance to increase student participation in international experiences is recognized by the U.S., only 4% of engineering students in the U.S. actually do participate in an international academic experience, compared to 20% in Europe[19]. Moreover, the number of foreign students entering the U.S. has decreased significantly in recent years, reducing opportunities for American students to have an international perspective[20].

In this article, the authors provide an overview of the critical aspects of developing a consortium among two universities in the U.S. and two Brazilian universities with the goal of establishing a self-sustainable student exchange program in undergraduate engineering education, and to increase the participation of American students in international experiences. The activities in this program include the establishment of an agreement between the institutions, the implementation of a course transfer process, and the development of a procedure for foreign language training and cultural preparation. In addition, we also discuss the key lessons learned over the first three years of the program.

2. The U.S. – Brazil Engineering Exchange Program

The partner institutions of the exchange program described in this article are Michigan Technological University in Houghton, Michigan, and North Dakota State University in Fargo, North Dakota. The partner institutions in Brazil are Universidade Federal do Pará (UFPA) in Belém, State of Pará, and Universidade Estadual de Campinas (Unicamp) in Campinas, State of São Paulo. The UFPA is the largest and most influential institution in Brazil's Amazon region, and the Unicamp is a leading national research university that is responsible for approximately 15% of the Brazilian scientific production and is the originator of about 40% of all Brazilian doctoral dissertations in Electrical Engineering. The consortium was formed by these particular four institutions mainly due to existing links between the program directors. Support for the U.S. side of the program comes from the U.S. Department of Education's Fund for the Improvement of Postsecondary Education (FIPSE), and for the Brazilian side comes from the Coordenação de Aperfeiçoamento de Pessoal de Nivel Superior (CAPES) of the Brazilian Ministry of Education.

The U.S. – Brazil Engineering Exchange Program described here has four phases in its development, execution and long-term support. The preparation phase occurred in the first year of the program, October 2007 - September 2008, and was reported in Oliveira, *et al.*[21]. The execution phase happened during the October 2008 through September 2011 time frame, when student exchanges occurred. The evaluation and sustainability phases occurred as well during this time.

2.1. Program preparation phase:

During the program's preparation phase, besides strengthening existing relationships, the partner institution cooperatively developed the infrastructure to support junior- and senior-level undergraduate students in electrical and computer engineering, mechanical engineering, and electrical engineering technology as they participate in exchange. The goals of the preparation phase included:

- Logistics discussions with partners about how to prepare the Memorandums of Understanding (MoUs) for the undergraduate-level student exchanges. The discussion included issues such as payment of tuition and fees, and exchange duration;
- Addressing curriculum and credit equivalency issues, so that the students can graduate in a timely fashion. This was initially discussed during short faculty visits to partner campuses in U.S. and Brazil to familiarize faculty with the class syllabi, educational process, and resources employed in both countries;
- Developing a language and cultural preparation program that is necessary to enable students to actively and effectively participate in the educational activities during the exchange. Classes in Brazil are taught in Portuguese, similarly, classes in the U.S. are taught in English;
- Developing an infrastructure (academic/living arrangements) to support exchange students in the disciplines of electrical engineering, mechanical engineering, and electrical engineering technology during the academic and professional exchange;
- Sharing information on program management, program evaluation, recruitment, industrial internship opportunities, and criteria for yearly program assessment;

- Creating a website containing a comprehensive set of information including program description, student selection criteria, student funding, credit transfer, how to apply for the program, and partner institutions description. The website also provides guidelines for institutions that are planning to develop similar programs. The website was developed in the summer of 2008 [22].

2.2. Program execution phase:

In this phase, the actual student exchanges occurred. Activities included in this phase were:

- Assessed the language skills of the exchange students and make adjustments for language preparation;
- Performed a formative assessment to document the effectiveness of program execution strategies and to make adjustments for future cohorts;
- Provided mentoring to the exchange students to facilitate their adjustment to the foreign environment;
- Cooperate with the industrial partners and faculty-led academic laboratories to pursue the offering of internships and cooperative education opportunities for the exchange students.

2.3. Program evaluation phase:

The program evaluation determines the extent to which program outcomes (described in Section 4) have been achieved, and the effectiveness of the modifications implemented during the execution phase to improve the program. Internal and external evaluations were conducted at least once a year, and include students and instructor interviews, grade examinations, and feedback from the faculty-led research labs and companies employing student interns. Performance indicators were collaboratively established between the partners and summarized in Section 11. Success indicators of the U.S. - Brazil exchange program were collaboratively established between the partners as follows:

1. The number of students that participated in the program;
2. The academic performance of the participating students during the academic exchange;
3. The satisfaction of the students that participated in the program;
4. The satisfaction of the faculty that participated and contributed to the program; and
5. The satisfaction of the industries providing internships, and of the student interns.

In addition to these quantitative measures gathered by the in-house Advisory Board, an independent external evaluator conducted a formative assessment throughout the entire duration of the program. The assessment methods and tools used for the program included direct and indirect measures. More detail on evaluation/assessment is included in Section 11 of this article.

2.4. Program sustainability phase:

Assessment of the program performance obtained in the evaluation phase allows the participating institutions to better prepare and advise future exchange students. An integral component of the program's sustainability is the development of an effective language and cultural preparation for the exchange students. In order to continue the student exchange after the support from FIPSE and CAPES is no longer available, we intend to extend the program to other majors, and to work with each partner university to continue to exchange students at a one-to-one exchange basis, where students will continue to pay tuition and fees to the home institution while studying abroad. Through the equivalency work done during the planning phase, extensive advising, and careful prepa-

ration, students will continue to be able to take coursework at the host institution and transfer the credits to their home institutions. This will enable the exchange students to continue progress towards their degree to avoid delays in their graduation. The faculty and staff involved in the program at all four institutions will continue to provide support and advising for students. More detail on the sustainability phase of this program will be described in the next section of this article.

3. Program objectives

The main objective of this program is to overcome curriculum, linguistic and cultural differences between students and faculty members in engineering and technology programs in the U.S. and Brazil to promote a self-sustainable academic exchange between the two countries with emphasis in the area of renewable energy sources such as wind, solar, biomass, and water power. New technologies for these energy sources are of increasing interest and investment in both countries, in addition to the enormous interest for biofuel[23, 24]. To do so, the faculty members perform curriculum study with the goal of achieving credit equivalencies for the exchange students. The staff provides support to the students, and the regional industry and academic research laboratories facilitate student internships. This process will ultimately lead to the education of engineers and technologists that have an understanding of the technical norms and the business environment in both countries. The detailed main program objectives are:

- Establish a process to assess course equivalency between American and Brazilian institutions;
- Establish a process for the selection and preparation of the students for the exchange through a language and cultural training program, including both on-line and on-site courses, with an immersion session in the host country before the start of classes;
- Identify and correct potential difficulties with adapting to life in unfamiliar surroundings while they are in the host country through an active mentoring program;
- Promote opportunities for the exchange students that can lead to the sustainability of the program;
- Disseminate the knowledge acquired during the exchange to facilitate the establishment of other U.S. - Brazil universities consortia of higher education.

3.1 Activities taken place for each objective:

- **Establish a process to assess course equivalency between American and Brazilian institutions;**

The partners have identified a set of courses in the four institutions that are equivalent to each other. A matrix with all the equivalent courses was established and has been used as reference. Other courses may be transferred between institutions provided that there is a significant amount of similarity in the course content. Students have been able to transfer courses among the four institutions without any major issue.

- **Establish a process for the selection and preparation of the students for the exchange through a language and cultural training program, including both on-line and on-site courses with an immersion session in the host country before the start of classes;**

The partners have established a selection process based on a resume, essay, and transcripts submitted by the students, GPA, language skills, motivation to learn another language and culture, and interview outcome.

American students can start their language preparation at NDSU and at Michigan Tech several weeks before their departure to Brazil. The pre-departure language preparation is based on the Rosetta Stone Software: Version 3, Levels 1 and 2. The students arrive in Brazil and start intensive Portuguese training 6 weeks before the start of classes. In addition, they have on-site semester-long Portuguese classes during the academic semester while in Brazil. So far, six out of seven Michigan Tech students participating in the program during the Spring 2009, Fall 2009, Spring 2010, and Fall 2010 semesters have learned Portuguese sufficiently well enough to succeed in their engineering classes and interact with professors, fellow students, and the local population. Five NDSU engineering students took part in student exchange in Brazil during Fall 2009, Spring 2010, and Fall 2010, in which all the classes were taught in Portuguese.

- **Identify and correct potential difficulties with the adjustment of the students while they are in the host country through an active mentoring program;**

Faculty and staff members involved in the program actively provide mentoring for the students. The students from Brazil that went to Michigan Tech didn't have any major issues with adapting to their surroundings. The majority of the Brazilian students that went to Michigan Tech had excellent academic performance, taking 12 and 13 credits with very good GPAs. One reason for the smooth transition between the Brazilian and the U.S. educational system was the fact that the Brazilian students already had fairly good English proficiency. They interacted very well with classmates, especially with international students. A survey taken by all the Brazilian exchange students revealed that they were impressed with the organization and infrastructure that Michigan Tech and North Dakota State University had to offer to domestic and international students. The students also felt that the professors from both the American and the Brazilian institutions had similar level of preparedness to teach engineering classes.

The adjustment of the American students that participated in the exchange in Brazil during the Spring 2009, Fall 2009, Spring 2010, and Fall 2010 semesters was not as smooth mainly due to language issues. However, the American students (with exception of one) quickly adapted to the Brazilian way of life, and were able to learn Portuguese after attending an intensive course six weeks prior to the beginning of the academic semester, which was complemented by an on-site semester-long Portuguese course during the academic semester. The faculty participants think that this adjustment was facilitated by the opportunities to interact with the Brazilian exchange students in the U.S. before they traveled to Brazil. Several of the students that had previously participated in the program had served as ambassadors for the program by encouraging and helping some of the prospective exchange. In order to facilitate the adjustment of the American students in Belem, UFPA identified a host family to provide housing for the students who were attending UFPA. The program coordinators and the Office of International Programs of both institutions also provided active mentoring for the students.

- **Disseminate the knowledge acquired during the exchange to facilitate the establishment of other U.S. - Brazil University consortium of higher education.**

To disseminate the knowledge acquired during the exchange, we have created a website, and have published articles about the program in conferences and meetings, in addition to presentations on participating institu-

tions' campuses.

- **Promote opportunities for the exchange students that can lead to the sustainability of the program;**

We are assisting the exchange students in their pursuit of assistantships in partner institution labs, and possible internships in regional industry. In the Fall 2010 semester, one Michigan Tech student took advantage of the program structure to extend the length of his exchange without receiving any additional stipend. This exchange student participated in a paid internship in a laboratory facility at a partner institution during that semester, extending his academic exchange in Brazil from six months to one full year. We are also assisting American students to obtain housing from host families, in some cases the hosts are families of former Brazilian participants in the program.

In order to maintain the exchange parity between the U.S. and Brazil, and be able to offer to Brazilian students the possibility of studying in the U.S. while paying no tuition, we are currently proposing that each prospective Brazilian student houses one American exchange student in Brazil for one semester, and to offer to the American student advice on the culture and the customs in Brazil, in addition to offering full immersion in the Portuguese language. The American students would still be responsible for all other expenses, including meals (as they would have in the U.S.), and the travel expenses. The housing savings that the American students experience would help them to cover travel expenses and, possibly part of the expenses they will have with intensive Portuguese language training prior to the start of the academic semester.

The logistical support of a local student in the host country will give the American students a sense of security, knowing that they won't be on their own upon arrival in Brazil. This arrangement not only presents the Brazilian student with the opportunity to learn about American culture and customs while hosting the American student, it will also give the opportunity to study one semester in the U.S. without paying tuition and fees as is the case in their home institutions. The Brazilian students will still be responsible for the housing expenses in the U.S., where they could decide to reside in the campus dorms.

4. Program Outcomes

The U.S.–Brazil exchange program is expected to produce multiple, long-term benefits for participants. At the conclusion of this exchange program, the following outcomes related to the skills, knowledge, and behaviors that participants will acquire as they progress through this program are expected:

1. Provide students with the language, culture, technical, and business skills to work for international companies;
2. Create course articulation agreements for transferring of credits between participating institutions;
3. Develop a system for linguistic and cultural preparation for students participating in the foreign exchange;
4. Provide industry with culturally and technically proficient professionals qualified to work in several locations for multi-national companies;
5. Document results of successful relationships between program participants (students, institution administration, participating faculty, industry advisory committee) that lead to educational and disciplinary research;
6. Develop outreach activities to make the program better known inside and outside the consortium. These activities include: development of program website, publishing and presenting conference papers, giving talks at both the home

and host institutions.

In addition, the program seeks to improve the quality of teaching and student learning. Students participating in this exchange have the opportunity to experience a different culture and learn a different language. Language learning is highly correlated to a better understanding of the local culture[2]. Language skill is considered as a key element for the success of this program. Moreover, the engineering students have access to classrooms and laboratories in a foreign country, and have an opportunity to learn about similarities and differences on how engineering is taught elsewhere. The students have the opportunity to be involved in one or more research projects in several research laboratories at UFPA and at Unicamp on renewable sources of energy and on biofuels. This experience is expected to have a positive impact on the professional careers of the students, and also give them a better understanding, appreciation, and respect for the diverse values existing in different cultures.

5. Student participation

The students participating in the program are junior level (third-year) or later in their engineering or technology major. The disciplines included in the exchange are electrical engineering, mechanical engineering, and electrical engineering technology, with preference given to students with interest in the area of renewable sources of energy. Each program director in the consortium is responsible in his or her institution for recruiting, providing language training, and advising their students and the guest students in the exchange at their institution. For that purpose, all the partners follow similar procedures. The program directors advise both outgoing and incoming students in the exchange at their institution.

The exchange of students occurs at a one-to-one exchange basis, with tuition obligations covered at the home institution and a simple exchange of students which must balance out over the long run. Students pay tuition at home, but room and board costs at the host institution. The American students selected for awards receive a USD $4,500 stipend to pay for expenses (Airline ticket, housing, etc), $1,000 of which is applied towards Portuguese language training. The USD $4,500 stipend is per student, and is entirely covered by the FIPSE grant in the U.S. side. The institutions do not contribute funds for this program. From previous students' experiences, approximately USD $2,000 is left for room and board, which is enough to cover most of the students' expenses for one semester (including the six weeks of intensive language training). If the student stays for an additional semester, he or she needs to cover his/her own expenses by taking an internship in an academic, faculty-led laboratory or in the local industry. One of our students worked as an English instructor in his second semester in Brazil.

The program is aimed at enhancing the education of the exchange students while they make progress toward graduation. Through extensive advising and careful preparation students are able to take course work at the host institution and transfer full credit back home whenever possible, thereby ensuring no loss of time toward their degree. So far, 16 Brazilian students from UFPA and Unicamp participated in the student exchange at NDSU and at Michigan Tech since the Fall 2008 semester, and a total of 7 students from Tech and 5 from NDSU participated in the program since Spring 2009. Two of the American students were female, representing 17% of the American students (marketing did not specifically target female sudents for this program). The program goal is to send 18 engineering students from NDSU and Tech, and receive 18 students from UFPA and Unicamp. This target is expected to be completed in the fourth year of the program (the current year). Because the

fiscal year starts in October 1st, the last cohort of exchange students in the fouth year will include students that are going to participate in the exchange during the Fall 2011 semester, 3 students from Michigan Tech were already selected to participate in the program during Fall 2011. To our knowledge, the participation in the program did not delay the graduation for any of the students.

Brazilian students have enough proficiency in English to attend courses in the U.S.; on the other hand, American students face an initial language barrier during the exchange in Brazil, given that Portuguese is not an international language. For that reason, American students receive intensive Portuguese classes 6 to 8 weeks prior to the start of regular classes in Brazil. The American students also start to receive Portuguese training at their home institutions as soon as they are accepted into the program and prior to their departure to Brazil.

An exchange program is beneficial not only to the students going abroad but also to the students of the host institutions. Home students benefit from an international perspective by having international visiting students in their classes and laboratories. In addition, the institutions also benefit from the return of the students to their home campus, since they share their international experience with their peers.

6. Language Preparation

The exchange students start their pre-departure language preparation at Michigan Tech and at NDSU several weeks before their departure to Brazil. The pre-departure language preparation is based on the Rosetta Stone Software Version 3 Levels 1 and 2. When the students arrive in Brazil, they start an intensive Portuguese as second language training 6 weeks before the start of classes. The intensive Portuguese classes are small (with four students or less) and have the duration of up to 4 hours/day, 5 days/week. In addition, students also take Portuguese classes during the semester while at the Brazilian university. The Brazilian immersion language preparation was developed in conjunction with the Institute of Communication and Language (Instituto de Letras e Comunicação Social) at UFPA and at Unicamp. For instance, the Tech students participating in the exchange during the Spring 2009 semester had intensive Portuguese classes from January 19 to February 20, 2009, completing 90 hours total. They also had one semester of Portuguese classes in addition to traditional engineering classes during the semester. The total number of hours was 40, (1 hour and 40 min/day, 2 days a week, 12 weeks, with 3 students per class.) The progress and the performance of the students in the language courses are monitored by program coordinators fluent in both English and Portuguese. The exchange students' language skills were also assessed based on their academic performance in their engineering classes taken in Brazil. In addition, students write the final exchange report in Portuguese, and they are interviewed in Portuguese by the faculty advisors in the U.S. side, who are fluent in both Portuguese and English. Students' feedback, however, suggested that the Portuguese training with regular classes should start a few months earlier in U.S. institutions; however, very few U.S. institutions offer Portuguese classes. A proposed alternative would be to enroll in Spanish as a second language, which has many similarities to Portuguese. Therefore, the American students that have prior knowledge of Spanish can more easily learn Portuguese with the proper training.

7. Brazilian Students' Feedback

The assessment methods and tools applied to the first student cohort from Brazil to the U.S. include: language proficiency (TOEFL), collective course GPA, student surveys, written final report, and written reviews and

comments from students. All the Brazilian student participants in the first cohort had TOEFL scores higher than normally required by the two U.S. institutions (minimum 550 PBT, 213 CBT, 79 iBT). The collective courses GPA for all the participants were 3.5 or higher (out of 4). The engineering courses taken by the students include: Electric Energy Systems, Power System Analysis, Engineering Electromagnetics, Linear Systems and Control, Microcontroller Applications, and Electronics. The Brazilian students in the first cohort that came to Michigan Tech collectively worked on a written report on renewable sources of energy, which was published in the proceedings of a technical conference in that field. In addition, each student also wrote a final report on the overall program participation, which included a description of the courses taken, the language improvement, the cultural proficiency, difficulties, and suggestions for program improvement. The summary of the students' comments in different categories follows below:

Facilities: All the students stated that the American institutions offered excellent structure, with 24 hour access to laboratories, well equipped classrooms, efficient staff, wireless internet across campus, and excellent libraries.

Teaching: While in Brazil, the exams usually consist of a few difficult problems with enough time given for the student to think of a solution; In the U.S., exams have a large number of easy problems with not enough time to think. Grading in Brazil is a combination of the grades obtained in exams, while in the U.S. a significant portion comes from homework and quizzes. The students also noticed that the instruction levels in the U.S. and Brazil are comparable.

Language skills: All the students indicated significant improvement in their language proficiency.

Cultural experience: The students related that, even though the American students were always polite and willing to help, they were individualist and emotionally distant (with no hugs, no hand shaking, no loan of objects, little to no study in groups, etc). As a result, the Brazilian students had the tendency to interact socially more often with other international students. The students also noticed how clean and safe the cities of Houghton, MI and Fargo, ND were compared to their home towns in Brazil. They enjoyed the season change from fall to winter, and the opportunity to see snow for the first time in their lives. The students also benefited from contact with people from diverse countries, with different perspectives, and the maturity development while dealing with different situations.

Negative points: Long processing time and costly visas, costly housing arrangements, homesickness, and the need to adapt to cultural differences.

8. American Students' Feedback

Like the Brazilian students, the American students participating in the program wrote a final report on the overall program participation, which included a description of the courses taken, language improvement, cultural proficiency, difficulties, and suggestions for program improvement. The summary of the students' comments in different categories follows below:

Facilities: The students stated that libraries, laboratories, classrooms were accessible for furthering their education at both Brazilian institutions. Both Brazilian institutions have one main library with access to educational and fictional books, ranging in variety from Harry Potter to engineering topics. In addition, each course department has their own library for students. These libraries had books specific for classes and furthering knowledge outside of the classroom. Some of

the facilities such as libraries and laboratories had wireless internet. The classrooms were adequately set-up for teaching students; however, professors usually needed to bring white board markers and erasers on their own.

Teaching: Like the Brazilian students, the American students also found that the instruction levels in the U.S. and Brazil were comparable. The atmosphere in the classrooms, however, was much different than in the U.S., it was very casual and comfortable between the professor and students. The students felt comfortable asking questions without hesitation in the classroom. On the down side, it was difficult to catch a professor outside of classes since the professors did not offer office hours. The engineering classes offered are normally the same offered in the U.S. The classes in both countries usually cover the same material from the same books in the same amount of time. Negative points considered by the students were: homework assignments were not graded, and sometimes professors missed classes without warning.

Language Skills: The American exchange students had language skills assessed based on their academic performance in their engineering classes taken in Brazil, the final exchange report written in Portuguese and English, and the interview with the faculty advisors in the U.S. conducted in Portuguese. The faculty advisors in the U.S. are fluent in both English and in Portuguese. Michigan Tech students that already participated in the program were interviewed in Portuguese by their academic advisor/program director and demonstrated to be mastering the Portuguese language at an intermediate to advanced level. However, most of the students reported their struggle with the language barrier in the first weeks of the program.

Cultural experience: The consensus among American students is that the experience was a unique opportunity for opening their minds to a new culture and to new ideas. The students also agreed that, in general, Brazilians liked to help foreigners as much as they can, and are generally more open minded than people typically are in the U.S. On the other hand, there were some negative habits in the Brazilian culture, such as "cutting in line" in public places, adding to the frustration that standing in lines is common nearly everywhere, such as in banks, public offices, etc. The American students enjoyed the opportunity to travel to different places in Brazil, and try new types of food. Since the Brazilian institutions did not have on-campus housing, the students that didn't live with host parents (very common if the university is in the same city in which their parents live) normally lived in houses called "Republics." Republics are big houses with several students (usually 5-10, only male or only female). Our exchange students lived either in Republics or with host families.

Negative points: American students pointed out the mismatch between academic calendars in the U.S. and in the Brazilian institutions posed an additional hurdle to them. The process to obtain a student visa is still lengthy, requiring many documents, and plenty of time for the application. Also, the Portuguese language training should start in the U.S. several months before the students travel to Brazil.

9. Differences in teaching philosophy for engineering degrees in the U.S. and Brazil

As discussed by Downey *et al.* [25] in their work on "Engineering Cultures," engineers should be trained to be global problem solvers, and for such, they should enhance the ability to engage in activities of problem definition with people who are at a different geographical location, and are likely to define problems

differently. To engage in effective problem definition across differences, global engineers must know with whom they are working. Therefore, engineering students should be competent in problem definition across differences. Downey and his co-authors stress the importance of mapping different engineering perspectives by studying the emergence of engineering as a professional practice in different countries. Four different questions must be addressed in order to understand key different engineering perspectives: 1) How did the nation state evolve? 2) How have engineers emerged in this country? 3) What is the typical career trajectory for an engineer? 4) What are key emerging trends for engineers and engineering? Students must learn that differences in what counts as engineers and engineering knowledge can have implications for practices of problem definition. One particular example is cited in Downey's work[25] with regards to significant differences among engineers within France and the U.K., "an informed student can reasonably expect French engineers to embrace the mathematical dimensions of a given problem to facilitate planning, leaving more practical problems to lower-status workers, while expecting British engineers to consider practical dilemmas and, hence, mid-course corrections as central to their responsibility and effective engineering practice."

Following this concept, American students engaged in the program observed key differences in the way that engineers are educated in Brazil due to historical and cultural reasons. These key differences resulted in some difficulties experienced by American students while in Brazil, but we believe that experiencing these differences have helped the American students in the following ways: to meet and work with engineers from different countries, and to better understand the different perspectives in an engineering problem especially in international contexts. Part of the difficulties that American students had while studying in Brazilian universities were due to the differences in teaching philosophy for engineering degrees in the U.S. and in Brazil. The American students usually did not have enough background to follow the engineering classes at Unicamp – a state university, and UFPA– a federal university. To start with, the government– run universities in Brazil require a highly competitive common entrance exam, which initially filter students with a better background in all disciplines up to high school. In addition, the engineering courses in Brazil are more math/theory oriented as opposed to more hands-on oriented as in the U.S. counterpart. The U.S. institutions are usually better equipped with state-of-the-art laboratories and can provide more hands-on oriented engineering courses, lacking in the math fundamentals and scientific theoretical principles. It is also important to mention that due to the high competition of Brazilian universities, faculty members have the tendency to have high expectation from students. The Brazilian faculty members also don't have the same pressure that tenure-track faculty members in the U.S. usually have. Faculty members in the U.S. need to avoid bad instruction evaluations from the students to gain tenure. Brazilian faculty members, on the contrary, are not pressured to garner favor from the students and therefore have more freedom to set very high standards in their classes.

10. Lessons learned and hurdles

In this section, we wish to share a few observations based on the efforts to build this program over the past three years. A summary of the hurdles encountered in the first year of the program was reported in Oliveira *et al.* [21]. Some of the lessons learned by our program collaborators are similar to what was observed by other programs such as the program described in Grandin[26].

10.1. Bureaucracy in the institutions: The bureaucracy in the institutions – spe-

cially the Brazilian ones, which delayed the approval of the Memorandums of Understanding (MoU) for the student exchange at undergraduate level in engineering and in engineering technology. Each participating institution in the U.S. had a separate Memorandum of Understanding with each participating institution in Brazil, totalizing four documents. The four MoUs were necessary because there was no prior student or faculty exchange collaboration among these four institutions. Tuition and fees were dealt with through our MoUs. The students pay tuition and fees at their home institution and paid no tuition or fees at the Brazilian institutions. Similarly, the Brazilian students don't pay tuition in the U.S. partners' institutions.

10.2. Cross disciplinary collaboration and commitment: Building cross-disciplinary programs and achieve equivalency in junior and senior level courses to enable the exchange students to use those credits towards their degree requires innovation and collaboration among faculty and staff members who are not necessarily accustomed to working together. For this to happen, people across campus need to collaborate and commit a significant amount of time and effort to the program. As pointed out in Grandin[26], little will happen on a long-term basis with ideas supported by just one or two persons or by one side of two-sided partnerships, or without the involvement of influential persons in the campus community.

10.3. Difference in academic calendars, housing, and visa issues: Some of the difficulties we are experiencing is the mismatch between academic calendars in the U.S. and in the Brazilian institutions, and the lack of dedicated housing for exchange students, especially in the Brazilian universities since Brazil doesn't have an on-campus housing culture. In addition, the difficulty completing the necessary paperwork for Brazilian students to obtain a student visa in American Embassies, and to take the English placement tests, was a major hurdle to overcome. Also, it is important to mention that it is more difficult to have American students joining the program during Fall semesters to accommodate the language training prior to the beginning of classes, and be ready for the start of the Brazilian academic calendar. Many American students participate in internships, co-ops, or have summer jobs which interfered with the early preparation for a Fall semester start in Brazil. Another reason for the difficulty to meet our mobility target during certain semesters is the language barrier, as American students fear they will not be able to learn Portuguese prior to the start of the academic classes in Brazil. On the Brazilian side, there were delays in the delivery of documentation, provided by CAPES, to Brazilian students so they could obtain the necessary forms from Michigan Tech and NDSU to apply for a student visa to the U.S. in a timely fashion.

10.4. Recruitment of excellent student candidates: Because the concept of bilingual American engineers is still relatively new, it cannot be assumed that large numbers of students will enroll in engineering study abroad programs without active encouragement. The second language is still a significant barrier for American students to overcome, even considering that our program will provide language training and doesn't require prior knowledge of Portuguese. Any engineering study abroad programs, therefore, must rely on an active advertising, promotion, and recruitment program. Recruitment efforts consisting of email messages to student email lists, brochures distributed in the student commons, sporting facilities, and other places at the university with a high concentration of students from several majors. Newspaper and journal advertisements, class announcements, web sites, and even word of mouth are a part of the regular cycle.

10.5. A long-term commitment: An international engineering exchange program requires a long-term commitment and a steady, sustained effort. As we are now completing our third year of the program, there is still much work to be done. Though significant progress has been made in many aspects of the program, there is no assurance that the program is going to continue without the steady efforts of its key advocates--the faculty and staff. Each year a new group of qualified students should join the program, and each year the program coordinators need to work on retention rates by motivating and supporting the students. Each year, a new group of interns needs to be placed, scholarship funds needs to be generated, language training must be effective, all the paperwork for admission and visa must be prepared in a timely fashion, and so on.

10.6. Partnership with the private sector: As reported in Grandin[26], academia must learn to be responsive to societal needs and must continually ask itself if its curriculum is indeed in line with the requirements of the workplace and the demands of a continually changing and evolving economy. International engineering, as an interdisciplinary response to the demands of today's global workplace, is a good example of academic entrepreneurialism. In order to build an internship program, a university representative must visit leadership-level personnel in the companies involved. In most cases this calls for good presentation skills, and, in the case of visits abroad, presentations in a language other than English, with sensitivity to cultural differences.

10.7. External funding: International programs are labor intensive, and require many activities beyond the normal routine of the academic year. Faculty need to travel to develop internships, to maintain relationships with the private sector, to recruit and to develop study abroad opportunities. A program such as the international engineering exchange program also requires continual curriculum review and the creation of specialized courses such as intensive Portuguese classes. To do this work properly, faculty need release time and, in some occasions, they also need to work during part of the summer break. Expenses such as these are not generally allowable within the budgetary framework of most mid-size institutions. Therefore, international engineering exchange programs often rely on external funding for their development. Once the exchange program is established, it is easier to maintain a program less dependent on external funds. However, as mentioned above, it is not feasible to run a 100% sustainable program in engineering, especially considering language training costs, airline tickets, and other expenses. As previously described in the end of Section 3.1, we are considering an alternative path in order to continue to support student mobility when federal funding is no longer available to support the program.

10.8. Faculty rewards: While participation in the U.S.– Brazil exchange program is a gratifying experience, it is important to mention that working in such a program requires a substantial time investment. Faculty members working on this program need to dedicate a large number of working hours to the program, which may result in time reduction to work on other scholarly activities. A large amount of the grant is dedicated to travel expenses for faculty, and to pay for students' stipends. Only a small amount is used to cover summer salaries. The grant only covers one or two weeks (depending on the program year) of summer salary for the PIs. One additional benefit of a program like this one is fostering faculty research collaboration. The program director from NDSU is taking his sabbatical year in 2011 at Unicamp, collaborating with another program director in a specific research area of Electrical Engineering. The faculty member from NDSU is not covered by the FIPSE grant for this trip. Overall, the authors of this paper

believe that the benefits of such collaboration outweigh the difficulties. However, young engineering faculty members are promoted according to their ability to teach, to attract funding and to carry out significant research programs. In Grandin[26], the author points out that the traditional academic tenure and promotion system is not designed to support faculty who commit large amounts of time to programs such as this international exchange program. Higher education must expand the scope of appropriate research and publication to include internationalization of engineering education related activities and their associated dissemination activities as acceptable items for a tenure/promotion portfolio.

11. Program assessment

A number of meetings have been held to discuss course equivalencies, recruiting efforts, and student mobility. Success indicators of the U.S. –Brazil exchange program have been collaboratively established between the partners, as follows:

1. The number of students that participated in the program;
2. The academic performance of the participating students during the academic exchange;
3. The satisfaction of the students that participated in the program;
4. The satisfaction of the faculty that participated and contributed to the program; and
5. The satisfaction of the industries providing internships, and of the student interns.

In addition to these quantitative measures gathered by the in-house Advisory Board, an independent external evaluator conducts formative assessment during the entire duration of the program. In the first two years of the program, the assessment had particular emphasis on initial direction of the preparation phase. These assessment sessions were performed by the external evaluator and were included in the program annual reports. Some of the assessment methods described below were suggested by our external program evaluator.

The assessment methods and tools used for the program include:

Direct Measures

- Formal articulation agreements;
- Written performance reviews of student interns (from industry participants);
- Student performance in class (exams, written reports, etc);
- Student overall performance (collective course GPA);
- Student performance on standard tests (Fundamentals of Engineering Exam, Brazilian National Final Exam);
- Student performance on language tests (TOEFL);
- Student numbers (program participants);
- Pretest/post test (student preparedness and performance);
- Student performance in the Capstone class;
- Associated project (documented educational and research-related collaborations).

Indirect Measures

- Student surveys (related to instruction);
- Student surveys (related to exchange program performance);
- Faculty and advisor surveys (related to student preparedness and performance);
- Faculty and advisor surveys (related to exchange program performance);
- Employer surveys (related to the performance of interns);
- Written reviews and comments from the industry advisory committee;
- Graduation exit interviews (from stu-

dents who have completed the program).

For each of the surveys (indirect measures), a consistent numeric scale was used to provide a means of comparing the collected data between the administered surveys. In addition, student performance (direct measures) was converted to the same scale for consistency.

In Table 1 we provide a summary of responses provided by 12 American exchange students to the 21 survey questions. Responses with a mean of 3 or higher indicate student satisfaction with that particular item. It also indicates that they felt that most of the exchange program learning outcomes had been achieved satisfactorily. There are 14 items falling in this category, indicating that overall student participants (Spring 2008 – Fall 2010) were satisfied with their experiences. The highest survey ratings by students were given to questions relating to the impact the exchange program had on their understanding of different cultures and perspectives. In addition, students were confident in their abilities to work in multi-national teams and in emerging industrialized context. Thus, the outcomes of this program, which include overcoming curriculum, linguistic and cultural differences between students in engineering and technology programs in the U.S. and Brazil, and provide industry with culturally and technically proficient professionals qualified to work in several locations for multi-national companies were met by the program.

Students gave their highest ratings to the following specific learning outcomes:

1. Recognition that there are different ways to achieve goals (mean = 3.7);
2. Respect that one approach to solving a problem is not necessarily better than another (mean = 3.7);
3. Understanding and value of different cultural perspectives (mean = 3.7);
4. Ability to work in a multinational engineering team (mean = 3.9);
5. Confidence to travel abroad and operate effectively in a foreign country (mean = 3.7);
6. Ability to work with different cultures and ethnicities (mean = 3.9);
7. Understanding of the meaning of 'global economy' (mean = 3.7);
8. Awareness of technical constraint differences that exist between a highly industrialized country and an emerging industrialized country (mean = 3.7);
9. Confidence in being assigned to work in an emerging industrialized country (mean = 3.7);

The survey questions which had student responses ranging between agree and disagree (mean between 2 and 3) were related to the sufficiency of the funds available for the exchange, Portuguese preparation prior to exchange, degree of preparation prior to exchange, and contact with International Office and faculty at their home institution in the U.S. The language barrier was overcome by most of the students, who learned Portuguese sufficiently well to succeed in their engineering classes and interact with professors, with other students, and with the local population.

12. Summary

Globalization has transformed the way businesses operate and has changed the character of the engineering profession and the profile of an engineer. The need for engineers with the skills to succeed in a globalized society requires academic programs to provide them the opportunity for international experiences, where they can learn at least one foreign language and familiarize with a foreign culture while they complete part of their engineering education. However, very few American engineering students have any international experience. A disproportionally

small percentage of those students participate in student exchange in Brazil, considering the economic relevance of that country. In this article, we provided an overview of the critical aspects of developing an international engineering educational partnership, as well as the key lessons learned over the first three-year of the program. Feedback from student participants of the program indicates that the program has achieved most of its goals. Despite the "ups and downs" common in any long-term program, students have classified the experience as having excellent elements of culture and learning, and being an "once-in-a-lifetime" opportunity. For the students, the exchange experiences were valuable both professionally and personally, and they stated that they would do it all again. They also pointed out that the experience helped them to learn more about themselves.

Student rating on item: 4 = strongly agree, 3 = agree, 2 = disagree, 1= strongly disagree	Mean
1. The goals of the exchange program were clear.	3.0
2. I believe the program goals were met as a result of my participation in the exchange program.	3.3
3. The funds available to me through the exchange program and my regular funding sources were sufficient to cover my expenses.	2.9
4. I learned sufficient Portuguese prior to, in the initial phase of my exchange visit, and during my visit to enable me to communicate effectively.	2.9
5. The program activities prior to my exchange prepared me adequately for what to expect.	2.6
6. I graduated (or am on track to graduate) within the time frame I originally anticipated.	3.2
7. I had sufficient contact with the international office at my USA institution during my time in Brazil.	2.9
8. I had sufficient contact with the faculty at my USA institution during my time in Brazil.	2.9
9. My stay in Brazil helped me to recognize that there are different ways to accomplish a goal.	3.7
10. Because of the exchange, I respect that one approach to solving a problem is not necessarily better than another.	3.7
11. I better understand different cultural perspectives and values because of my stay in Brazil.	3.7
12. Because of the exchange experiences, I would be able to work in a multinational engineering design team.	3.9
13. The experience increased my confidence to travel abroad and operate effectively in a foreign country.	3.7
14. The experience increased my confidence to work among different cultures and ethnicities.	3.9
15. I learned new technological tools for use in engineering.	2.9
16. I have a better appreciation for global issues.	3.6
17. I have a better understanding of the meaning of 'global economy'.	3.7
18. I have a good insight into other technical cultures and perspectives as a result of the exchange.	3.4
19. I became aware of technical constraint differences that exist between a highly industrialized country and an emerging industrialized country.	3.7
20. I would feel confident being assigned by my employer to work on a project in an emerging industrialized country because of my exchange experience.	3.7
21. I would do it all again.	3.9

Table 1: Summary of student responses to survey questions. (Survey questions based on survey by North

Carolina State University U.S.-Brazil Consortium Program 2002-2007).

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