AC 2011-2334: INTEGRATION OF CAPSTONE DESIGN EXPERIENCE WITH THE INTERNATIONAL EXCHANGE PROGRAM

Juan C. Ordonez, Florida State University

Juan C. Ordonez is an Associate Professor in the Department of Mechanical Engineering and the Center for Advanced Power Systems at Florida State University. He completed his Ph.D. in Mechanical Engineering at Duke University in 2003. His research interests include thermodynamic optimization, constructal theory, heat transfer, and thermal modeling of advanced power systems.

Jose Vargas, Universidade Federal do Parana
Dr. Chiang Shih, Florida A&M University/Florida State University
Necesio Gomes COSTA, Universidade Federal de Itajub

He graduated in Metallurgical Engineering from Universidade Federal Fluminense (1983), master's degree in metallurgical engineering from the Catholic University of Rio de Janeiro (1988) and Ph.D. in Materials Science - The University of Birmingham (1996). He is currently Associate Professor I, Federal University of Itajub. published numerous articles in professional journals and papers in proceedings of international events. GUIDELINE: directed several dissertations, works of undergraduate research and technological work of completing an undergraduate, participated in several bunkers of defense completion of course work (doctoral, masters, undergraduate). He is currently general coordinator of international cooperation between French Univerisdades (ENSAM - cole Nationale Suprieure et Mtiers darts, ENSIAME - Ecole Nationale Suprieure Ingnieurs en Informatique Automatique d Mcanique nergtique Electronique and ENSMN - Ecole Nationale Superieure des Mines de Nancy) in the areas of Aeronautics and Technology Oil. He has experience in Materials Engineering and Metallurgy, with an emphasis on ceramics, mainly in the following areas: biomaterials, mechanical properties, bioceramics, coating and plating. Ouvir Ler foneticamente Dicionrio - Ver dicionrio detalhado

Integration of Capstone Design Experience with the International Exchange Program

This work presents an overview of our recent efforts introducing international aspects into the senior capstone design curriculum. Partly based on our previous experience, we proposed and received funding for the integration of international design project collaboration into an international exchange program between U.S. and Brazil funded by the U.S. Department of Education's Fund for the Improvement for Post-Secondary Education (FIPSE) and the Coordination for Graduate Studies of the Brazilian Ministry of Education (CAPES). The proposal involves four universities, two from U.S. and two from Brazil and encompasses two main research areas in aerospace engineering and renewable energy. We plan to formalize the international design collaboration as an integral part of the exchange experience by engaging visiting students in specifically arranged design projects, which require close interaction between students from both countries. This paper reports the experience learned in the initial design and implementation of these projects and our recommendation to fully integrate the design project into the curriculum of the exchange program.

1. Introduction

In this increasingly globalized market, it is critical for educational institutions to prepare engineering students with international experience beyond traditional technical knowledge and engineering skills. It has been suggested in a recent article[1] that global competency is one of the three key axes of engineering education, complementing the two traditional engineering competencies of professional and technical skills. To be internationally competitive, it is important that our graduates be able to adapt to a global work environment, which demands the capability to function effectively across national borders and to pursue opportunities and establish collaboration with international partners[2-5].

Brazil and U.S., being the two largest countries in the Americas in terms of the size of the economy and total population, are well situated for such exchange programs. Brazil has developed into one of the world's most dynamic economies in recent years resulting in growing potential for Brazil and U.S. to further increase their bilateral educational exchange. For example, a recent report on international educational exchange[6] shows the total number of Brazilian students studying in U.S. (8,767 ranking 13th among all foreign countries in 2008) has been substantially fewer than the similarly situated countries of India (103,260 in 2008) and China (98,510 in 2008). Furthermore, even fewer U.S. students (2,723) had studied in Brazil. In light of this, it seems imperative that we explore opportunities to strengthen U.S. and Brazil's educational collaboration.

In light of this consideration, we established the Brazil-U.S. Partnership in Sustainable Energy and Aeronautic Engineering Program (SEAEP), which integrates the academic strengths of the two U.S. universities and two Brazilian universities by expanding the educational and research experience of U.S. and Brazilian students through a structured exchange program. We propose to expand the program by leveraging on the long-term educational and research alliances already in place among faculty members at the partner universities.

2. Senior Capstone Design Project Class and our Prior International Experience

The Department of Mechanical Engineering curriculum is capped with a one-year senior design project in which the students will bring together their technical knowledge working in teams to design and implement products or systems under the sponsorship of an industrial partner. Students must develop skills in team organization, time management, self-discipline, and technical writing, in order to be successful in this course. An important goal of this course is to expose students to a 'hands-on' experience in which they have to specify, conceptualize, and design, beginning from relatively ill-posed needs stated by a 'customer', to the full realization of a complete system. Over the years, we have tried to enhance the design experience by engaging with more industrial partners for the development of realistic projects[7], increasing projects with multidisciplinary components, and by the addition of projects involving international collaborations[8,9].

We started in 2005 with two international teams composed of students from the Department of Mechanical Engineering at a University in the U.S. and (i) the Department of Mechanical Engineering at a Brazilian University and (ii) the Department of Electrical Engineering at a University in Romania. After completing the second round of teams, we were able to evaluate and report[8,9] corrections made after the first year. These include lessons learned regarding the team selection process, how to improve communication, the funding concerns, and positive and negative elements associated with the experience.

During this period, we coordinated five projects and the involvement of ten international teams. In the following, we will briefly summarize our experience

*Teams composition***:**

	Number of students	
Year	US/Brazil	US/Romania
2005-2006	5/3	3/3
2006-2007	3/3	3/3
2010-2011	4/2	
Sum	12/8	6/6

In an effort to describe qualitatively the “intercultural communication”, we tried to use concepts introduced mostly by anthropologist Edward Hall[11]:

Polychronic vs. monochronic time[12]: Monochronic cultures tend to handle events sequentially, while polychronic cultures and individuals tend to span their attention to multiple events at the same time. The way time is handled in a culture has a lot to do with the structuring of space (urban structures)[13]. Although both Brazil and US are considered "western" cultures, they can vary substantially in their focus on monochronic or polychronic time. Americans are strongly monochronic, and this was the style adopted by the projects: there was a timetable with well defined targets and deliverables, and the groups were prepared and focused on the specific topics during meetings and group discussions (via chat, Skype or phone)[14]. We believe the Brazilian culture has more polychronic aspects to it; however, the culture surrounding engineering projects

tends to be monochronic. The Brazilian team had no problem to adapt to the sequential approach demanded by the project.

High vs. low context cultures: "A high-context communication is one in which most of the information is either in the physical context or internalized in the person, while very little is in the explicit part of the message" [13]. A low-context communication is the opposite such that the majority of the information is in the explicit code"[13]. Generally, the faculty advisors involved are communicating through the "high context culture" due to previous collaborative connection, whereas the students are connected by a "low context culture".

*Cross-cultural exposure***:** in general Brazilians students are exposed through their lives to American culture. There is less exposure for the American students to Brazilian culture. So far only Brazilian students traveled to the US and we have not noticed any issues regarding this imbalance. In an effort to enhance the exposure to Brazilian culture, the US students that will be involved in future exchanges will be trained in Portuguese language and cultural aspects.

3. FIPSE-CAPES PROGRAM

We propose the integration of the international design project collaboration into an international exchange program between U.S. and Brazil funded by the FIPSE-CAPES program in 2010. In the current consortium, we kept the Brazilian partner from previous years and added a second Brazilian university with a strong affiliation with the leading aeronautical industry, which will provide a unique opportunity for professional training, mentored internships and long-term cooperation.

In this way, the FIPSE-CAPES SEAEP program integrates the academic strengths of two U.S Universities and two Brazilian Universities to expand the educational and research experience of U.S. and Brazilian students beyond their respective national borders. The program will provide students with training in the technical areas of sustainable energy and aeronautical engineering, while emphasizing facilitation of the mobility of current students and future engineers between the two countries. The key to this training is the development of a seamless process integrating recruitment, language preparation, international design projects, student exchange, mentored internship and graduate-level research collaborations between two countries.

3.1 Integration of capstone design experience with the international exchange program

One of the most important components of the program is centered on the international capstone design project course. Under this arrangement, select U.S. students will travel to Brazil in Fall, also the Brazilian "Spring" term. They will participate in one of the international capstone design projects developed during the summer before their departure. They will join a group of non-FIPSE-CAPES Brazilian students to undertake the design and planning of the projects in Brazil.

Concurrently, Brazilian exchange students at one of the U.S. universities will be involved in corresponding international capstone design projects with a group of non-FIPSE US students. The involvement of non-FIPSE-CAPES students from both institutions guarantees project continuity when the FIPSE students return to their home institutions. At the conclusion of the

Fall semester (the Brazilian Spring semester), US exchange students will return to FSU to complete the design projects. Currently, students from all four institutions are being recruited to participate in the program. Special Portuguese language classes have been arranged to prepare U.S. students for them to transition smoothly to study at one of the Brazilian universities. We expect the first cohort of students will start their exchange programs in the U.S. Fall semester, 2011. We expect at least 16 students from the United States and Brazil will participate directly in the exchange program while many more will be involved in the international senior capstone design collaborations to promote international learning experience beyond the program.

Special attention must be made for the composition of the team members since those students in the exchange program will spend time on different campuses during the lifetime of the project and their absence could potentially disrupt the coherence of the group. We feel it is important to mix FIPSE-CAPES students with other non-FIPSE-CAPES students to maximize the interaction for all parties. The idea is to assign a group of the students to affiliate with the international design teams at each home university. These students will not travel during the project period so they will function as the core guiding individuals to maintain the stability of the project execution when the other students travel abroad during their exchange visit. On the other hand, the CAPES and FIPSE participants who travel abroad during the project duration will have to concentrate more on collaborative tasks such as the establishment of rapport, effective communication coordination, and the stimulation of innovations by learning from team members from the other country. Collectively, they have to delegate responsibilities and manage the projects with all these added complications to make sure both teams function effectively. To ensure successful integration, performance metrics on these relatively ill-defined tasks will be assigned with consequential grade distribution at the beginning of the project.

3.2 Project phases (short and long term)

The strategy to carry out the capstone design project is to develop the collaborative effort in consideration of both short and long term objectives:

The short term plan is summarized by the following activities:

- During this phase, an international senior design project in the area of sustainable energy is being conducted as a test case for the SEAEP exchange-project collaborative program.
- Junior level students (current candidates for the exchange program) have been selected to be observers of the current international capstone design project.

For the long term, we intend to:

- Expand the research collaboration with our Brazilian colleagues in the area of sustainable energy using an existing collaboration on a microalgae photobioreactor project (described later).
- We intend to carry out a sequence of international senior design projects associated with this endeavor. Following this model, we can learn from previous years' experience and establish a longitudinal assessment of the collaboration for the improvement of international program.
- We will leverage on well-established design competition events for the aeronautical engineering component of the program and this will be detailed in a later section. We

hope to implement, compare and improve these two distinct modes of operation for the development of future international learning experiences for our programs.

4. Collaborative themes and project selection

As explained earlier, two main themes of aeronautical engineering and sustainable energy have been identified for the international exchange program due to academic and research strengths of the partner schools. In the following, we will discuss the selection of design projects commensurate with these topics.

4.1. Aeronautical Engineering

The preliminary decision is to participate in the Society of Automotive Engineer (SAE) 2012 Collegial Aero Design competition (see SAE site: http://students.sae.org/competitions/aerodesign/about.htm for more information). There are several advantages we can take advantage of the design competition, such as (1) It is an international program with competition events in both U.S. and Brazil; (2) the Brazilian university has several years of design and competition experience in the event already; (3) the U.S. university also has ongoing experience in similar model aircraft design competition such as the American Institute of Aeronautics and Astronautics (AIAA) Design/Build/Fly competition (see AIAA site http://www.aiaadbf.org/ for more information); (4) it aligns with local research interest to develop stronger aeronautical-related activities which guarantee the involvement of faculty mentors and resource allocation.

We expect two teams will be formed with a mix of U.S. and Brazilian students to build two aircrafts to compete in events at their respective countries. FIPSE-CAPES exchange students will serve as liaisons between two groups for establishing effective communication and technical interface. They will spend the first semester (U.S. Fall/Brazil Spring) as exchange students in host campus working with non-FIPSE-CAPES students during the project planning/concept generation phases. They will return to their home department the second semester to join their home team for the implementation, optimization and competition phases of the project. We expect both teams to communicate regularly through videoconference for information exchange and progress report and, hopefully, learn from their counterpart of all pros and cons to optimize the project.

4.2. Sustainable Energy

Microalgae are microscopic factories that have been using techniques (photosynthesis) refined over time to fix carbon dioxide using light into lipids (oil), biomass, and oxygen. Some strains can double their weight in a few hours under the proper conditions. Algae can grow in freshwater, salt water or even brackish (contaminated) water. Also, under the proper conditions algae have been predicted to be able to generate 30 times more oil per acre than plants used for biodiesel and other biofuels. Algae also could do this without competing with food crops (e.g., vertical photobioreactors). Researchers have shown that algae can grow more fat and faster if they are force-fed extra carbon dioxide, and deprived of nitrogen. This could help alleviate the

buildup of greenhouse gas emissions from power plants by "scrubbing" them using algae thus keeping the majority of greenhouse gases out of the atmosphere.

This project is being developed as a test case for the SEAEP exchange-project collaborative program as part of our short-term plan. In the current term:

- The US team is focusing on the design of a prototype unit for monitoring and controlling CO_2 to maximize algae growth in a photo-bioreactor. The unit will be used for the determination of guidelines for CO_2 concentrations to maximize biomass yield and minimize pull up time to reach a stable production.
- The Brazilian team is working on the thermal and structural analysis of a large-scale photo-bioreactor for industrial-scaled operation.

The general objective of this project is to contribute for the future construction of a High Density Microalgae Biodiesel Production Plant (HIDENBIOPRO). For that, several specific objectives will be pursued along the duration of the FIPSE-CAPES program and the future possibly new funded projects that will follow. Some of them are listed as follows, but as the project develops new specific objectives will be added to the project according to necessity:

1. Recovery of brackish water via microalgae cultivation;
2. Life cycle analysis of sustainable power generation from microalgae derived biodiesel;
3. Evaluation of the environmental impacts of sustainable power generation from microalgae derived biodiesel;
4. Development of environmental impact remediation strategies;
5. Study of technical, economic and environmental viability for the replication of sustainable power generation plants fed by microalgae derived biodiesel;
6. Mathematical modeling of life cycle, environmental impacts and remediation of the plant processes, experimental validation and thermodynamic optimization, and
7. Publicize the Project results, increase the general knowledge on microalgae cultivation technology, system performance evaluation and replication possibilities.

Figure 1 shows aspects of the current stage of the industrial microalgae cultivation in compact photobioreactors at the Brazilian university.

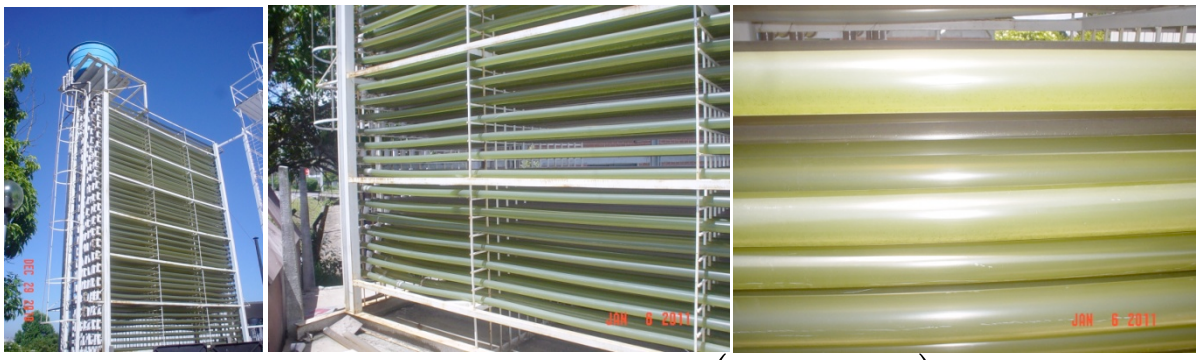

Figure 1. Microalgae growth in compact photobioreactor $(5\,\mathrm{m} \times 2\,\mathrm{m} \times 8\,\mathrm{m})$ at the Brazilian university

5. Conclusions and Lessons Learned

This paper describes the efforts to implement an international collaboration between American and Brazilian Universities. The international collaboration started in 2005 with joint senior design projects involving students from the institutions. With the experiences learned from those initial steps an international exchange program for the expansion of the collaboration was established in 2010.

Under the technical areas of aeronautical engineering and sustainable energy, the FIPSE-CAPES program will be carried out for the next four years to integrate the senior capstone design project collaboration with the international exchange program. Two operational modes have been proposed with the first one concentrating on the expansion of an ongoing research endeavor and the second one leveraging on the use of a design competition event organized by a professional society. We intend to track the progress of these projects for assessment and future modifications of the program for the enhancement of global competency for our students. We believe the integration of the senior capstone design projects with the international exchange program can potentially make the long-lasting impact for the success of the program and beyond.

In our experience so far, it has been challenging to maintain an active collaboration when the teams are remotely located. We have in occasions addressed this issue by selecting highly interdependent projects. In our current project on sustainable energy the task of each team are not directly interdependent but rather complementary. It is our observation that the students initially found difficult to see a clear interconnection between the Brazilian and US projects because there seems to have relatively little interdependency between the two teams. Furthermore, they feel little or no direct input needed from their counterparts to carry out their own design. This misconception has been corrected by several group meetings with faculty advisors from both sides to establish the relevancy of tasks between the prototype and full-scaled system. Clear mandates and design guidelines had been established to interface these two projects so more effective collaboration can be carried out.

Typically, the US team meets biweekly with the senior design coordinators and, separately, with their faculty advisors along with two major progress report presentations each semester. Although students are asked to report specifically on their collaboration during these meetings, yet we still notice that additional efforts are required to get to an acceptable level of proactive collaboration. We expect that the student mobility strategies described in this paper will significantly enhance the overall experience.

So far, no major challenges have been met within the authors institutions in support of this exchange experience due to the following reasons: First of all, the PI has prior experience in establishing several international exchange programs. Second, department heads and international coordinators from both US and Brazilian schools are either co-PIs or involved at the inception of the proposal. Third, the authors are responsible for the coordination of the current senior capstone design course and previous international design collaborations. Fourth, two of the authors have established long-term research collaborations. Finally, the timely financial support provided by the FIPSE-CAPSE funds. As a matter of fact, the alignment of all these favorable considerations is one of the major motivations to initiate these challenging endeavors.

The inclusion of international design project collaboration and its integration with the FIPSE-CAPES exchange program is certainly an exciting component added to our senior capstone design curriculum. It brings additional complications such cultural and language barriers, curricular disparity, long-distance communication and resource allocation into perspective. However, we believe that these challenges could be overcome and all participants (FIPSE-CAPES and others) will benefit greatly from this experience.

Acknowledgments

The authors acknowledge the dedication of all students involved in this experience and the support from FIPSE-CAPES (USA and Brazil), the Center for Advanced Power Systems (CAPS), the European Center for Nuclear Research (CERN) and the Brazilian National Council of Scientific and Technological Development (CNPq).

References

1. Hirleman, E.D., Groll, E.A., and Atkinson, D.L., "The Three Axes of Engineering Education," *International Conference on Engineering Education, ICEE 2007, Portugal*.
2. Oberst, B.S. and Jones, R.C., "Canaries in the Mineshaft: Engineers in the Global Marketplace," *Proceedings of the 2004 American Society for Engineering Education Annual Conference, Salt Lake City, Utah, 2004.*
3. Grandin, J. M. and Hirleman, E. D., "Educating Engineers as Global Citizens: A Call for Action /A Report of the National Summit Meeting on the Globalization of Engineering Education," *Online Journal for Global Engineering Education*: Vol. 4: Issue 1, Article 1, 2009.
4. Albers, A., Burkardt, N. And Becke, C., "GEARE: Global Engineering Alliance for Research and Education – For Engineering Students: Extensive Possibilities in Programs Focusing International Project Work and Study and Intern Abroad," *Proceedings of International Conference on Engineering Education, August 2009, Seoul, South Korea*
5. Hirleman, E.D., Atkinson, D., Groll, E.A., Matthews, J., Xu, L., Allert, B., Hong, W., Albers, A., Wittig, S.L.K, Lin, Z.Q., Xi, L.F., " GEARE: A Comprehensive Program for Globalizing Engineering Education", Proceeding of the 2004 American Society for Engineering Education Annual Conference & Exposition, Salt Lake City, UT, 2004
6. "Open Doors 2009 Report on International Educational Exchange," an on-line report by the Institution of International Education, available at http://opendoors.iienetwork.org/
7. Luongo, C.A., Shih, C., "Senior Design Projects in Mechanical Engineering -- A Case Study of Capstone Experience with Strong Industrial Participation", 2006 ASEE Annual Conference, Chicago-Illinois, June 16-21, 2006.
8. Ordonez, J.C., Vargas, J.V.C., Morega, A., Luongo, C.A., Shih, C "An International Component to Capstone Senior Design Projects," 36th ASEE/IEEE Frontiers in Education Conference, October 28, San Diego, CA, 2006
9. Ordonez, J.C., Vargas, J.V.C., Morega, A., Luongo, C.A., Shih, C."International Capstone Senior Design Projects," Proceedings of the Fifth LACCEI International Latin American and Caribbean Conference for Engineering and Technology, May 2007, Tampico, Mexico
10. Beer J. 1997 Communicating Across Cultures, http://www.culture-at-work.com/highlow.html
11. Edward T. Hall. (2011, March 8). http://www.edwardthall.com/
12. Hall, E.T. (1959). The Silent Language, New York: Doubleday
13. Missana, S., "The Grip of Culture: Edward T. Hall", http://ishkbooks.com/hall.pdf
14. Straker, D. (2007), Hall's Cultural Factors, http://changingminds.org/explanations /culture/ Hall_Culture.htm