Engineering Education Solutions to a Global Economy

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Abstract - **Engineering education has to face challenges that globalization poses and to adapt itself to a divers global work environment characterized by the increasing flow of economic goods, knowledge and information between countries and cultures. Extending multidisciplinary, senior design problem- and team-oriented projects, where students from different areas of engineering collaborate by adding an international component seems to be a natural, rewording path to follow. We have started with an international team composed of students from the Faculties of Electrical Engineering, Computer Sciences and Automatics and Electronics, Telecommunications and Information Technology – at POLITEHNICA University of Bucharest (Romania) – and from the Department of Mechanical Engineering at the FAMU-FSU College of Engineering (USA), in parallel with a second team made of students from the Department of Mechanical Engineering at the Federal University of Parana (Brazil) and the Department of Mechanical Engineering at the FAMU-FSU College of Engineering (USA). The paper disseminates the strategy we used and the experience we gained in the selection of the team, the funding solutions, and the positive and negative elements of this first attempt to include an international component to the senior design project.**

Index Terms - Capstone Senior Design, Multidisciplinary, Multi-country senior design project, International.

INTRODUCTION

Economic globalization and off-shoring of jobs [1]-[4] poses new challenges for education. This historical process accompanies the human innovation and technological progress, and it is in large part driven by engineers. To comply with it, engineering educators and students must learn to adapt to a global work environment were there is less and less resistance to the flow of economic goods, knowledge and information between countries and cultures.

In the pursuit to find means and methods to merge with the globalization stream, integrated curricula were adopted in the late 90s. For instance, the Department of Mechanical Engineering at the FAMU-FSU College of Engineering developed a curriculum that features a capstone one-year senior design course in which students work in teams to tackle engineering problems provided and sponsored by industrial partners. As the course matured, more and more industrial sponsors were attracted, such that today almost all the senior projects are sponsored by industry [2].

This paper describes the international component of the capstone senior design course, aimed at exposing students to a global working environment. In addition to the complexity of team dynamics, the students have to face challenges associated with distance, language, schedules, majors and curriculum differences. We started two years ago, with two international teams composed of students from the Department of Mechanical Engineering at the FAMU-FSU College of Engineering (USA) and (i) the Faculty of Electrical Engineering at POLITEHNICA University of Bucharest PUB (Romania), and (ii) the Department of Mechanical Engineering at the Federal University of Parana UFPR (Brazil). As the second round of teams has completed now their projects, we are able to evaluate the results [5] and report in our strategies and lessons learned regarding the team selection process, the selection of effective communication channels, the funding, and positive and negative elements associated with the experience.

PROJECT SELECTION AND SPONSORSHIP

The entire pedagogical premise of the capstone experience revolves around engineering design projects, and great effort goes into mimicking as much as possible the conditions encountered by engineers in industry, therefore it is important to expose students to a global working environment. The projects with PUB were selected and sponsored by CERN (the European Organization for Nuclear Physics Research in Geneva, Switzerland). The project with UFPR was selected jointly by FAMU-FSU and UFPR and received sponsorship from Shell and the Center for Advanced Power Systems at FSU. FAMU-FSU level of

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funding for both projects was similar to other teams, with no international counterpart ($3000 approximately). PUB utilized own funding for sustaining the projects. In the case of the UFPR teams there was an additional $2000 dollars budget allocation to sponsor a one-week visit to FAMU-FSU by a team member in the two collaborations.

TEAM ASSIGNMENTS AND ACADEMIC CALENDAR

At FAMU-FSU the capstone senior design team selection starts in August, and the projects run until April of the following year. The make-up of each team is very important: the success of the senior capstone experience rests on the ability to assemble high-performance teams [2], and the main motivations behind the capstone experience is to expose students to team-based design and procedures.

The FAMU-FSU techniques to assign teams are based on the experience aquired in this area. It is fair to say that if students were allowed, they would make their own teams based on friendship and level of comfort. Also, as observed during the first year of course (1999) in which the studens were offered some latitude to choose projects, there would be a tendency for teams to cluster by GPA (with some teams nucleating all class overachievers, while other teams would be composed of students with low GPAs). Beginning with the second year of the capstone course the instructor assigns the teams and forces students to work in groups without the comfort level of picking teammates. The process is somewhat complicated because certain constraints need to be observed:

- Ensure the teams are composed by students from both universities represented at the college: FAMU and FSU
- Consider the student's career interest or objectives as much as possible (e.g., students going into a bioengineering program in graduate school, students supported by certain fellowships from specific industry sectors, etc.)
- Allow members of students chapters (e.g., SAE, ASME) to work on specific projects sponsored by such organizations
- Allow students on the BS-MS (co-terminal) track to work on projects sponsored by certain industrial partners that also serve as hosts for summer internships

Besides these constraints, the method used to assign teams is rather straightforward. Each student in the class is assigned to one of four groups according to GPA (top quartile, second quartile, etc.). Each team is given four 'slots', one from each GPA quartile group, and a random drawing is used to pick a student's name and then allow him/her to choose a project with an open 'slot' for the GPA group the student is in. The result is that all teams have the same 'average GPA', and to the extent that name drawing is random, most of the students (but not necessarily all of them) should be satisfied with their projects and teammates. Even though prior GPA is not at all a good indicator of performance in the capstone course (most of the top performers in senior design come, in fact, from the second quartile group rather than the top), the method ensures a fair distribution of GPA among all teams and indeed project execution and performance tend to be quite uniform for the entire class.

At PUB (Romania) the last semester of the fifth year (the tenth semester) – from March to June – is devoted to the Diploma project that concludes the studies. However, since Romania is EU member and it is currently concerned with the implementation of "Bologna declaration on the European space for higher education"[6], the capstone project will be in effect in a couple of years, in the eighth semester to conclude the currently under implementation four years curriculum. Such differences bring some difficulties to overcome, regarding the synchronization of the work of the two design teams. However, the adopted criterion was that the host Department (FAMU-FSU) conducts the project with the assistance of the PUB team therefore the Romanian team works together with the FAMU-FSU team to finish the project at the end of the FAMU-FSU school year in April. The time left until June is used to provide assistance in pursuing the experimental work and prepare the diploma defense at PUB.

The PUB teams are selected based on a different strategy: they are made of undergraduate and first year graduate students. This hierarchical composition provides for a smoother transition between generations, and – in this particular case – it helped the integration with the FAMU-FSU team. This decision solved also the difficulty related to the Romanian academic year (October-June) that does not entirely match the US calendar. Currently, at PUB, the senior design project makes the object of the tenth semester of the curriculum (March-June), and it encompasses the full-time activity for the senior undergraduate students (i.e., that is the only course during the final semester).

As the Romanian team's tasks in the multi-disciplinary joint projects were monitorization, control, data acquisition and data reduction, the selection pool comprised the areas of electrical engineering, electronics, information technology, automatics and computer science. Communicating in English is not a problem, since the majority of engineering students in Romania speak English.

The Department of Mechanical Engineering at the Federal University of Parana (Brazil), UFPR, has a similar course system to FAMU-FSU, i.e., divided in semesters, with two Senior Design courses in the two last semesters. However, since Brazil is in the southern hemisphere, the summer starts in December and ends in March. Therefore, the summer vacation occurs during the FAMU-FSU spring semester. The academic year at UFPR ends in the middle of December, whereas the end of the school year at FAMU-FSU is in the middle of April. Such differences bring natural difficulties to be overcome, regarding the synchronization of the work of the two design teams. In this first experience, the adopted criterion was that the host Department (FAMU-FSU) would conduct the project with the assistance of the other team (UFPR), therefore the Brazilian team would have

[6] The *Bologna Declaration* is a pledge by 29 countries to reform the structures of their higher education systems in a convergent way. The process originates from the recognition that in spite of their valuable differences, European higher education systems are facing common internal and external challenges related to the growth and diversification of higher education, the employability of graduates, the shortage of skills in key areas, the expansion of private and transnational education, etc. The Declaration recognizes the value of coordinated reforms, compatible systems and common action [8].

to follow the FAMU-FSU semesters, i.e., to work together with the FAMU-FSU team, finish and present the project at the end of the FAMU-FSU school year in April.

For this first experience, all senior ME students at UFPR were eligible to apply and the opportunity was offered at the Department Internet site and in the classroom. The Brazilian team selection criteria were: i) an individual interview conducted in English to evaluate language skills; ii) only students with a GPA above 65 % of the maximum GPA were considered, and iii) a committee consisting of three professors, the ME Department Coordinator, the Senior Design Project coordinator, and the faculty supervisor, made the final decision to select the three students for the first team. For the first collaboration, a decision was made to allow the students to conduct freely their activities. The idea behind that decision was to analyze by the end of the first experience, without any bias, the performance of our selected students from UFPR and how they interacted with the FAMU-FSU team.

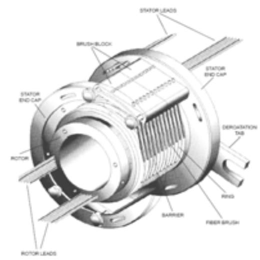
PROJECTS DESCRIPTION

The Romania-USA team projects were proposed by the European Center for Nuclear Physics (CERN) based in Geneva, Switzerland, the organization that is currently building a large particle acceleration facility. The accelerator will operate on an array of superconductive magnets, running at near absolute-zero temperatures. The operation of the particle accelerator relies on large superconducting magnets. To ensure the necessary precision of these devices, magnetic measurements are made using a probe. It was desired to design and build a new rotating coil system (which utilizes slip-rings) that increases measurement efficiency through (1) faster rotational speeds, and (2) continuous rotation of the system. Therefore the first project was concerned with the design and building of a test-bed for assessing the performance of several signal acquisition slip-rings eligible to be used in the new rotating coil system aimed at increasing measurement efficiency. Three different types of slip-rings were evaluated to quantitatively assess performance degradation versus lifespan. The test-bed had to accurately simulate the operating conditions of the rotating coil system, and the experiment had to run long enough (300 millions revs.) to satisfactorily characterize the entire lifespan of the slip-rings.

PUB TEAM

FAMU-FSU TEAM

THE SLIP-RINGS TEST BED



SLIP RING ASSEMBLY

FIG 1. THE EXPERIMENTAL SETUP AND STUDENTS DURING PREPARATION (ROMANIA-USA CERN PROJECT)

In determining which slip-ring is best for the application at CERN, metrics to measure slip-ring quality were developed, weighed accordingly to their importance for the application, and then applied for each slip-ring. A mathematical model was developed to analyze the results and to outline the correlation between the number of revolutions of each slip-ring and its wear or performance degradation. The project was successfully concluded in March 2007, after months of continuous run at PUB, and the CERN was provided the data to make its decisions.

The second project was concerned with the design of a system and the development of a methodology for balancing the ceramic shafts used by the CERN Twin Rotating Unit (TRU) device. The project's topic emerged off the demand that the magnetic field for each superconductor must be kept in prescribed limits to ensure proper accelerator operation. To do this, field measurements are to be taken to compare magnets to each other using the TRU. Since higher rotation frequencies are desired, shaft balance becomes a concern as unacceptable imbalances may cause erroneous field measurements and component failure due to fatigue loading. This project required the design and construction of a test-bed (FAMU-FSU task) to measure and help correcting the ceramic shafts eccentricity. It had to be stand-alone, and capable of handling shafts of various lengths, and the balancing method employed must not include magnetic components, and must be able to function at superconductor operating temperatures. A data acquisition system (PUB task) was needed to collect and process the measurement data. The system had to be sensitive enough to measure in the microvolt range, and had to gather the necessary data, including sensor output voltages, shaft rotation rates, etc. A test procedure was also developed in order to verify that the device performs at necessary quality levels. CERN supervised experiments will follow the design and buildup phase.

In both cases, the Romanian team was responsible to develop data acquisition and processing methods and software needed for the shaft calibration and balancing. This includes: background research, with focus on sensor (accelerometer, tachometer) data acquisition, software design, testing procedure and data analysis. The group implemented also the motor control. The US team was responsible for the mechanical design and implementation of the experiment, as well as the actual running of the experiment at Florida State University. The Internet was used to transfer data in real time between the test bed and the Romanian team. All data collection and processing was automated, implemented in LabView and Matlab programs. The progress of the experiments was documented and metained on the PUB IEM lab server through a web-accesible database and a wiki interface, visible to and editable by both teams. Communications were conveniently supported by e-mail, voice over IP (VoIP) conferences, chat-conference, and web and wiki pages. Telephone conference was initially used, but soon discarded in favor to VoIP technology.

In the first year the Brazil-USA team developed a Tri-generation System for Distributed Power, Refrigeration and Hot Water Supply. This project was selected in collaboration between UFPR, the Center for Advanced Power Systems and the Sustainable Energy Science and Engineering Center at Florida State University. The aim of this project was to design and build a prototype of a tri-generation system that will serve as an experimental unit to investigate the potential of tri-generation systems for energy conservation and production. The tri-generation system uses the waste heat from an internal combustion engine to produce hot water and a cold space. Electricity is also produced through an electrical generator coupled to the IC engine shaft.

FIGURE 2. EXPERIMENTAL SETUP AND TEAM DURING PRESENTATION (BRAZIL-USA)

While this system serves as an experimental unit it has the potential for use in other applications. For example, the system could aid returning hurricane victims by providing electricity, hot water, and refrigeration to homes without power through one cost effective, convenient system. It could also be used in recreational vehicles to decrease dependency on external power sources and increase the efficiency of the vehicle. The work consisted of the design and assembly of a prototype in the laboratory, its characterization and instrumentation. In a final stage, using the experimental measurements, the team performed a thermal analysis of the system, aiming the optimization of the operating and project parameters for maximum thermodynamic performance of the produced technological innovation. The prototype was built at the facilities of the Center for Advanced Power Systems at Florida State University. All students were required to undergo basic laboratory safety training and examination to gain access to the facilities.

During the second year, a new team was assigned to the tri-generation project with a multitask assignment: modify the system, previously running on gasoline, to be able to accept multiple fuels, introduce a water distiller unit, include bypass valves in order to allow system reconfiguration and control, and the generation of an additional cold space using the refrigeration effect associated with compressed gas expansion when a compressed gas is used as fuel.

The communication channels were videoconference, teleconference via phone line, e-mail, web conference, chat, voice over IP, web pages.

In the first year, we had different experiences with the two teams: in one case, active communication was observed, mostly motivated by the inherent dependence of the ongoing activities at each site. On the other case, the communication was poor: there were technical difficulties during the first videoconference and the team members backed to simpler but less engaging methods of communication (email and web pages). At the end of the second semester two students from Brazil visited the US team for the final presentation and senior design open house event. This face-to-face encounter and the opportunity to visit the host department motivated the students and decisively contributed to final success of the project.

The issue of communication was addressed closely in the second year, partially through better project definition. For example, the teams at each location designed and built components that were assembled together by the end of the period. This strategy made the success of the project more dependable on the continuous interaction between the teams, which actually happened in the second year with a better student selection, as discussed earlier in the text. During the second year, in order of importance, the communication channels between Brazil-USA team have been: videoconference (weekly), using messenger, and e-mail.

Summing up, good communication is facilitated by proper project definition, realistic planning, and constant pacing with respect to the proposed objectives.

BRIDGING CULTURAL DIVERSITY BY COLLABORATION

In what concerns the teams composition, at PUB there were three students in 2005-2006, two students in 2006-2007; at UFPR three students in 2005-2006, two students in 2006-2007; at FAMU-FSU five students in 2005-2006, three students in 2006-2007.

Due to the EU context, the Romanian students are generally introduced to cross-cultural concepts; the same is true for Brazil. In the specific cases reported here, there was a previous exposure of the teams to cross-academic educational activities.

The advisors of the teams are by a "high context culture" related (i.e., by previous common work), whereas the students are connected by a "low context culture". The projects add to this the general "high context European - American cultures", which is rather similar in what concerns technical education, etc. [6]

EU, Brazil and US are "western" cultures, and vary in their focus on *monochromic* or *polychromic* time. Americans (Germans too) are strongly monochromic, and this was the style for both projects: there was a timetable with well-defined targets and deliverables, and the groups were prepared and focused on the specific topics when meeting and discussing (by chat, VoIP and or phone) [7].

Regarding the "in-person visit experience", there was a meeting at the end of the project and only in the Brazil-USA collaboration. FAMU-FSU students served well as hosts and the meeting impacted the final project presentation. The PUB projects did not benefit of in-person visits. The teams were able though to fulfill in due time the tasks, and produce quality deliverables.

Overall, we consider the idea of a cooperative, international project very useful, exciting, challenging, professionally rewarding, and not the least a friendship relation builder.

CONCLUSIONS

In the pursuit of providing for higher professional standards in a more and more global economy, the joint senior design projects brought together teams from the FAMU-FSU Department of Mechanical Engineering, POLITEHNICA University of Bucharest, and the Federal University of Parana. Some lessons that we learned that may help bridging different cultural and educational environments throughout the world (USA, Europe, and Latin America) are:

- Securing good projects implies identifying industrial partners and, more specifically, individuals that are willing and able to work with the students throughout the academic year. The projects must be relevant to the industrial partner, if any, yet not be mission-critical; funding must be available to construct prototypes or other hardware as required by the project.
- An adequately long announcement time provides a better student selection, with excellent results in team related communication and project outcome.
- A clear outline of the tasks division between the local and the abroad teams and a tighter project specification with special emphasis on interface formulation are desirable, and prove to be successful.
- It is important that team spirit and research skills should be developed at an earlier stage of undergraduate education. The selection for the senior project is then just a matter of meeting the project's specific objectives.
- Team selection for the international collaboration should benefit from some freedom to allow students that are highly motivated about the idea of interacting with teams abroad to be part of this experience.
- The strategy in selecting the Romanian team carries the difficulty of grading the undergraduate, non-senior students invited to join the team, as they conduct the work for extra credit and outside a design class framework. However, this work adds true value to their research, team-oriented experience, and it counts on a longer term in their academic evaluation – e.g., they may present their research at the Students' Research Conference at PUB in May, each year.
- The teams face difficulties in developing an international collaboration, in terms of drawing tasks and terms, deadlines and the final goal to be achieved. Therefore the project should be formulated in a way that the technical issues require simultaneous involvement of both teams. Without proper communication the project cannot be completed satisfactorily, however the modern, Internet based technologies provide for convenient solutions.

- Multidisciplinary projects may enhance team interaction: for example the Romania-USA project had strong mechanical, electrical and information technology components. This created dependence between the USA team (composed mainly of mechanical engineering majors) and the Romanian team (with electrical and information technology majors).
- International capstone design projects [1] can serve as "check points" or calibration tools for different undergraduate curricula. The international exposure benefits not only the capstone senior design but the programs involved too.

In general, we consider the idea of cooperative, international projects very exciting, challenging, professionally rewarding, and not the least a friendship relation builder.

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