AC 2012-3657: ENHANCING SENIOR CAPSTONE DESIGN COURSE THROUGH INTERNATIONAL AND MULTIDISCIPLINARY PROJECTS

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Chiang Shih is a professor in the Department of Mechanical Engineering (ME), FAMU-FSU College of Engineering, Florida State University (FSU). He received his Ph.D. degree from the Aerospace Engineering Department at the University of Southern California in 1988 and joined the Department of Mechanical Engineering shortly after. Shih served as the Chair of the department from 2002 to 2011, during which time he led efforts in advancing both educational and research programs of the department. He spearheaded the enhancement of the capstone design curriculum by the establishment of strong multidisciplinary and international collaborations. At the graduate level, he was instrumental in the revamp of the five-year B.S.-M.S. dual degree program and the development of a strong doctoral program, which received excellent ranking in the most recent National Research Council (NRC) doctoral program assessment. Working with FSU administration and engineering colleagues, Shih spent the past four years (2008-2012) working on the establishment of a coalition across disciplinary boundaries in Aeropropulsion, Mechatronics and Energy (AME). The research consortium consists of 13 core faculty from three different engineering departments, 10 postdocs and research scientists, four full-time staff, and more than 50 graduate students. The center has recently moved into a newly completed AME Center, a $22 million, 60,000 square feet, multi-disciplinary applied research building with a state-of-the-art research infrastructure and educational facility, where Shih currently serves as the inaugural Center Director.

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Enhancing Senior Capstone Design Course through International and Multidisciplinary Projects

Abstract

Over the years the Mechanical Engineering capstone senior design course at Florida A&M University-Florida State University College of Engineering has evolved to parallel the real world engineering design projects found in industry. This course is designed to better prepare our senior mechanical engineering students for realistic industrial hands-on, team based projects. With globalization most engineering projects are becoming multidisciplinary and international in nature making it imperative that our students are exposed to projects of this nature. In recent years we increased our multidisciplinary projects significantly, closer to 50% of our total number of projects have been multidisciplinary involving industrial, electrical and computer engineering. This year we have introduced three international projects, two with Brazil with two different universities and one with Armenia. 10% of our senior design students are involved with these international projects. The introduction of multidisciplinary and international aspects has proven to be an exceptional conduit to educate our students in team-based strategies, and globalization. The experience gained by our students far outweighs the challenges, we as educators face with the implementation of these kinds of projects. This paper discusses the challenges, changes and accommodations we incorporated as part of this course for executing those multidisciplinary / international projects where students are from different engineering departments and countries. It explains how these challenges are addressed in the capstone design courses between departments and Universities.

Introduction

Going global? Increasingly more US companies in order to keep up with the business growth and to stay competitive are going global, which has created a demand for a new breed of workforce engineers, including engineers that not only master the engineering field but also embrace social and cultural issues of global international projects. Increasingly more companies are turning to the engineering colleges to training the next generation of global engineers. [1]

The Mechanical Engineering capstone senior design course has been the ideal course to introduce and train senior engineering students for global international projects. Over the years while trying to keep up with the industry's demand for our engineering students, our senior design course has gone through an evolution of improvements. Four of which have had a major impact on the senior design course. [2] First exposing our students to real-world project cycles and approaches

required the course evolve to the current two-semester project-based format. Secondly for our students to gain the experience of dealing with real-world and industrial-like projects, more industry-sponsored projects were introduced and, currently make-up almost 80%. Thirdly to prepare our students to deal with multidisciplinary engineering projects, we increased the number of multidisciplinary projects with electrical and industrial engineering to about 50%.[8] Recently, the fourth improvement was an effort to expose our students to the global engineering environment, where we focused our energy on increasing our international projects and now we are close to 12% of our students engaged on international projects. Presently we have three international projects where we are working with two Brazilian universities, and one Armenian university.[2]

An international project introduces the students to a host of challenges and demands that requires they work as an integrated and cohesive team. We have found that with a geographically distributed team it is critical hat the coordination be carefully thought out and well-prepared and the team have clear and effective communication, which will help overcome language barriers, cultural differences as well as other obstacles that occur. Becoming skilled at effective communication with each other and with the industrial partners is important, so that the students gain an understanding of how to successfully manage those projects. Scheduling for the students becomes difficult when there are several time zones between them. They are required to hold regular team meetings, sometimes biweekly, so coordination is a key to their success and functioning as a cohesive team. How the workload is distributed and managed between the team members is another key component to address when working on an international capstone design project. [2]

Figure 1 shows the evolution of the industry sponsored senior design projects in the past 13 years in the Department of Mechanical Engineering at our university. It is also shown the increase in the number of students and projects in the same period.

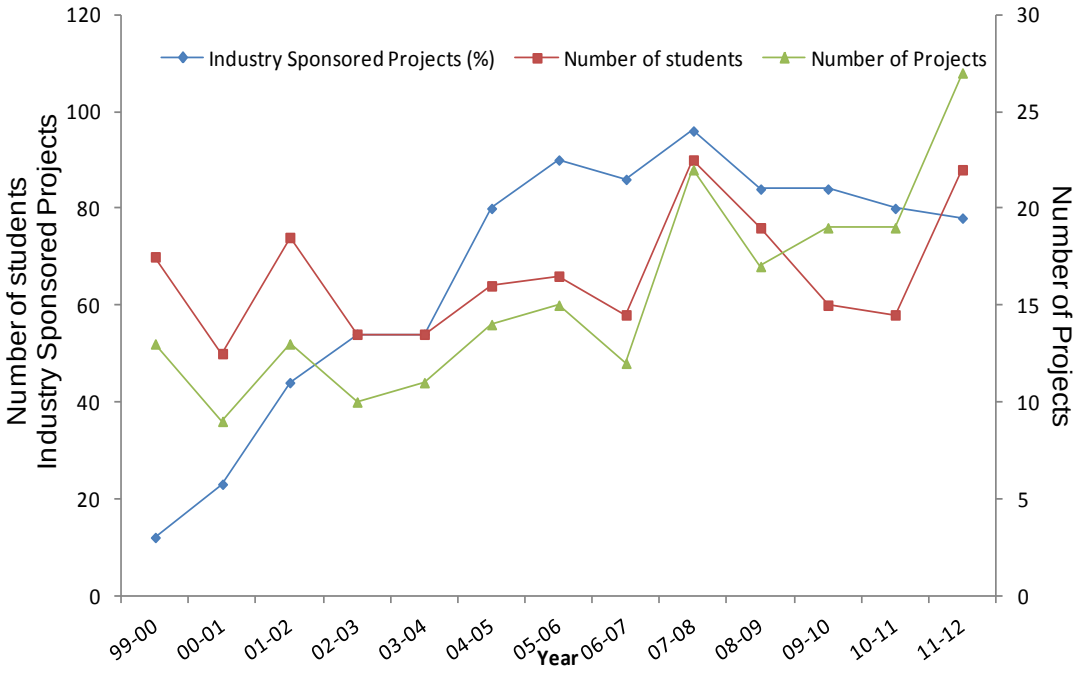

Figure 1. Growth of industry sponsored projects for the past 13 years

International Design Projects

In the past the Mechanical Engineering capstone senior design course worked with universities in Brazil, and Romania. [6,7] This year we expanded our international projects to, two universities from Brazil, Federal University of Parana (UFPR-Brazil) and Federal University of Itajuba (UNIFEI-Brazil), and one university from Armenia, The American University of Armenia (AUA). The Brazilian projects are leveraging on collaborative experience, a consortium co-sponsored by the U.S. Department of Education's Fund for the Improvement of Postsecondary Education (FIPSE), and Brazil's Ministry of Education. This consortium was established in 2010 to integrate the participation of four universities (two from U.S. and two from Brazil) to expand the educational and research experience of U.S. and Brazilian students beyond our respective national borders. One of the most important components of the consortium is centered on the international capstone senior design project course. Under this arrangement, four U.S. students, two at each Brazilian university, traveled to Brazil in the fall, which is actually the Brazilian "Spring" term, where they participated in two of the international capstone design projects that were developed during the summer before their departure. In Brazil the students joined a group

of non-FIPSE Brazilian students to undertake the planning and design phase of their projects in Brazil. Concurrently, five Brazilian exchange students traveled to the US where they integrated with three other capstone senior design projects. At the conclusion of the fall semester the US exchange students returned to US to complete the design projects with their US counterparts.

The international senior design projects between US and Brazil teams were defined based on the lines of research of existing funded scientific projects to Federal University of Parana (UFPR-Brazil) and Florida State University (FSU-US), and Florida State University (FSU-US), Federal University of Parana (UFPR-Brazil) and Federal University of Itajuba (UNIFEI-Brazil) [3,4]. Between UFPR and FSU-US, the students international team was assigned a project on the life cycle analysis of industrial photo-bioreactors that grow microalgae for biodiesel production and also the investigation of the utilization of gen-set emissions as a CO_2 source for microalgae growth.[3,4] The UNIFEI and FSU-US the students of the international team was assigned an aerospace design project.[4] At the foreign universities , the students joined the scientific projects research groups and were integrated in their day-to-day activities, participating of weekly meetings, reporting their progress on these occasions to the entire teams. Such close coordination substantially helped the successful outcome, yet total freedom was granted to the students to develop their engineering work.

The Armenian University international project was a multidisciplinary project between Mechanical, Electrical, Computer and Industrial engineering. Two students from Armenia were integrated remotely with a team of five US students, working on an industry-sponsored project. The objective of the project was to design and build a desalination device that would operate utilizing a midsize wind turbine (50kW) and is capable of producing the maximum amount of fresh water. The team divided the system into four subsystems, the control systems, power generation, power storage, and the desalination unit, in order to improve coordination and individual responsibilities.

Challenges of International Design Projects

The success of an international project can depend on how effective communication is between the team members, the team and their design instructors, and the instructors and the advisers. In anticipation of communication difficulties in Brazil special Portuguese language classes were arranged to prepare the US students to transition smoothly into their design team at the Brazilian Universities. Classes in Brazil were also taught in Portuguese so these students were able to attend and excel in them. In the Armenian University classes were taught in English and the team members from there spoke English so communication was much less of a challenge.

The international teams were expected to communicate regularly, at lease once per week and more frequently as they worked on deliverables and their presentations. Communications were

conducted through formal university video-conferencing, informal video-conferencing i.e. Skype™, AIM®, and web meetings for information exchange and progress reports. As the demand for communication increased the students also relied on social networking i.e. Facebook™ as a means of communication which proved to be very effective for the success of their projects.

For better coordination and communication the senior design instructors at both universities and faculty advisors had to work closely with each other and exchange progress reports from each site to identify issues and problems before there were major roadblocks. This also encouraged the team to work more closely with each other and keep the lines of communication ongoing. It also highlighted another challenge when working with the Armenia team, which was the time difference; coordination of times that would work for both teams introduced another level of cooperation and consideration to them.

The international teams were encouraged to work on their deliverables as a team and share the workload between them independent of their geographical distribution. The teams were expected to give joint presentations over video-conferencing, which encouraged effective communication, closer collaboration and better team integration.

Industry-sponsored Projects

Industry sponsored projects provide many benefits to an academic design program since they often expose students to real-world challenges[6,7]. The students experience is enhanced with exposure to real world challenges, teamwork, group problem solving, and with engineering professionals who serve as mentors, providing an industry like environment in which to address the open ended challenges these projects presents. [5,8]

In the summer prior to the fall semester classes starting we work with the industry partners to define the projects, their expectations and discuss the value to our students. The industry sponsored projects are varied and can pose a variety of managerial problems, especially if the industry sponsor is not actively involved with the design team; therefore, for these design projects to provide the needed educational experience to the students and value to the industry it is crucial to select the projects carefully, mentor them closely, and coordinate activities between all the stakeholders.

We have been fortunate with the participation of the Mechanical Engineering Advisory Council (MEAC) and many long-term industry sponsors who have provided high quality industry sponsored and engineering relevant projects. MEAC and our industry partners have been actively involved in the definition and the selection of the industry projects where we have steadily increased our industry sponsored projects from a very few to the majority of the projects over the

years. For example, over seventy eight percent of this current year's projects are sponsored by industry shown in Table 1.

Table 1
Industries sponsoring projects for the past 13 years

1999- 2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012
Cummins	Cummins	Cummins	Cummins	Cummins	Cummins
Lockheed	Lockheed	Lockheed	Lockheed	Lockheed	NHMFL
Eglin/AFRL	Eglin/AFRL	Eglin/AFRL	Eglin/AFRL	Eglin/AFRL	Eglin/AFRL
CERN[M,I]	Sandia	Harris	Harris[M]	Harris[M]	Harris[M]
Boeing	Boeing	Boeing	Mosaic	FSU-CAPS[M,I]	FSU-CAPS[M,I]
NHMFL	Turbocor	Turbocor	Turbocor	Turbocor	Turbocor
ASHARE	NHMFL	NHMFL	Mergenet Med.	Seven Hills Eng.	GE - Oil & Gas [M]
CAPS [M,I]	FL. Dept. of Health	FL. Dept. of Health		Keuka Wind	Keuka Wind [M,I]
SubZero		NASA	NASA[M]	NASA[M]	NASA[M]
Shaw Ind.		Tyndall-AFB	Tyndall-AFB		FSU-CISCOR
Sandia Nat. Lab					FSU- FCAAP [M]
Talla-Tech					FSU-Marine Lab [M]
Benedict Eng.					Brogan Museum
Shell[M,I]					TECT-Power [M]

Superscript:
M= Multidisciplinary Projects
I= International Projects

Multidisciplinary Projects

The real-world engineering challenges and projects mostly involve different engineering disciplines working together. In recent years we also noticed an increase in demand from our industry sponsors to include students from other departments to make up multidisciplinary teams. Earlier in the program we found litter success establishing true multidisciplinary teams by including students from other departments as a result of the disparity in the curricular requirements among the different departments. Despite this we start by including students from the Physics, Electrical, and Business departments as their honors thesis program or a special topic courses. In 2009 this changed when other engineering departments at our college adapted a yearlong, project based senior design courses into their curriculum making them more compatible and allowing the students to follow the respective design process without significant disruption, which fostered a collaborative effort and defined a better process with cross disciplinary projects, thus allowing us to establish true multidisciplinary teams by including students from the Electrical and Computer department and the Industrial engineering department as seen in Table 1 and Table 2.

Which multiple departments working together we found a need for more structured and formal coordination between them, therefore the design coordinators from each department worked

together throughout the year to establish guidelines for the students working outside their departments. For effective assessments they also developed a grading rubric for how individuals and groups are to be evaluated which made the grading more objective and consistent, and provided the students with in-depth feedback on each graded assignment and overall course grade. [10] The design coordinator responsible for the lead department also meets with each team in a staff meeting setup at least every other week scheduled and more frequently if requested by the team or the coordinator to address any issues or challenges that the team is facing. The design coordinator will also meet with the faculty advisor with or without the team as needed during the year to address any issues or challenges that the team is facing.

Those students working on projects sponsored outside their home department are followed closely by the design coordinator from the department leading the project. The students' home department senior design coordinator provides the oversight for these students by participating in major design review presentations throughout the year to ensure that the students follow the proper design techniques and methodologies. Additionally, two faculty advisors, one each from the home department and the leading department, are assigned to assist the students for technical issues from respective disciplines.

Multidisciplinary projects exposed our students to the ability to work and learn from other disciplines. Most Engineering students start their professional engineering career they have relatively little knowledge of the Quality functional deployment (QFD) process and other six sigma tools, enabling the determination of what the customers perceive to be critical to quality (CTQ), addressing the necessary issues, and placing controls to ensure that the proffered solutions are implemented correctly.[8] By working together on the QFD process such as the employment of "The House of Quality" methodologies the team can better define the customer requirements and clarify the deliverables and expectations of the project outcome.[11] Based on our experience, other quality system methodology that has been learned by the Mechanical Engineering capstone senior design students is the Fishbone diagrams. The use of the diagram forces the project team to think of all possible causes of the potential design issues during the project development by helping to identify all factors which can lead to design failure in a more structured and controlled way. We have found out that although not all of the projects are multidisciplinary or uses QFD process, yet most students are exposed to these concepts during the project presentations.[11]

Over the years we have realized an increase in positive feedback from our students, alumni, Mechanical Engineering Advisory Council (MEAC) and industry partners for our multidisciplinary senior design projects after integrating Mechanical Engineering, Electrical and Computer Engineering and Industrial Engineering students in our senior design course. In the current year forty two percent of our total number of students (37 out of 88 students) are working on multidisciplinary projects as seen in Table 2

Table 2
Multidisciplinary Projects and Number of Students from Each Department

Academic Year	Project	# ME	# ECE	# IE
2009-2010	Solar Car	3	4	
	Formula Hybrid Car	4	4	
	NASA Regolith	4	3	
	Maple Seed Sensor	3	2	
	LabView Advanced Controller Unit	3	2	
2010-2011	Solar Car	3	3	3
	Formula Hybrid Car	3	3	
	NASA Lunar Regolith Excavator	3	2	
	Bridge Scour Detection	2	3	
	AIAA Unmanned Elec. Aircraft, Design/Build/Fly Competition	3	2	
	Wii Controller for Health Care	3	2	
	Experimental Propulsion System in Micro Air Vehicles	3		3
	Carbon Nanotubes Based Antenna	2		3
	AUVSI - RoboSub	3	3	
2011-2012	North American Solar Car Challenge	3	3	
	Formula Hybrid Car	4	3	3
	NASA Lunar Mining Competition	3	3	
	AUVSI– Unmanned Air System Competition	3	3	
	AUVSI – RoboSub	3	3	
	COMICI- Cosmic-ray astronomy	3	2	
	Marine Lab- Roboboat Autonomous Water Quality Sampler for Shallow Water	2	4	
	Marine Lab- Instrumented Drifter	2	2	
	Autonomous Palm Pruning Device	3		3
	Automated Resin Infusion Equipment	3		3
	GE Oil&Gas- Google Mobile App for Compressor Performance	3	2	
	Keuka Wind /CAPS – Water Desalination Using Wind Energy	3	3	2
	TECT Power – Turbine Blade Material Handling and Processing	2		3
	(2011-2012) - 37 out of 88 ME students are working on Multidisciplinary Projects (42%)			

Projects Deliverables

The deliverables for all three types of projects, International, Multidisciplinary and Industry Sponsored, are the same. During the Fall semester the teams had three oral presentations, Design Concept, Interim Design, and Final Design Presentations, and each team delivered four reports, Project Need Assessment and Scope, Project Plan, Concept Generation and Final Design Report. During the spring semester the teams have four presentations, three project review presentations and a final presentation. In the Spring semester is where they present their Final Project report. All presentations are required to be given by all the team members multidisciplinary and international students included.

At the end of the second semester and just before graduation, the capstone design course concludes with a one-day conference like review event featuring all the project's final presentations called "Open House". During the "Open House" event we invite all the faculty advisors from all the multidisciplinary departments, industry partners, industry mentors and junior mechanical engineering students to the "Open House". All teams make oral presentations describing their projects and findings this will be followed by a poster session where teams showcase their projects and the actual hardware and/or demonstrations. We have also integrated the annual open house with our continuous assessment process to identify any strengths and weaknesses of the curriculum for modifications and improvements. This tightly interwoven relationship between the capstone course, curriculum evaluation, and MEAC participation has served the department well in many fronts: continuous improvement of the capstone course and curriculum, harvesting of relevant projects for the capstone course through strong industrial involvement, and expanded career opportunities for our graduates.[2]

Conclusion

In this paper, an evaluation of the senior capstone design course at our university has been addressed as it has evolved through the past 13 years. The adaptation to the recent globalization scenario has been described, including the increasing participation of the industrial sector, project multidisciplinary and study-abroad program student exposure through international team projects.

In sum, our capstone senior design course has matured, with the creation of a firm foundation for attracting and fostering our industrial partners that provide the project ideas, funding, mentoring, and support of our students. It has also never stopped improving, thus the recent addition of global multidisciplinary projects, through which we see a new breed of students entering the workforce. These students not only have industry project experience, they now have the experience of dealing with obstacles once must jump over when working globally. It is expected

that as these students enter the workforce they will do so with extra confidence and an edge over many other applicants without such experience.

As this capstone course has proven, the multidisciplinary approach is an exceptional conduit to educate our students in team-based strategies and in the use of the fundamentals of engineering to real industrial problems. Now we have taken it to the next level, globalization, where our students must find a way to work with other engineering disciplines within our College of Engineering, as well as international university students, and the "customer", our industry sponsor. Globalization and multidisciplinary approach to solving a project benefits the industry by the team providing them a comprehensive solution, and with a group of students ready to enter the work force with global experience. The experience gained by our students far outweighs the challenges, we as educators face with the multidisciplinary approach and globalization.

Globalization is the future in engineering and our capstone senior design course is at the forefront, paving the way for our students. The course will continue to evolve by adding more global multidisciplinary projects and enhancing what is already in place.

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