# AC 2012-5262: REFLECTIONS ON TEACHING A CONSOLIDATED CAPSTONE DESIGN COURSE TO A MIXED STUDENT BODY

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# Reflections on Teaching a Consolidated Capstone Design Course to a Mixed Student Body

## I. Introduction

Design is widely considered to be the central or distinguishing activity of engineering [1]. The *Capstone Design* course has usually been designed as a senior project laboratory to allowing graduating seniors become prepared for working in industries or continuing graduate studies. Capstone is a standard course in almost every engineering specialty curricula, due to the strong encouragement of the ABET engineering accreditation criteria [2]. At Southeast Missouri State University, two ABET accredited programs, engineering physics (EP) and computer science (CS), had offered capstone design courses independently for many years. Virtually there were no interactions between these two courses offered at two departments.

In the last several years, under the intense financial pressure more courses have been consolidated to reduce the cost. Sometimes even similar courses offered at different departments were consolidated. This trend of consolidation to reduce cost has both the up and down sides. The down side is that the departments may lose the full control of the consolidated courses. The up side of this trend, however, is that such consolidations can potentially open the doors for more interdisciplinary collaboration opportunities. At our university, starting Spring 2010, capstone courses have been consolidated into one course that is offered to all seniors student from the above two majors. The course has been offered twice (Spring 2010 and Spring 2011), and this article presents our reflections on teaching such a course.

This paper is organized as follows. Section II gives the curricular background of the two majors and the delivery aspects of previous capstone courses before consolidation. Section III discusses the content of the new capstone course. Section IV presents our assessment and evaluation of the new format and compares it with the old offering. Section V concludes the article.

## II. Course Background and Organization before Consolidation

Southeast Missouri State University (Southeast) is a moderately selective, regional, comprehensive, public university. The main campus is located in Cape Girardeau, Missouri, on the bank of the legendary Mississippi River, with regional campuses in Sikeston, Kennett, Malden, and Perryville. Southeast offers more than 200 areas of study, with more than 9,000 undergraduate students and nearly 1,000 graduate students. Both EP and CS undergraduate programs at Southeast are relatively small, with enrollment of about 100 students each. The EP program is accredited by ABET EAC, and follows standard engineering curriculum. Most students in the program take a freshmen engineering design course in the first semester and gets their first exposure to the engineering design. They then take the two-semester capstone design course sequence in their senior year. In Fall semester, they take EP480 *Capstone Design I*, which is a one credit hour course that let students get started and primed for the main capstone course in the Spring semester. EP480 focuses on the early stages of design procedure, particularly defining the design problem, evaluation of alternative solutions, and system-level design. Students will form teams and choose their projects.

The Computer Science department offers two programs: Computer Science and Computer Information Systems (CIS). The CS program at Southeast is accredited by ABET CAC, and follows standard computer science curriculum. The CIS program, which is not accredited, has an application focus in that it requires a minor in some domain. Both CS and CIS majors have several common courses that include a three-course computer science sequence, database, data communications, software engineering (CS445) and capstone experience (UI450). The students coming to the CS445 course have considerable object oriented programming background. In CS445 they learn object oriented analysis and design and use modeling tools to produce system specifications. This prepares the students well for the UI450 apply these analysis and design skills and also produce a prototype to meet a client's computing system requirements

Before the course consolidation, both EP and CS programs offered their individual UI450 Capstone course tailored to their programs and students. The CS capstone continued content from their CS445 and covered many software engineering topics via their design projects. For the EP program, the capstone was more about letting students integrate and apply what they have learned in previous courses. The focus and the projects were also different in these two Capstone courses. For EP program, the projects were usually originated from the instructors' research activities and focused more on exploring new methods, materials, and/or procedures to solve an engineering problem. Because most EP projects were originated from faculty's on-going research, the source of funding for the projects was mainly internal, from departmental operation budget and from faculty's research funding. Besides writing project reports and presenting project progresses, most EP students wrote conference posters and papers and presented at regional, national, and/or international conferences.

For CS/CIS programs, the projects were usually originated from local and regional industries and organizations and focused more on delivering what the clients wanted. The CS/CIS students also learn some of the software engineering management concepts such as quality management, configuration management in UI450. These are in addition to Project Management and Communications Management that are common to all the UI450 students. To facilitate such variations, the class as a whole meets once a week to learn common topics. Faculty from both EP and CS share the load in teaching these common topics. During the second session, faculties meet with students from their respective majors and teach topics relevant to their majors.

Though EP and CS capstone courses were quite different, there were also a lot of similarities. Both courses were three credit hours and focused on project design and implementation. Both courses emphasized professional skills, including project design process and constraints, project management, team skills, oral and written communication, prototyping and testing, and professional ethics. All these professional skills were heavily linked to the capstone projects. Both courses required students to give presentations to their peer students and external evaluators. These differences and similarities were also consistent with the national trend [3-5].

## III. New Capstone Course

Due to the economy conditions and financial situations starting in Fall 2008, our university started to consolidate courses. Through the discussions in the Spring and Fall 2009 semesters, we decided to offer a consolidated capstone course starting Spring 2010 semester. We decided that the new course will be team-taught, with CS faculty directing CS students and EP faculty directing EP students. A primary instructor was selected to facilitate and coordinate the teaching process. We also decided that the course would meet three times a week, one hour each time. Among the three hours, each project team would meet with their supervisors two hours a week and discuss project-related issues. The remaining one hour would be the common hour that all CS and EP students would attend together and learn the common content of the course, mainly professional skills. This one hour would also be used for all the oral presentations and peer evaluations. Table 1 shows a typical course schedule for the common hour.

Broadly stating, the students work on the analysis and design of the system during the first eight weeks of the semester and on implementation in the second eight weeks. During the first half, they also learn and take exams on the support process, present their results orally for the other student teams to review, and prepare intermediary project reports. During the second half of the course, the students make the research presentation, complete the project, make the project presentation, demonstrate the system to evaluators, and prepare the final project report.

**Table 1**: Common Hour Schedule

| **Week #** | **Course Content** |
|---|---|
| 1 | Course overview, project management (plan) |
| 2 | Presentation #1: project scope and plan |
| 3 | Communications management (review meetings, delegation, negotiation) |
| 4 | Presentation #2: requirements specification (submit requirement specifications) |
| 5 | Project management (control) |
| 6 | Working in the global village (overview of cultural divergence) |
| 7 | Presentation #3: preliminary results of the project (submit requirement analysis report) |
| 8 | Discussion on new technologies (e.g., nano tech) |
| | Spring break, no class |
| 9 | Professional ethics and case studies |
| 10 | Presentation #4: project design (status) (submit project design report) |
| 11 | Presentation #5: ethical case studies |
| 12 | Project review meeting (submit progress report) |
| 13 | Project review & planning session for final product/findings presentation |
| 14 | Presentation #6: preliminary project presentation to class |
| 15 | Project demo of final product/findings to the public and external advisors |
| 16 | Final project documentation and other materials due |

The following professional skills were covered in the common hour: project design process and constraints, project management (including time and financial management), teambuilding and team dynamics, oral and written communications, prototyping and testing, professional ethics. Oral and written communications were emphasized; students gave six presentations to their peers and submitted quite a few reports related to their projects.

A course of this nature required careful planning. For EP students, the teams were formed and the projects were decided in the fall semester during their EP480 course. The projects usually originated from faculty members' research. The two faculty members teaching Capstone focus their researches in nano-science and robotics, so the team projects were in these areas. Some examples were:

- Synthesis of externally tunable, biocompatible, multifunctional nano-carriers for controlled release of drugs into neurons;
- Characterization of the specific absorption rate (SAR) of the magnetic nanoparticles encapsulated in hydrogel;
- Mechanical characterization of alternating magnetic field responsive hydrogels at the micro-scale;
- Toxicity study of the hydrogel encapsulated magnetic nanoparticles;
- Mobile robot navigation control using Apple iPad and Android smart phones;

In the CS/CIS capstone course, the projects from both internal and external clients were solicited during the fall semester. Ideal projects were those that were not time critical, that were put on ice for some reason (e.g., resource constraints), or that were left behind as alternatives but required a proof-of-concept. The instructor then compiled project outlines from different clients and presented them to the students during the last four weeks of their CS445 class in the fall semester. The students formed their own teams and chose their projects. Some projects may require students to research and learn new tools. In some cases, the students may have to seek additional domain knowledge. Because these projects were sponsored by industries and organizations, the emphasis was to deliver what the clients wanted. Some examples were:

- **Contract management system,** sponsored by a medical-equipment supply company and a software consulting company;
- **Flight data simulation,** sponsored by an aircraft manufacturing company;
- **Diagnostic articulations test systems,** sponsored by the paramedical training unit at our university;
- **Academic music search system**, sponsored by the Music Department at our university.

## IV. Assessment and Evaluation

Several assessment tools were used to evaluate students' performance in this course. The main assessment component was the completion of the client-sponsored project by the teams. The assessments involved oral presentations, a demonstration of the project, and written reports (delivered in four/five stages). We list below the various assessments and their weightings toward the final grade. See [6] for details on deliverables.

- Project reports in three parts (Analysis, Design, User Interfaces): 20% (5%, 10%, 5%)
- Project Demo to Advisory Board and other Faculty in CS/CIS: 10%

- Final Project Report: 10%
- Project Presentations – four (in class, peer evaluated): 20% (four each 5%)
- Project review participation: 5%
- Personal reflection (Individual): 5%
- Ethics Presentation (Common to all students): 10%
- CS/CIS Assessments (Exams in Management topics): 20%

All presentations and project demos were peer-graded by all the students enrolled in the course. A Likert scale based grading sheet was given to each student ahead of time so that the student could also know what were expected in their project. Because we have a mixed student body, this has enforced the students to learn how to present their ideas to "outsiders" and force them to practice their communication skills. A sample rubric on Week #2 presentation on project scope and plan presentation is given below:

**Table 2**: Evaluation Tool for Week #2: *Project Scope and Plan* Presentation

**Project Scope and Plan**: Orally present the context of the project, what are its broad aims, what are its major activities and the plan (who and when) for carrying out these activities.

Project Name: ______________________________________________

| Circle the number that indicates the appropriate rating of the presentation for the criteria listed below | | | | | |
|---|---|---|---|---|---|
| Criterion | Definitely Disagree | Disagree | Not Sure | Agree | Definitely Agree |
| The context was clearly stated | 1 | 2 | 3 | 4 | 5 |
| The aim of the project was clearly explained. | 1 | 2 | 3 | 4 | 5 |
| The activities needed for completing the project were discussed | 1 | 2 | 3 | 4 | 5 |
| The solution plan – time scale and resources –seem feasible | 1 | 2 | 3 | 4 | 5 |
| The team seems to be on the right track | 1 | 2 | 3 | 4 | 5 |

As mentioned before, most EP projects were in the fields of nano-science and robotics. Because nano-science and robotics are interdisciplinary research fields, these projects also often involved students from other departments, particularly biology, chemistry, and industrial and engineering technology. Besides what was required by the course, these students also wrote conference papers and presented their findings at the regional, national, and international conferences. A few examples were:

- C. Yuen, T. Nguyen, E. Bowers, K. Mabery, T. Boyd, and S. Ghosh, "Dose-dependent cyto-toxicity evaluation of a Quantum Dot based, Multifunctional, Nanoscale System for Biomedical Applications," *AAAS annual meeting*, San Diego, Feb 19-22nd, 2010.
- S. Meyer, L. Nickleson, R. Shelby, J. McGuirt, J. Peng, and S. Ghosh. "Mechanical Characterization of Alternating Magnetic Field Responsive Hydrogels at Micro-scale," *Society of Experimental Mechanics Annual Meeting*, Indianapolis, June 3-7, 2010.
- Lumpkin, J., Yuen, C., Rhodes, M., Bowman, S., Meyer, J., Peng, J., and Ghosh, S., "Renote-controlled, multifunctional nano-reservoirs for delivery of drugs into neurons", *Missouri NanoFrontiers Symposium, 3rd Annual Meeting*, Springfield, MO, October 25-26th, 2011.
- Lumpkin, J., Yuen, C., Burford, N., Gidney, E., McCallister, T., Peng, J., and Ghosh, S., "Evaluation of magnetic field induced losses of thermoresponsive, multifunctional, magnetic nano-carriers for hyperthermia and controlled drug release", *Materials Research Society Fall 2011 Meeting*, Boston, MA, Nov 27-Dec 2, 2011.

Overall, the course has been generally well-received by all the students. Most of them realize the importance of the "soft" skills, particularly the skill of how to communicate with people from different backgrounds. The exposure to a wide variety of design projects, however, has a polarizing effect: some students become interested in other majors while others withdraw and become detached.

## V. Conclusion

Capstone design courses provide students with an invaluable opportunity to apply the knowledge and skills that they have gained over the course of their educational project into an integrative, real world experience. It also provides students with a well-rounded experience applying both technical and professional skills. Due to the economic conditions and financial pressure, two capstone courses offered at both engineering physics (EP) and computer science (CS) departments at the authors' institution were consolidated to save the cost. The consolidated course actually turned into an integrated learning experience for both the EP and CS students alike. Students had the added value of working with users and developers of multiple levels and skills with different backgrounds and appreciated the interdisciplinary nature of capstone design projects.

The CS students submit a final project document that contains all aspects of the project. It includes the students' reflections, their specific contributions and a letter from the client regarding the acceptance of the final product. The students are allowed to borrow this document for showing it to their future employers when they go for employment interviews. Even though the instructor has to spend a significant amount of time in planning the projects, it is worth the trouble since real world projects add value to the overall quality of the students' educational programs.

For the EP students, besides the comprehensive final project document containing all aspects of the project, we also push them to publish their findings into research papers and present their papers at the regional, national, and international conferences. Integrating the capstone projects with undergraduate research has greatly benefited our students. More than half of the EP graduates have entered graduate programs at other universities to purchase master's and Ph.D. degrees.

We intend to continue with the combined Capstone Experience class for a few more years. We also plan to introduce more rigorous review processes for the analysis and design specifications by peers in order to enhance learning from each other. Further, the concept of integrated teams will be explored in the future.

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