

Computer Engineering and Systems Capstone Design Course at UW Tacoma

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In this paper, the CES capstone design course at UW, Tacoma is introduced. In this two-quarter course, seniors are required to work with freshmen-level CES students. They take on a project leader's role and provide the freshmen "interns" with the opportunity to learn how projects are developed and to participate in the development. Objectives, organizations, as well as outcomes of this course are presented. In the end, future plans to improve the teaching and learning experience are discussed.

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Introduction

The Computer Engineering and Systems (CES) program of the Institute of Technology at the University of Washington, Tacoma (UWT) was established in 2006 to satisfy the growing demand for engineers within the South Puget Sound region and to spread the prosperity of the high-tech economy to more residents of Washington State. The program produced its first graduates in June, 2009 and is preparing for an ABET (Accreditation Board for Engineering and Technology) accreditation visit in the fall of 2010.

The mission of the program is to educate each CES student to be a responsible and productive engineer who can effectively apply emerging technologies to meet future challenges. The CES curriculum was designed to include, science, mathematics, and engineering. It includes both the hardware and software aspects of digital systems and focuses particularly on embedded systems. A CES student must complete courses in electrical engineering fundamentals, courses in computer science fundamentals, and core courses in computer engineering. The program culminates with a capstone, senior design project.

The CES capstone design project at UWT is a two-quarter (Winter and Spring) sequence that is designed in accordance with the ABET requirements¹ for engineering programs. During the two quarters, students apply what they have learned from earlier courses in the program to develop an engineering project that is an integration of hardware and software components.

The purpose of this paper is to describe the CES senior capstone courses, TCES 481 and TCES 482, that were offered in 2009. This was the first time the courses were offered and the students who took these courses were the first graduates of the program.

The first course, TCES 481, is used to assess two ABET program educational outcomes: (g) an ability to

communicate effectively, and (i) a recognition of the need for, and an ability to engage in life-long learning. TCES 482 is used to assess outcomes (b) an ability to design and conduct experiments, as well as to analyze and interpret data. ABET outcome (e) an ability to identify, formulate, and solve engineering problems is assessed over the two-course sequence. Both TCES 481 and 482 cover materials related to outcomes (d) an ability to function on multi-disciplinary teams, and (k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice, but these outcomes are assessed in other courses.

Two important features of the CES capstone design courses at UWT are: (1) students are required to demonstrate proficiency in writing and inspecting engineering documents; (2) seniors taking the capstone courses are required to work with students in the freshmen-level courses TCES 102 and TCES 103. Compared with the EPICS program at Purdue² where multidisciplinary teams of undergraduates are designing, building, and deploying real systems to solve engineering-based problems for local community service and education organizations, our capstone project focuses on providing the seniors with the opportunity to take on a project leader's role and providing the freshmen "interns" with the opportunity to learn how projects are developed and to participate in the development.

In the remainder of the paper, we will present the course objectives, organization, and outcomes. Finally, we will discuss plans to improve the course.

Course Objectives

As the last courses in CES curriculum, the capstone design sequence requires the students to apply their knowledge on electrical engineering, computer science and computer engineering to complete an engineering project that demonstrates their ability to solve problems

in both software and hardware areas. All the objectives of the two courses are oriented toward the successful completion of a meaningful engineering project.

The TCES 481 objectives are that the student shall (1) gain experience defining, designing and managing a project; (2) learn how to document user and technical requirements; (3) become proficient in documenting designs; (4) gain experience giving technical presentations to groups; and (5) participate in peer reviews of engineering documents.

To satisfy these objectives, TCES 481 focuses on how to prepare the various documents needed in the early stages of the development process.

The instructor uses a combination of lectures, discussions, and laboratory activities to help each student prepare the documents needed for his or her capstone design project. These documents include project definition, project requirements, preliminary design, and work schedule. In addition to specifying the technical aspects of the projects, students must also address human factors, safety, reliability, maintainability, and customer cost.

The TCES 482 objectives are related to the later stages of the product development life-cycle. In this course the students must (1) know how to develop a test plan based on requirements; (2) understand how to define, design and implement a complete system; and (3) know how to test a project to determine whether it meets requirements.

This course focuses on the development and testing of the project specified and designed in the first course.

Based on the planning and preparation completed in TCES 481, students are organized into small teams to work on tasks associated with the later phases of the product development life-cycle. Although most of the work in TCES 482 is done in the labs, a few lectures on topics such as PCB layout and validation testing are given to help the students in specific areas. Students are also required to write and present status reports and to develop a validation plan.

Two goals for the courses that are not stated in the objectives listed above are to give the seniors some experience managing teams and to give freshmen the chance to see the type of projects seniors develop and how the life-cycle is used to guide development. The freshmen are also given the opportunity to work with laboratory equipment and to help construct and test the components of the projects. Seniors are required to meet with freshmen at least one day a week. The purpose of this weekly meeting is to give seniors the opportunity to develop leadership and project management skills. The seniors were also expected to define project tasks that freshmen were able to perform. The freshmen were put into an environment where they could understand the mission and requirement of our CES program, understand the concept of engineering project, learn

what is expected of a computer engineer, and learn importance of teamwork. It was also hoped that by participating in the senior design projects the freshmen would be more motivated to stay in the CES program. The effectiveness of the course in motivating and retaining the freshmen is reported in another paper³.

Course Organization

This section describes of the organization of the capstone courses. Table 1 shows the timeline of TCES 481. In addition to the deliverables that are bolded, Table 1 indicates the topics that are discussed in the lectures attended by seniors.

Table 1: Timeline of TCES481

Week	TCES 481 Topics and Deliverables
1	Lecture - Course Introduction; Engineering Product Design Process, Project Concept Generation and Evaluation, Time Management; Review of Project Concept and Oral Status Report templates
2	Lecture – Focused Inspections; Review of Technical Requirements template Project Concept due
3	Lecture - Review of Technical Requirements template, and Design Template
4	Lecture – Testing; Review of Test Plan template, and Status Report template
5	Lecture – System Reliability; Review of Project Schedule template
6	Lecture – Engineering Requirements Oral Status Reports due
7	Lecture – Professional and ethical dilemmas in software engineering; IEEE code of ethics Technical Requirements due
8	Preliminary Project Schedule due
9	Design Documents due
10	Project Presentations
11	Written Status Report due; Project Documentation due

Lectures in the first seven weeks are oriented toward helping students prepare the course deliverables rather than focusing on technical material. Topics include the product development life-cycle, project concept generation and evaluation, teamwork, project requirements, project design, project testing, reliability, and engineering ethics. Since we are trying to impress upon students the need for life-long learning, we require outside reading on topics related to product development. The article, “Professional and Ethical Dilemmas in Software Engineering⁴,” is required reading because it provides a good basis for discussions on engineering ethics issues. To broaden students’ perspective on engineering project management, the book *Design for Electrical and Computer Engineers: Theory, Concept and Practice*⁵ was introduced.

The last three class periods were for one-on-one meetings where progress was checked, and issues

students had regarding their projects was discussed. We provided templates and guidelines for students to write required project documents, and their writing homework was graded by using rubrics that were given to the students before the assignments were due. Because rubrics were used, students knew what was expected of them and seemed satisfied with their final grades.

Each of the seniors chose to work individual projects. Seniors first presented their design concepts to the freshmen. Freshmen then prepared their resumes stating their background and interests. After reviewing these resumes, seniors “hired” interns they felt could contribute to their projects.

An important group activity in this class was peer review of the project documents. The peer review process used was similar to the inspection process described by Gilb and Graham in *Software Inspections*⁶. Inspections are a structured activity involving a small number of people (author, moderator to organize and control the inspection, reader to interpret the document being inspected, and inspectors with specific checklist) to find omissions, ambiguities, or other defects in work items. Each inspection was led by a senior; others joined as inspectors and used checklist that were provided for each project document.

To ensure the successful teamwork, Dr. Jim L. Borgford-Parnell, who is the Assistant Director of CELT (Center for Engineering Teaching and Learning) at the UW Seattle campus, was invited to give students guidance on team work at the beginning of the quarter. Two evaluation forms were used to assess the teamwork at the end of the quarter: one to evaluate freshmen’s performance in the team and the other the other was used to evaluate the senior’s leadership and project management skills. After the students completed the relevant forms, we had a short meeting with each group to inform them the results, and more important, to give them instructions on how to improve teamwork in the following quarter. Students’ feedback together with the final course evaluation comments showed that seniors appreciated the opportunity of leading freshmen.

The timeline of TCES482 is shown in Table 2. Again, all the required deliverables are bolded. Guests from academia/industry were invited to the class to discuss engineering issues: one was on PCB layout and construction, and the other was on the writing of test plan.

Most of the team activities for the second quarter were related to building and testing the projects. The freshmen were able to contribute in many of these activities including: soldering components onto boards, testing wiring to verify correctness, writing simple test programs, developing mathematical models, finding parts, and testing components and the final projects. The interns also helped present status reports to the class.

Table 2: Timeline of TCES482

Week	TCES 482 Topics and Deliverables
1	Course requirements and deliverables; Review of Project Concept Document, Project Requirement Document, and Oral Status Report templates
2	Review of Design Template Oral Project Status due; Schedule update due
3	Guest lecture: PCB design using EAGLE Final design documentation due
4	Review of Test Plan template
5	Written project status report due
6	Guest lecture: How to go about making a validation plan? Draft test plan and procedures due
7	Review of Project Binder Requirement
8	Final test plan and procedure due
9	Oral Project Status due
10	Review of Presentation and Demonstration Guidelines
11	Final Presentation and Demonstration Project documentation binder due

Assessment of Course Objectives

To assess how well the seniors achieved the objectives of the two courses, the project documents, oral status reports, the project demonstrations, as well as the final project portfolios were evaluated.

Upon completion of TCES 481, the evaluation described above showed that all seven senior students had demonstrated the ability to:

- prepare a project concept document;
- write a technical requirement document;
- develop architectural and detailed design documents;
- make oral presentations;
- create and maintain a project schedule.

Upon completion of TCES 482, six out of seven senior students had demonstrated the ability to:

- develop detailed design documents;
- make oral presentations;
- maintain a project schedule;
- develop a test plan for a project;
- build a system or system component;
- test the operation of a system or component to prove it meets the requirements.

One student failed TCES 482 due to incomplete detailed design. This caused problems with the schedule and other documents. As a result, by the end of the course, he couldn’t present a complete project.

Example Project

An example of a successful design project, “Bigfoot” is described in this section.

Prior to the beginning of the capstone classes, several students visited the Smile Factory that is part of the

Child Therapy Unit at the Good Samaritan Hospital in Puyallup, WA. The students were shown the type of work done at the Smile Factory and told about the technology needs of the unit. One student was particularly interested in helping make improvement to a battery powered cart that children with special needs use to learn how to operate mobile devices. The Smile Factor loaned our student a cart that was controlled by a steering wheel and an acceleration pedal. The problem with the existing controls was that many of the children cannot operate a steering wheel with their hands or control an accelerator with their feet. The student developed an alternative control system that could be operated by pressing large buttons instead of turning the steering wheel and/or pressing the acceleration pedal. Children with poor motor skills can now drive the cart by simply pressing buttons. A parental override controller was also designed and added to protect the child.

“Bigfoot” was a well-balanced integration of both hardware and software, and equally important, it shows how a computer engineer can contribute to society.

Course Improvement Plan

Based on the students’ feedback and comments in course evaluation, we have planned to make a number of changes in the way the capstone course is taught. This was the first offering capstone design course and the students complained that there were not enough detailed examples of project documents for them to use as examples. In the next offering of the courses more example documents will be provided and discussed to help students in understanding and preparing their project documents.

The order of some lecture topics will be adjusted so that the material is presented at a more appropriate time and some topics will be moved from TCES 482 to TCES 481. The PCB layout and construction lecture, for example, is being moved to the first quarter so that students can order boards earlier, if they are ready.

In the first offering, seniors’ performance was assessed based on their attendance, project documents writing, oral presentation, team leading skills, and the project quality. We decided that the students would benefit from some quizzes throughout the quarter so that they would be motivated to keep up with the reading assignments. The bulk of the grade will still be determined by the quality of the project documentation.

Lab logs will be formally required. Group work, especially lab activities, is a big portion of the capstone design course. By requiring a lab log, hopefully, students will come to each lab with a clear objective in mind and proceed step by step to achieve success.

The first author has been awarded the Curriculum Enhancement Grant by UWT’s Center for Leadership

and Social Responsibility for the year 2010. This grant will be used to enhance the material presented on social responsibility. Students will be exposed to a series of activities including presentations by distinguished professionals, video programs, group discussions and debates, field trips to industrial sites, and visits to community organizations.

One of the senior project leaders set up a blog to facilitate communication with his interns. This was deemed a success by both the interns and the project leader. Therefore, all project leaders will be required to use blogs to communicate with their teams this year.

Some project leaders made very effective use of their interns but some did not. To try to improve this situation, project leaders will be required to develop a task list for their interns.

A final change will primarily affect the freshmen interns in the first course, TCES 481. This past year the interns met with the seniors every week and were involved heavily in the inspection process. After the project concept document, the interns felt they had very little to contribute to the process and they were bored. Therefore, in the next offering of the class, the interns will only be working with the seniors for three or four weeks. The remainder of the time they will be learning MATLAB and given brief introductions to logic design and circuit design.

Conclusions

In this paper, we described our first experience in offering capstone design courses, TCES 481 and TCES 482, to UWT CES students in year 2009.

As with most new courses, there were some good features and some that needed improvement. We plan to continue having freshmen interns work with the seniors in the coming academic year but we will make some changes to improve teamwork and give the freshmen a more stimulating experience.

References

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