ASEE 2022 ANNUAL CONFERENCE
Excellence Through Diversity
MINNEAPOLIS, MINNESOTA, JUNE 26TH-29TH, 2022 ASEE
Paper ID #37813

Capstone Courses in a New ABET Accredited Electrical Engineering Program

Afsaneh Minaie

Afsaneh Minaie is a Professor of Electrical and Computer Engineering and Interim Dean of the College of Engineering and Technology at Utah Valley University. She received her B.S., M.S., and Ph.D. all in Electrical Engineering from University of Oklahoma. Her research interests include gender issues in the academic sciences and engineering fields, Embedded Systems Design, Mobile Computing, Wireless Sensor Networks, Nanotechnology, Data Mining, and Databases.

Reza Sanati-mehrizy (Professor)

Capstone Courses in a New ABET Accredited Electrical Engineering Program

Abstract

The purpose of capstone design project courses is to provide graduating senior students the opportunity to demonstrate understanding of the concepts they have learned during their studies. As with many computer science and engineering programs, students of the electrical engineering program at Utah Valley University (UVU) conclude their degree programs with a two-semester capstone design experience. The intent is for students to utilize competencies developed in the first three years of the curriculum in the solution of a complex design problem.

This paper will elaborate the detail content of the curriculum for our new electrical engineering program as well as the two-semester long capstone design courses. The paper also presents the primary experiences of teaching capstone I and II to our electrical engineering students. The description of these courses is first given, including course contents, learning outcomes and instruction approach.

Introduction

Utah Valley University is a comprehensive regional university with over 41,000 students charged with serving Utah County, which is the second largest county in the state. UVU is regionally accredited at the institution level by the Northwest Commission of Colleges and Universities. UVU has a dual mission – that of a comprehensive university offering 91 bachelor's degrees and 11 master's degrees, and that of a community college offering 65 associate degrees and 44 certificate programs. To fill its community college mission, the institution maintains an open-enrollment policy. UVU has a high percentage of low-income (38%) and first-generation (37%) students. It also has a high number of non-traditional students (29%), students with spouses (35%) and/or children under age 12 (19%). Even though tuition is low, part-time attendance is high at 36% of degree-seeking students. These factors affect the overall graduation rate, which is low at 33% (nationally standardized IPEDS rate for completions in 150% time) and the overall 1-year retention rate of 67% for baccalaureate-degree seeking students.

As an integral part of its mission and core themes, UVU seeks to engage students using real-world contexts within and outside the curriculum to increase professional competence and confidence. The university has been designated a Carnegie Community Engagement Institution for both Curricular Engagement and Outreach and Partnerships and takes pride in this distinctive approach to teaching and learning. Engaged learning (active learning) has been incorporated into the curriculum for the target engineering and computing programs. Faculty consciously aim to create an environment conducive to engaged learning—a friendly, productive environment where students are known by name and know one another, where they learn to develop and

respect diverse talents through collaborative projects in pairs and in teams, and where they learn by doing and by communicating about what they do [1-5].

UVU's Engineering and Computer Science Initiative

To address a critical shortage of engineers and computer scientists [6], the governor and state legislature established the Utah Engineering Initiative in 2001 and have continued its funding [7]. The ongoing initiative provides money to engineering and pre-engineering programs so they can increase their capacity to train students; it aims to double the number of graduates in engineering and computer science. UVU has received funds to build new engineering programs, hire new faculty, and equip laboratories. In support of the Utah Engineering Initiative, John Warnock, co-founder of Adobe Systems, Inc., wrote the following for the *Salt Lake Tribune* in 2019: "Among Utah's legislative strategies for growing the economy, the long-running Engineering Initiative stands out as an unqualified success." He cites the strategic location of technology companies in the area—Adobe, IM Flash, L3 Technologies, Northrop Grumman, Ancestry, Boeing, BAE Systems, and Overstock—to attract engineering and computer science graduates from Utah universities. He notes that Hill Air Force Base typically hires nearly 200 engineering graduates per year. "Perhaps the Engineering Initiative's greatest success has been the creation of high-paying jobs for Utah's university graduates. An engineering or computer science graduate coming out of one of Utah's eight universities and colleges today can expect multiple offers from established companies and new ventures" (Warnock, 2019). The new electrical engineering program will build on this strong foundation and help UVU contribute to state efforts.

Engineering Department

To meet one of the region's most pressing workforce needs, UVU initiated three new engineering programs in Fall 2018. The new bachelor's degree programs in Electrical Engineering, Civil Engineering, and Mechanical Engineering have joined UVU's established programs in Computer Engineering and Pre-Engineering in a new Department of Engineering. The new programs were immediately popular with students, with 300 students enrolling for Fall 2018. Currently, the new Engineering Department has more than 900 students in five programs which are housed in that department.

The Electrical Engineering program is accredited by the Engineering Accreditation Commission of ABET (Accreditation Board for Engineering & Technology). New faculty have been hired with an emphasis on expertise and commitment to teaching, a background in industry, and having received both a bachelor's and Ph.D. in the field they are teaching. The Electrical Engineering program has an advisory board comprised of representatives of local industry who assist in aligning the program to industry needs and helping to acquire industry support and resources. In relation to COVID-19, all courses now have the capacity to be delivered online.

Utah Valley University maintains an open admission practice, admitting all applicants whose qualifications indicate they may benefit from the instructional programs offered. Admission to the University does not constitute admission into an individual major or program of study. Students are admitted to the Electrical Engineering Program after having been admitted to the university and after completing a selected set of courses with specific grade and GPA requirements.

Admission to the Electrical Engineering Program

To be admitted to the Electrical Engineering Program at UVU, a student must complete the foundation courses as listed in Table 1 with a minimum grade of C in each course and a cumulative grade point average of 2.5 or above.

A student not meeting all the admission requirements, may request in writing, a provisional admission status for a semester from the department. The provisional admission status must be approved by the electrical engineering program coordinator.

Table 1 - Foundation Courses Required for Admission

Area		Course	Credits
Electrical and Computer Engineering (ECE)		ECE 1000 - Introduction to Electrical and Computer Engineering	3
		ECE 2700 - Digital Design I	3
		ECE 2705 - Digital Design I Lab	1
		ECE 2250 - Circuit Theory	3
		ECE 2255 - Circuit Theory Lab	1
Mathematics		MATH 1210 - Calculus I	4
		MATH 1220 - Calculus II	4
Science		PHYS 2210 - Physics for Scientists and Engineers I	4
		PHYS 2215 - Physics for Scientists and Engineers I Lab	1
		PHYS 2220 - Physics for Scientists and Engineers II	4
		PHYS 2225 - Physics for Scientists and Engineers II Lab	1
Computer Science		CS 1400 - Fundamental of Programming	3
			Total: 32

Students with a cumulative GPA less than 2.5, more than two courses missing, or not meeting the minimum course grade of C at the time of application are automatically denied.

Graduation Requirements:

1. Completion of a minimum of 125 semester credits, with a minimum of 40 upper-division credits.
2. Overall grade point average of 2.5 or above, with a minimum grade of C in all discipline core and elective requirements.
3. Residency hours - minimum of 30 credit hours through course attendance at UVU. Ten of these hours must be within the last 45 hours earned. At least 12 of the credit hours earned in residence must be in approved CS + ECE courses.
4. All transfer credit must be approved in writing by UVU and the electrical engineering program coordinator.
5. No more than 80 semester hours and no more than 20 hours in CS and ECE courses of transfer credit.
6. No more than 6 semester hours may be earned through independent study.
7. Successful completion of at least one Global/Intercultural course.
8. Taking Fundamentals of Engineering (FE) (NCEES - Electrical and Computer Engineering) exam.

The graduation requirements for the Electrical Engineering (EE) program are summarized in Table 2.

Table 2: Summary of Graduation Requirements (Total Program Credits: 125)

Basic Engineering and Computer Science (14 credits):			**Credits**
	ECE 1000	Introduction to Electrical and Computer Engineering	3
	CS 1400	Fundamental of Programming	3
	ECE 2250	Circuit Theory	3
	ECE 2255	Circuit Theory Lab	1
	ECE 2700	Digital Design I	3
	ECE 2705	Digital Design I Lab	1
Mathematics and Science (34 credits):			

	MATH 1210[1]	Calculus I (also meets general education requirements)	4
	MATH 1220	Calculus II	4
	MATH 2210	Calculus III	4
	ECE 3710	Applied Probability and Statistics for Engineers and Scientists	3
	ECE 2750	Engineering Analysis	3
and	CHEM 1210[2]	Principles of Chemistry I (also meets general education requirements)	4
	CHEM 1215	Principles of Chemistry I Laboratory	1
and	PHYS 2210[3]	Physics for Scientists and Engineers I (also meets general education requirements)	4
	PHYS 2215	Physics for Scientists and Engineers I Lab	1
and	PHYS 2220	Physics for Scientists and Engineers II	4
	PHYS 2225	Physics for Scientists and Engineers II Lab	1
General Education Requirements (26 credits):			
or	ENGL 1010	Introduction to Academic Writing (3)	3
	ENGH 1005	Literacies and Composition Across Context (5)	
	ENGL 2010	Intermediate Writing Academic Writing and Research	3
Complete one of the following:			3
	HIST 1700	American Civilization (3)	
	HIST 1740	US Economic History (3)	
and	HIST 2700	US History to 1877 (3)	
	HIST 2710	US History since 1877 (3)	
	POLS 1000	American Heritage (3)	
	POLS 1100	American National Government (3)	
Complete the following:			

[1] Also meets general education requirement in course catalog

	PHIL 2050[4]	Ethics and Values (also meets a Global/Intercultural course requirement)	3
or	HLTH 1100	Personal Health and Wellness (2)	2
	PES 1097	Fitness for Life (2)	
Distribution Courses:			
	Biology Distribution		3
	Fine Arts Distribution		3
	Humanities (COMM 1020 Recommended)		3
	Social/Behavioral Science (COMM 2110 Recommended)		3

Upper Division Core Requirements (40 credits):			**Credits**
	ECE 3250	Energy Conversion	3
	ECE 3350	Control Systems	3
	ECE 3450	Electromagnetics and Transmission Lines	3
	ECE 3730	Embedded Systems I	3
	ECE 3740	Digital Design II	3
	ECE 3760	Electronic Systems	3
	ECE 3765	Electronic Systems Lab	1
	ECE 3770	Signals and Systems	3
	ECE 3780	Communication Systems and Circuits	3
	ECE 3785	Communication Systems and Circuits Lab	1
	ECE 4700	Computer Architecture for Engineering Applications	3
	ECE 4730	Embedded Systems II	3
	ECE 4750	Digital Signal Processing	3

[2]Also meets general education requirement in course catalog
[3]Also meets general education requirement in course catalog
[4]Also meets general education requirement in course catalog

	ECE 4755	Digital Signal Processing Lab	1
	ECE 4760	VLSI Design	3
	ECE 4765	VLSI Design Laboratory	1
	ECE 4900	Electrical and Computer Engineering Capstone I WE	3
	ECE 4950	Electrical and Computer Engineering Capstone II WE	3
Upper Division Elective Requirements (6 credits):			
Students choose 6 credits from the following.			6
	ECE 4770	Artificial Neural Networks (3)	
	ECE 4780	Wireless and Mobile Communications (3)	
	ECE 4250	Power Systems Engineering (3)[6]	
	ECE 481R	Electrical and Computer Engineering Internship (3)[7]	
	CS 4480	Digital Image Processing and Computer Vision (3)	

The Electrical Engineering program awards a Bachelor of Science in Electrical Engineering. The electrical engineering curriculum was designed to give our students strong background in the fundamentals of electrical engineering and adequate knowledge in advanced topics in this ever-changing field. A balance between theory and practice is carefully incorporated into the curriculum by the faculty. In order to graduate with an electrical engineering degree at UVU, students must complete 125 semester hours of course work. The current curriculum consists of 36 hours of General Education requirements and 83 credit hours of Discipline Core requirements, and 6 credit hours of Elective requirements.

Electrical Engineering Capstone I and II Writing Enriched (WE) Courses

Capstone courses play a crucial role in Electrical Engineering curricula. The principal purpose of a Capstone project course is to offer a summative opportunity for graduating senior engineering students to apply their professional skills and knowledge in a single experience and prepare them for work in industry. Like many engineering programs, students at UVU complete their requirements for graduation with a two-semester long capstone design project courses. The intention of these courses is to apply competencies gained during their first three years toward the solution of a design problem. Our senior design courses are structured as a collection of independent student projects. As our students are required to design, build, and troubleshoot a fully functional project, they find these courses both challenging and rewarding.

The purpose of senior projects is to provide students with realistic project development experience similar to what may be expected in industry. The senior project experience is divided into building skills in four major areas:

- Teamwork
- Project Management
- Research & Development
- Communication

These are the most important skill areas to the success of an engineer.

Teamwork - Engineering projects typically take place in teams. Each member of a team must fulfill his or her share of the load, and ideally, improve the performance of other members of the team. Team members must help each other both to define and to accomplish the task of the team. In this course, team building situations naturally arise and students are evaluated based on how they respond to those situations and their overall effectiveness as a team.

Project Management - Delivering projects in a timely manner within budget is key to competitiveness in electrical and computer related industries. Careful planning and execution of a project plan are very important to controlling schedules, costs and features for development projects. Successful engineers understand project management and its importance to the organization.

Research and Development - Engineers must be technically competent to design circuits and systems to solve problems, but not all designs need to start from scratch. Engineers must be able to perform research that leads to solutions, and they must be able to apply design principals learned elsewhere to the problem at hand. Furthermore, engineers must be able to fabricate professional quality prototypes to implement and test their designs.

Basic knowledge of soldering, printed circuit design, and hardware skills are required for well-built prototypes.

Communication - Engineers must be able to clearly document their activities so others can easily understand what they have done. Products require enough documentation that allows someone else to understand and modify the product for different applications. Schematics and block diagrams must follow industry standards. Circuit descriptions must be technically correct and easy to read. Engineers must also be able to verbally communicate with clarity and ease of understanding. Presentation skills are important for all engineers, particularly those working in teams.

Capstone I Course (ECE 4900)

Capstone 1 is the first course in the series of two required for graduation. The course requires the completion of the following significant milestones:

1. Form a Team
2. Proposal Approved
3. Project Plan Complete
4. Hardware Components in Hand
5. Critical Circuits Proven
6. Preliminary Design Review

The faculty advisor will meet with each team individually on a weekly basis at a regularly scheduled, mutually agreeable time. At each meeting, issues associated with the project will be discussed and a status report will be provided to the advisor. After the teams have been formed, each team will meet with the faculty advisor each week. Students are expected to contribute about 10 hours per week for a total 150 hours during the semester. A letter grade will be given at the end of the semester.

Course Schedule:

The following is a general schedule template, typical of this type of research project:

Week	**Activity**
1	Work on Project Proposal
2	Submission of project proposal
3	Finalization and acceptance of project proposal by faculty advisor
4	Project Plan and Research
5	Project Plan and Research
6	Project Plan Submission
7	Research and Work on Prototype
8	Research and Work on Prototype
9	Work on Prototype
10	Work on Prototype
10	Proposed Design
11	Proposed Design
12	Write Report
13	Write Report and develop oral presentation

14	Proposed Design Review
15	30-minute Oral Presentation of Prototype and Proposed Design

Grading Rubric:

The final grade is calculated on a 100-point scale, with the maximum number of points for each area of assessment as follows:

Quality and rigor of Report	20 points
Quality of Weekly Reports	10
Participation in Weekly and Team Meetings	5
Quality of Project Proposal	10
Quality of Project Plan	15
Quality of Prototype	10
Quizzes	10
Quality of oral presentation	20
Total possible points:	100

This course is offered every fall semester. Both electrical and computer engineering students are required to take this course. The prerequisite for this course is Embedded Systems I and University Advanced Standing. The course description is as follows:

This course focuses on team-oriented design projects and technical writing by incorporating group projects, oral presentations and written reports. Incorporates engineering standards and realistic constraints including economic, environmental, sustainability, manufacturability, ethical, health and safety, social, and political. Emulates the problems encountered by engineers working in commercial, industrial, and governmental entities. Capstone I and II must be taken in consecutive semesters.

Course Objectives: Successful completion of this course should enable you to do the following:

- Plan an engineering project involving multiple tasks
- Design electrical systems that meet defined constraints
- Communicate technical information on writing

- Identify business issues related to technology
- Explain the impact of engineering on societal issues
- Analyze the economics of designing and manufacturing the engineering artifact

Traits: Upon successful completion, students should have the following attitude(s)/traits:

- Confidence in their ability to design.
- Confidence in their ability to communicate technical information effectively.
- Effectively communicate through written reports, visual and oral presentations.

Textbook: "Design for Electrical and Computer Engineers: Theory, Concepts, and Practice", Ralph M. Ford and Chris S. Coulston, McGraw-Hill Higher Education, ISBN 987-0-07-338035-3.

The following topics are covered in this course:

- The Engineering Design Process
- Project Selection and Need Identification
- The Requirements Specification
- Concept Generation and Evaluation
- Teams and Teamwork
- Ethical and Legal Issues
- Engineering Economics

Capstone II (ECE 4950)

Capstone II is the second course in the series required for graduation. The course requires the completion of the following significant milestones:

1. Proposal Obligations Fulfilled
2. Project Demonstration
3. Documentation and Poster Complete
4. Final Design Review
5. Logbook Complete

The course objective is as follows:

Course Objectives: Successful completion of this course should enable you to do the following:

- Design an electrical system or process to meet given specifications with realistic engineering constraints
- Use effective team processes, communication, and conflict resolution skills

- Implement an electrical system
- Troubleshoot an electric system
- Present the design project results orally and in writing format

Traits: Upon successful completion, students should have the following attitude(s)/traits:

- Confidence in their ability to design.
- Confidence in their ability to communicate technical information effectively.
- Effectively communicate through written reports, visual and oral presentations.

The prerequisite for this course is Capstone I. This course does not have a scheduled lecture time. The faculty adviser will meet with each group of students weekly. The following is a general schedule template, typical of this type of research project:

Week	**Activity**
1	Course Overview and Introductions. Project Design
2	Project Design – Design Specification
3	Project design - Acquisition of Project Resources
4	Project Execution – Register for FE Exam
5	Project Execution
6	Test Plan Generation and Testing
7	Testing; Complete Proposal Obligations
8	Write Project Report; Writing Center Visit 1
9	Hardware Demo
10	Software Review
11	Prepare Abstract and Poster for a Conference
12	Write Project Report and Operation Manual
13	Write Project Report and Develop Oral Presentation; Writing Center Visit 2 Complete Logbook – Should have taken the FE Exam
14	Submit Written Project Report to Faculty Adviser
15	45-Minute Oral Presentation of Project Results (15 minutes presentation for the university's website)

The primary deliverable is a written project report. The project must be thoroughly documented, so that someone with general computer and electrical engineering expertise would be able to fully understand it without any prior exposure. Another deliverable is an oral presentation to Engineering Department faculty, industry, public, and students. During this 45-minute presentation, the student will explain the project at a level appropriate for a general engineering audience (i.e., in less detail than the written report), demonstrate any products produced, and answer questions about the project. Note that the 45-minute time slot includes any time required to set up and remove equipment.

Each faculty member in attendance will evaluate the oral presentation using the following rubric, with the maximum number of points for each area of assessment as follows:

Quality of verbal communication	30 points
Quality and utilization of visual aids	20
Quality of project demonstration	20
Quality of responses to faculty questions	20
Relevance to student's program	10

Total possible points 100	

Also, a 15-minute video presentation for the department to be posted on the Engineering Department's website.

Grading:

The project final grade is calculated on a 100-point scale, with the maximum number of points for each area of assessment as follows:

Quality and rigor of research and research paper	20 points
Quality of weekly reports	5
Quality of other deliverables (hardware design, integration, management plan, code, etc.)	15
Degree to which project fulfills requirements specified in project proposal	20
Level of effort	5
Submission of Abstract and Poster to conference	5

Progress reports received on time	10
Quality of oral presentation	20
Total possible points:	**100**

At UVU, every student earning a bachelor's degree will need to have passed at least 2 Writing Enriched (WE) courses to graduate. A Writing Enriched course is a disciplinary class that includes not only written assignments but also writing instruction as important components. It is important to note, though, that Writing Enriched does not mean "writing intensive." The WE initiative is not asking for certified courses to be "writing classes;" instead, writing should be seen as one of several instructional focuses. Therefore, every Bachelor's-granting department will need to ensure they have 2 WE course within each of their majors. WE courses must include high-stakes writing assignments and frequent low-stakes writing activities. In the electrical engineering program, the two capstone courses are designated as WE course.

Concluding Remarks

This paper has discussed in some detail the curriculum design of a new electrical engineering program at the Utah Valley University which is an open admission university. This new program provides a four-year electrical engineering program with solid foundation in mathematics, science, and engineering fundamentals while providing the latest tools for engineering analysis and design. The emphasis of our new electrical engineering program is power engineering. We hope that this curriculum design will be helpful to other colleges and universities in developing new electrical engineering programs. This new program is designed to meet ABET requirements and is accredited by ABET.

References

[1] Chickering, A.W., Gamson, Z.F., "Seven Principles for Good Practices in Undergraduate Education", American Association for Higher Education, AAHE Bulletin, p. 3-7, 1987.

[2] Kissel, Z. A., & Stuetzle, C. S., "Experiential Learning Framework for Smaller Computer Science Programs", Consortium of Computing Sciences in Colleges, Northeast Region Available at: https://scholarworks.merrimack.edu/cs_facpub/17.

[3] Werner, L.L., Hanks, B., McDowell, C. "Pair-Programming Helps Female Computer Science Students, ACM Journal of Educational Resources in Computing", Vol. 4, No.1, March 2004, Article 3.

[4] DeClue, T.H., "Pair Programming and Pair Trading: Effects on Learning and Motivation in a CS2 Course", Journal of Computing Sciences in Colleges, May 2003.

[5] Phillips, H., Ivins, W., Prickett, T., Walters, J., and Strachan, R., “Using Contributing Student Pedagogy to Enhance Support for Teamworking in Computer Science Projects”, Computing Education Practice, Jan. 2021.

[6] Lee, J. “Demand outpacing supply of Utah tech and engineering grads”, Deseret News, Feb 23, 2015. Retrieved from https://www.deseretnews.com/article/865622637/Demand-outpacing-supply-of-Utah-tech-and-engineering-grads.html

[7] Warnock, “Utah’s Engineering Initiative has boosted state’s high-tech boom”, Salt Lake Tribune, January 21, 2019. Retrieved from https://www.sltrib.com/opinion/commentary/ 2019/01/31/john-warnock-utahs/.