Use of Senior Mini-Project for Electrical and Computer Engineering Curriculum Assessment

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Abstract

Although many mechanisms exist for engineering course assessments such as teacher/course evaluations, homework and test results, and student office visits, developing new mechanisms for curriculum assessment can be difficult to implement and analyze. This paper discusses the six-week mini-project for senior students in the Electrical and Computer Engineering program at Bradley University. Use of the mini-project to increase the design content in our curriculum has been in place for ten years. The results have been used successfully to implement course, laboratory, and curriculum modifications. The paper will discuss the small products developed, curriculum modifications, project development time and costs, and how the mini-project will be used in the new Engineering Criteria 2000 accreditation process.

I. Introduction

The six-week senior mini-project is a small but vital component of our Electrical and Computer Engineering (ECE) undergraduate laboratory sequence at Bradley University. The laboratory program consists of a five semester sequence of independent lab courses culminating in a capstone design project in the last one and one-half semesters. The mini project, which has been used since 1991, has been a valuable tool to assess students, curriculum, and laboratory facilities deficiencies. A new mini-project is developed each year which is a small product design that can be completed in a six-week period by two students. From a student point of view, the primary objective of the mini project is to design a product or instrument given a set of specifications.

Our department is preparing for our first ABET visit under the new Engineering Criteria (EC) 2000 guidelines. The paper will show how we are using this design project to satisfy items in Criteria 3: Program Outcomes and Assessment[1]. The paper is divided into the following eight sections: brief description of our laboratory program, mini-project description and grading methods, mini-project history, mini-project as an assessment tool, curriculum modifications, mini-project development time and costs, 1999 mini-project, and concluding remarks.

II. Laboratory Program

The laboratory program consists of a sequence of required independent laboratory courses during the sophomore, junior, and senior years of the undergraduate program. These laboratory courses draw on the concurrent and prerequisite required and elective courses in the undergraduate program for their experimental topics. The mini-project occurs during the student's senior year in the first semester laboratory EE451.

The required design component of the ABET guidelines for engineering accreditation has received much study during recent years[2-6]. Many required and elective engineering courses in our undergraduate curriculum involve a design component. This design component, related to individual course areas is important to the program and is commonly used to satisfy the majority of the ABET design component. However, the ECE faculty have long recognized that design cannot be taught in one course. Our students also gain design experience through the program's laboratory courses[6]. Each of the laboratories have several experiments where the student is required to design, build, and test a circuit or system for which a design specification is given. A short description of each laboratory is given below.

<u>EE206 Sophomore Laboratory</u>: This second semester laboratory course has a three hour per week laboratory period and a one hour per week lecture/discussion period. The experiments for the laboratory are taken primarily from the *introductory circuit analysis and digital design courses*, which are prerequisites.

<u>EE331-EE332 Junior Laboratory</u>: These laboratory courses are taken during the two semesters of the junior year. They are each a total of six contact hours on one day of the week. Experimental areas include the required junior level courses of *signals and systems, electronics, microcontroller interfacing and programming, electromagnetic field theory, and energy conversion*.

<u>EE451-EE452 Senior Laboratory</u>: These laboratory courses are taken during the two semesters of a student's senior year of studies. Each laboratory has a total of six contact hours on one day of the week. The first two weeks of the fall semester is devoted to the design of a differentiator circuit with relatively stringent specifications. The next six weeks is devoted to the mini-project design. The second half of the fall semester is devoted to preliminary design work and the writing of a formal proposal for the student's final senior capstone project. The second semester course is devoted entirely to the student's capstone project.

III. Mini-Project Description

The primary objective of the mini project is to design a product or an instrument given a set of specifications. Time constraints and project requirements require an efficient two-student design team approach. Division of the project tasks is critical for completion of product design because of the tight schedule of 36 hours of laboratory time (6 hours per week for six weeks). The projects are multi-disciplinary requiring experience in the analog, digital, microcontroller hardware, and software design areas. Sensors have been incorporated in all projects which are required for measurement of information such as temperature, humidity, velocity, pressure, sonar, and speech.

A one page condensed version of the mini-project requirements is given to the students one week prior to the official start of the mini-project. Previous years' project descriptions can be found on our mini-project web site[7]. Supplementary documents vary from year to year but always include grading information, suggestions for extra credit work, hard to find data sheets, and formats and requirements for the laboratory notebook and the preliminary and final reports. The mini-project represents 25% of the EE 451 Senior Laboratory I course grade. The components of the mini-project grading are shown below in Table I and the grading scale in Table II.

Table I: Mini-Project Grading Components.

Preliminary report	10%
Demo	20%
Final Report	35%
Notebook	35%

Table II: Grading Scale.

90-100%	A
80-89%	B
60-79%	C
40-59%	D
<40%	F

The preliminary report is due at the beginning of the 3rd mini-project period and has two main objectives; design reviews and continuous project documentation. Continuous project documentation is stressed because it is vital for a tight project schedule. Instructor/student "design" interaction is minimal during the first two weeks. It is felt that the students should explore alternative designs and converge to a division of tasks during this period. The report will include a system block diagram, software flowchart, preliminary circuits, how the project tasks will be divided, and a schedule of when the tasks will be performed. Graded proposals are returned during the 3rd period to allow students to make the necessary design adjustments.

During the last half of the sixth laboratory period, each team is required to perform a 15-20 minute demonstration showing they have a working product and have met the original specifications. Each student receives an individual grade based on the project division of tasks outlined in their preliminary report. A working product is the priority for the demo grade. As an example, using Table II, a 65% working product is given a numerical grade of 65 which corresponds to C- work. A maximum score of 110% is possible if the team adds extra product features. Detailed technical assessment is accomplished during the laboratory notebook and final report grading for consistency. However, any technical problems observed during the demo that would affect high-volume production are recorded for future notebook and report grading.

It is stressed to the students during the first mini-project period that although a working unit is a nice milestone, design for high volume production is the critical item for the mini-project. Therefore, this is the reasoning for the low demo grade percentage of 20% while the laboratory notebook and final report grade percentages are 35%. The key to "A" work is using non-cookbook and low-cost methods as documented in the laboratory notebook. Out of 18 student teams, normally 4-5 teams receive a demo grade of 100% or more. However, it has been observed over the years, these same teams' notebook grades can range anywhere from D to A work. This highlights that a "100% working product" can have many fundamental design problems in regard to high-volume production. Also, some students do a poor job with project documentation. Every aspect of the software and hardware design process is addressed during the notebook grading. Again individual grades are assigned based on the division of project tasks. Each notebook requires approximately 30 minutes to grade with the length varying from 10 pages (F work) to over 100 pages. There were 33 students in the 1999 class.

Each team submits one final report which is due the period following the demo. The report will include block diagrams, flow charts, final schematic, and a concise narrative of the product design and division of tasks. Only a summary of the major design items are discussed in the report. The report is graded strictly in regard to grammar and spelling errors, conciseness, and use of figures in the narrative. This year a record of the amount of time required for the project completion was required. The development time was separated into the following categories: hardware design, software design, system integration, system debugging, system testing, familiarization with development tools, and documentation. This experience should prove valuable when the students generate their schedule for their senior capstone project.

IV. Mini-Project History

Use of the mini-project to increase the design content in our curriculum has been in place for 10 years. Use of the mini-project as a formal curriculum assessment tool begin in 1996. Assessment will be discussed in the next section. Following is a list of the mini-projects from 1991-2000:

2000: Component Oven Temperature Control
1999: Object Detection Using Sonar
1998: Temperature/Humidity Event Recorder
1997: Blood Pressure/Heart Rate Measurement
1996: Voice Recognition System
1995: Motor Speed Measurement System
1994: Differential Frequency Counter
1993: Automatic Phase Meter Instrument
1992: Frequency Measurement Instrument for a Strobotac
1991: Capacitance Measurement Instrument

Up to 1996, students were provided the freedom of implementing their designs in discrete logic and analog circuitry, programmable logic devices, or microcontrollers. The majority were 100% hardware with discrete circuitry. For example, one group implemented the 1996 voice recognition system with approximately 50 logic gates and counters and several operational amplifiers with associated circuitry for the analog to digital interface. Their circuitry was contained on approximately eight seven by two inch breadboards and was about 75% functional at the end of six weeks. Another group used a microcontroller approach where the majority of the system functions were in software. Their circuitry was contained on one breadboard and fully functional. Although the first group gained valuable design experience, their method was not practical for an industry product with a tight product schedule. It could be argued that they could later implement their method in a programmable logic device but the primary goal of the mini-project is to have a working system after six weeks.

V. Mini-Project as an Assessment Tool

The student discrete-component design example initiated the use of the mini-project as a formal curriculum assessment tool by the authors. The design case formulated the following questions regarding our curriculum:

(1) Are we teaching our students to consider product schedules in their design cycle?
(2) Are we providing the necessary laboratory equipment and supplies for a short design cycle product? Equipment and supplies include instrumentation, software and hardware development systems, microcontrollers, programmable logic devices, etc.
(3) Are the junior laboratories and lecture courses providing the students the proper background for tight product schedules?
(4) Should we direct our students to one type of implementation? For example, should the focus be on a microcontroller, programmable logic array, or VLSI approach.
(5) How much faculty direction should be given during the mini-project?

The answers to the first two questions were “yes” if we looked at the senior capstone project as the main instrument in achieving these objectives. However, the authors felt these issues should be addressed earlier in the curriculum. Also there are a number of disadvantages of using the senior capstone project as an assessment tool. In our department, each team of students works with a faculty advisor for their senior project. The team is normally composed of two students but can have as many as six students depending on the project. The majority of project topics are in the faculty’s research area which in our department includes controls, audio systems, advanced digital and software systems, signal processing, robotics, communications, VLSI design, and neural networks. The diversity of the projects makes assessment difficult. Only a few faculty members or one can evaluate the students work. The projects also tend to be very specialized and therefore cannot test all the students’ talents and deficiencies. Curriculum deficiencies are even more difficult to evaluate.

The use of the mini-project has provided students with experience in tight product schedules before their senior capstone project. The idea of the mini-project has also filtered back to the junior laboratories. Three week mini-projects are being developed to replace optional experiments that were selected by the students based on their interests. Earlier the faculty felt that a common project would result in many similar or “copied’ designs. This was found not to be the case. However, a good mini-project topic will offer a number of alternate design possibilities. The faculty determined that a microcontroller-based implementation should be the focus of the senior mini-project because of the tight product schedule. This has led to procurement of new microcontroller hardware and software development systems for the mini-project and junior laboratories to facilitate the short design cycles.

Our department is currently preparing for our first ABET visit in Fall 2002 under the new Engineering Criteria (EC) 2000 guidelines. The mini-project addresses all the items contained in Criteria 3: Program Outcomes and Assessment. These items that an engineering program must demonstrate that their graduates have are[1]:

(a) an ability to apply knowledge of mathematics, science, and engineering
(b) an ability to design and conduct experiments, as well as to analyze and interpret data
(c) an ability to design a system, component, or process to meet desired needs
(d) an ability to function on multi-disciplinary teams
(e) an ability to identify, formulate, and solve engineering problems
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

The reader at this point should see that the mini-project covers items (a) through (k), although some stronger than others. The “strong” items (a), (c), (d), (e), and (g) are addressed in each of the six laboratory periods. Each mini-project requires interfacing with a transducer. Temperature, humidity, velocity, pressure, sonar, and speech transducers have been used in past projects. Before an interface can be designed, the students must understand the transducer characteristics from the data sheets and/or experimental results. This has been one of the more time consuming aspects of the mini-project design. Interpretation of other data sheets used in the design occurs throughout the design process. Therefore item (b) is considered a “strong” item. Item (k) is regarded as a “strong” item because of the use of simulation tools such as PSPICE and development system tools such as assembly language program debuggers.

Items (f), (h), (i), and (j) are considered the "weaker" items but have been strengthened further with curriculum modifications. Understanding of professional and ethical responsibility (item f) is addressed in the students' decision for the division of the project tasks and of course in carrying out this division. Items (h), (i), and (j) have been strengthened with modifications to our EE402 Undergraduate Design Seminar course which is offered in the spring semester of the senior year. This course revisits the mini-project in regard to high-volume production. Student teams (5 to 6 students) develop a functional description of the product, technical specifications, look at new design approaches, develop time and cost budgets, estimate the delivery date of the first 10,000 devices, and estimate the cost of the product based on a production of 50,000 units. Time and budget costs include manufacturing costs as well as design costs. Speakers from local industry have been used in the course to address these issues. This year, representatives from the College of Business will be incorporated into this course to further discuss budget issues.

In addition to addressing items (a) through (k), the engineering program must show that feedback mechanisms have been implemented to allow for continuous curriculum improvement[8]. The modifications to the EE402 course is one example of the feedback process. The change was suggested by a group of students during their exit interviews with the department chair in 1997. Other examples will be discussed in the next section.

VI. Curriculum Modifications Resulting From Mini-Project

Some of the curriculum modifications resulting from the mini-project have been discussed but all are summarized in this section.

<u>EE451-EE452 Senior Laboratory:</u> The mini-project itself has been modified over the years to address curriculum deficiencies. One deficiency area was in the students' early exposure to microcontroller-based products and use of hardware/software debugging tools. A new microcontroller hardware development board was purchased in 1999 prior to the Fall semester mini-project. The development board consists of a 16-button keypad, an LCD display, 8 channel A/D converter, 4 D/A converters, and the 80535 microcontroller. The 80535 provides 24 bits of digital I/O, 4 counters/timers, and 10 external interrupts. The microcontroller board is manufactured by EMAC Inc. The 80535 is an advanced version of the 8051/52 microcontroller.

A software development and debugging system was also purchased from Keil Software that is compatible with the microcontroller hardware. Programs can be easily developed in assembly language or C language or combination with this software package. Future senior projects that are microcontroller-based will use C language unless restricted by real-time issues. Two successful 1999/2000 senior projects used C language in their microcontroller-based projects. More use is expected this year for the 2000/2001 senior class.

EE402 Undergraduate Design Seminar: As discussed in the previous section, the mini-project product is further evaluated in this course in the context of high-volume production and cost issues. The course is offered second semester of the senior year.

EE365 Microcontroller Programming and Interfacing: The course was originally taught during the first semester of the senior year. It was moved to the first semester of the junior year because of the microcontroller emphasis in the mini-project design. Originally, the Intel and Motorola microcontroller families were discussed in this first course. Because of the lack of depth of interrupts and real-time issues, this year only the Intel family will be addressed in this first course. The emphasis will be on the 8051 microcontroller. This change was due to students lack of knowledge of the more advanced features of a microcontroller which was evident during the mini-project.

EE331-EE332 Junior Laboratory: New experiments have been developed for both semesters addressing the fundamental and advanced features of the Intel 8051/80535 microcontroller. Mini-projects are being used both semesters for further student and curriculum assessment.

VII. Mini-Project Development Time and Costs

A new mini-project is developed each year for the senior class. A topic is selected which will offer several good design possibilities. Because of the student time constraints, the majority of hardware and software design is performed by the instructor to assure reasonable specifications have been selected. The mini-project instructor is assigned a one course load in the spring semester for the project development for the following fall semester. Six weeks of two six-hour laboratory periods is considered a one course load in the fall semester. In addition to the laboratory contact hours, an additional 30 to 35 hours is required for final report and laboratory notebook grading. An average of six hours is required for final documentation of the mini-project results for assessment purposes. The cost of parts for the mini-project each year ranges from $800 to $1000. Parts from the senior mini-project are being used two to three years later in the junior and graduate laboratories.

VIII. 1999 Mini-Project

The objective of the 1999 mini-project was to design and construct an instrument that detects and displays distance to objects. The students were supplied with a Polaroid Corporation Sonar Ranging board and transducer, an extended version of the 8051 microcontroller, an LCD display, an LM34 temperature sensor, a 9VAC 500mA wall transformer, and an LM7805 five volt regulator. Their hardware design consisted of a power supply, speaker driver circuitry, and interfacing circuitry for the sonar board and temperature sensor. The product specifications are shown on the following page. The speed of sound is 331.3 meters/sec at standard temperature and pressure. The sound wave velocity cannot be assumed constant because of the wide temperature range specification (0E to 122EF).

Compensation for the variation in the speed of sound was accomplished in software.

<u>Product Specifications:</u>

1) Display Distance:	target distance in inches (18.3 for example)
	targets > 25.5 inches display all 8's, targets < 18.0 inches display all 0's
	display update time = 0.75 seconds
2) Display Temp.:	accuracy ± 2EF
	display update time = 0.75 seconds
3) Speaker:	alert tone if target < 20.0 inches
	sound level minimum: 6dB above ambient room noise
4) Power Supply:	supply sonar ranging board and instrument electronics
	5 Volt DC current < 100 ma (including LM7805 operating current)
5) Accuracy:	distance: ± 0.5 inches (excluding sonar module accuracy)
	temperature: ± 2EF
6) Operating Temp.:	Ambient temperature 0E to 122EF
7) Sonar Strobe:	10 Hertz, interrupt-driven software

There were 17 student teams in 1999. The major problem areas and grading results were supplied to the students and department faculty through email. This data can be observed on our mini-project web site[7]. As discussed previously, the 1999 results facilitated curriculum changes for academic year 2000/2001. In Fall 2000, the EE365 Microcontroller Programming and Interfacing course covered only the 8051 microcontroller family to strengthen fundamental and advanced concepts. The junior lab instructors removed some of the older experiments in the Fall 2000 laboratory and replaced them with microcontroller-based experiments. In past years, the microcontroller experiments were not introduced until the spring laboratory. The common theme in the teacher/course evaluation forms was the notebook grading was extremely tough and they were not prepared for this type of grading. Several noted that they wish this type of grading had been done in previous classes. Many mentioned this had been their best design experience in our program so far. Another common comment was to modify the junior laboratories so that the students receive more microcontroller experience.

IX. Concluding Remarks

As mentioned in the introduction, the senior mini-project is only a small component of our ECE undergraduate laboratory sequence at Bradley University. However, it has become our most useful tool for student and curriculum assessment. This is due to the common multi-disciplinary project which by design has many alternative solutions. One disadvantage may appear to be the decreased time available for the student’s senior capstone project. Many undergraduate programs use the full Fall and Spring semesters for their capstone projects. Our department also uses both semesters; although the laboratory time has been decreased by 6 weeks due to the mini-project. One of our Fall senior courses, EE419: Engineering Analysis and Design, was modified in 1998. The primary goal of this course is to have the student (and partner) choose a senior project and apply a top-down design approach to the project prior to implementation in senior lab. The combination of this course change with the mini-project has proved successful in the students' capstone designs.

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