Active and Collaborative Learning in an Introductory Electrical and Computer Engineering Course

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Electrical and Computer Engineering (ECE) 125, Fundamentals of Electrical and Computer Engineering, is a required course at the first-year level for students in electrical and computer engineering at the University of Alabama. The overall course objectives are to introduce first-year students to what practicing electrical and computer engineers do and to the various electrical and computer engineering specializations, to the need to use mathematics and mathematical tools, and to basic laboratory techniques. This course is critical in engaging the students in the degree program and to establish a foundation of basic engineering knowledge and practices that are essential for success in the degree program and beyond.

To assist in student retention, this course must actively engage students and provide a mechanism for understanding the practice of electrical and computer engineering. In addition to introducing required technical material, this course must assist the student in developing an understanding of the engineering design process, an appreciation for the ethical practice of engineering, an approach to lifelong learning to keep up with scientific and technical advances, and knowledge of how engineering professional societies can assist in these activities.

To actively engage the student, we selected multiple collaborative learning techniques around which to construct several active learning tasks to assess

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student understanding of five selected program outcomes associated with the course. The collaborative learning techniques selected include *think–pair–share* discussion, *case study* problem solving, and *round-robin* discussion (Barkley, Cross, & Major, 2005). Student efforts for all of the active learning tasks were assessed using a standardized rubric defined in Table 1. Although multiple assessments may be made for the active learning tasks, all faculty teaching ECE 125 used this rubric in their assessments of the selected program outcomes associated with the course.

Active Learning Task Materials and Methods

One goal of this course is to introduce the student to a formal design process and discuss how it differs from a "hobbyist" approach. An engineering design process is a formal decision-making procedure in which basic science, mathematics, and engineering principles are applied to a problem in devising a system or component to meet some stated needs. A hobbyist approach is ad hoc and trial and error in nature, generally lacking any critical review and analysis components. A lecture is presented defining engineering design and the various steps involved in an engineering design process. In a follow-up class the students have an opportunity to participate in a *think–pair–share* activity. Working individually, students develop a definition of an engineering design process. Working in pairs, students combine their individual definitions into a single definition. Working in pairs, students perform an Internet search to assist in refining their definition of an engineering design process. Students identify/define major elements of the design process and identify which elements of the design process

TABLE 1 Standardized Assessment Rubric for the Department of Electrical and Computer Engineering

Score	Description
NA	Did not complete the work required for these criteria
1	Demonstrates severe misconceptions about the important concepts; makes many critical errors
2	Displays an incomplete understanding of the important concepts and has some notable misconceptions; makes a number of errors when performing important strategies or skills but can complete a rough approximation of them
3	Applies appropriate strategies or concepts with some errors
4	Demonstrates a complete and accurate understanding of the important concepts

would not likely be employed by a hobbyist. Students submit initial definitions, the combined definition, and the final refined definition.

For instruction and assessment in defining engineering ethics and ethical codes, a lecture is presented defining engineering ethics and presenting formal engineering ethical codes from the Institute of Electrical and Electronics Engineers and the National Society of Professional Engineers. A collaborative *case study* activity is used where groups of two–three students select an example from the presented summary and prepare a two-page report describing their assessment of the case, the decision options available, specific engineering ethical issues involved, impact on the careers of the engineers involved, and their personal recommendation for a decision. Additionally, a class quiz is given to students based on sample engineering ethics questions from the National Society of Professional Engineers and the Foundations of Engineering exam administered as a part of the professional registration process. This quiz is used to assess student knowledge of engineering ethics and ethical codes and is scored using the standard rubric defined in Table 1. This assessment, though not an active or collaborative activity, provides an additional validation of student understanding.

In instructing and assessing how lifelong learning benefits practicing engineers, a lecture is presented defining basic concepts of lifelong learning with specific supporting references detailing the acceleration of scientific, engineering, and technological progress. Using a *round-robin* activity, students develop a list of ideas/scenarios where lifelong learning will be required. The student group submits the developed list at the end of the activity.

Finally, for instruction and assessment in understanding the value of professional engineering societies as a resource for lifelong learning materials, another *think–pair–share* activity is employed. A lecture is used to define the nature and roles of professional societies. Working individually, students construct a list of resources they believe a professional society could provide to assist in the process of lifelong learning. Working in pairs, students combine their individual lists into a single list of not more than ten items. Working in pairs, students then perform a search to locate actual resources provided by the Institute of Electrical and Electronics Engineers in support of lifelong learning and map these resources to their combined list. Finally, students submit initial lists, the combined list, and the final list with resource mappings.

The assignments based on five collaborative learning activities were graded using standard grading procedures. The raw data were then converted into a rubric score using the ECE Department's standardized rubric. The data collected for the spring 2009 term are given in Table 2. The average score indicates that students did grasp the concepts very well in almost all the activities.

This demonstrates that these first-year students developed an understanding of this material comparable to that of more advanced students in the program according to similar assessments that occur later in the curriculum.

As an additional assessment, a student survey was conducted at the end of the semester. Results of the survey from the spring 2009 semester are presented in Table 3. As is clear from the data, the majority of the students seem to have understood the material very well. Specifically, greater than 80 percent of students strongly agreed that they understood the engineering design process, engineering ethics, and the importance of engineering ethics in their career.

TABLE 2 Assessement Results for Collaborative Learning Activities

Collaborative Learning Activity	Program Outcome	Rubric Score					
		4 (*n* [%])	3 (*n* [%])	2 (*n* [%])	1 (*n* [%])	Mean Score	SD
Think–Pair–Share (*n* = 41)	Describe a formal design process and discuss how it differs from a "hobbyist" approach	41 (100)	0 (0)	0 (0)	0 (0)	4	0
Case study (*n* = 40)	Define engineering ethics and its importance in the career of an engineer	40 (100)	0 (0)	0 (0)	0 (0)	4	0
Case study (*n* = 41)	Define engineering ethical codes	32 (78)	8 (19.5)	1 (2.5)	0 (0)	3.76	0.49
Round Robin (*n* = 34)	Discuss how lifelong learning benefits practicing engineers	31 (91.2)	2 (5.9)	0 (0)	1 (2.9)	3.85	0.56
Think–Pair–Share (*n* = 46)	Understand the value of professional engineering societies	43 (93.5)	3 (6.5)	0 (0)	0 (0)	3.77	0.52

TABLE 3 Student Survey for Program Outcome Measure Assessments

Question	1, Strongly Disagree (*n* [%])	2, Disagree (*n* [%])	3, Agree (*n* [%])	4, Strongly Agree (*n* [%])	Mean Score	SD
1. I am able to describe a formal design process and discuss how it differs from a "hobbyist" approach.	0 (0)	2 (11)	1 (5)	16 (84)	3.74	0.65
2. I am able to define engineering ethics and its importance in the career of an engineer.	0 (0)	1 (3)	5 (16)	26 (81)	3.78	0.49
3. I am able to demonstrate knowledge of engineering ethical codes.	0 (0)	2 (6)	11 (34)	19 (59)	3.53	0.62
4. I understand how lifelong learning benefits practicing engineers.	0 (0)	0 (0)	14 (44)	18 (56)	3.56	0.50
5. I understand the value of professional engineering societies as a resource for lifelong learning materials.	0 (0)	0 (0)	12 (37)	20 (63)	3.63	0.49

Having a strong understanding of the engineering design process as a first-year student should significantly improve performance in follow-on, design-oriented courses throughout the curriculum. Additionally, 94 percent of respondents either agreed or strongly agreed that they could demonstrate knowledge of engineering ethical codes.

Student understanding of how lifelong learning benefits practicing engineers was somewhat weaker, with only 56 percent of respondents strongly agreeing. However, this response from first-year students is considered acceptable as they have not yet been exposed to the much larger and more complex body of knowledge that a practicing engineer must maintain. Additionally, these students have not yet discovered, in a formal setting, the need to refresh and update their knowledge and skill set as advances in technology demands. Once the necessity for lifelong learning is appreciated, the value of professional engineering societies in helping to meet this need becomes much more apparent.

Laboratory Experience in Creativity

As specified by ABET, the national accrediting body for engineering programs, the engineering design component of the curriculum must include the development of student creativity. Fostering creativity assists in most steps of the engineering design process but most importantly in steps including defining needs, finding alternative design solutions, presenting a design, and communicating/selling a product. These particular steps in the engineering design process generally require collaborative efforts and, as such, are well suited for collaborative exercises in the classroom and/or laboratory.

A laboratory has been developed for ECE 125 that is designed to exercise creativity. The idea for this laboratory was initiated by the Music Department as a way to promote collaboration and as part of a fund-raising activity. In this lab, students build lamps from retired musical instruments. The creative process is marked by a progression through various stages including brainstorming, formalizing a construction plan, drawing schematic representations of the instrument/lamp, generating a parts/tools list, and implementing the design. This project addresses the need to promote creative thought in engineering undergraduate students for enhanced product design. Creativity/artistry is especially important in today's competitive environment. This trait, creativity, is considered to impact globalization, yet most engineering programs do not emphasize this skill (Patton & Bannerot, 2002). Globalization is stressed as a critical issue for the success of future science, technology, engineering, and mathematics professionals in *The Engineer of 2020* (National Academy of Engineering, 2004) and *Educating the Engineer of 2020* (National Academy of Engineering, 2005).

A disadvantage in de-emphasizing creativity is that functionality may dominate the design process with little regard to visual considerations (National Academy of Engineering, 2004). In this project, attention is given to the artistic component, a view often neglected.

The development of this laboratory has recently received funding from the National Science Foundation Course, Curriculum, and Laboratory Improvement program. In the trial offering, forty-three total students were arranged into seven groups. The Music Department donated the instruments, which included a saxophone, clarinet, bassoon, piccolo, trumpet, mellophone, and trombone. The students were tasked to design and build a lamp from these instruments, and the team budgets averaged $60.00 per group. A competition was held, and the lamps resulting from this laboratory were sold at a fund-raising auction event. Details about the implementation of this lab are described elsewhere (Burkett & Snead, 2009). When this project was submitted as a proposal, its objectives were identified to include (1) making ECE more appealing to students early in their academic career, (2) demonstrating that engineering is a creative process, and (3) prompting students to think about problems in a nonformulaic manner.

In fall semester 2009, the second offering got under way, with students divided into eight groups. The Music Department again generously donated instruments for this laboratory. Based on feedback from the first group, we made several modifications to the implementation of this lab. One was to add mentoring by undergraduate students. Originally, one teaching assistant (TA) monitored all groups, and it was an overwhelming task. In 2009 we added four mentors and two TAS; therefore, we have one group/mentor and two groups/TA. This has been beneficial in providing the groups more supervision and attention. We now devote one full laboratory session to brainstorming and have added additional laboratory sessions to provide adequate time for ordered parts and supplies to arrive. At the end of the semester, a competition is held and judged by College of Engineering faculty, staff, and students.

Evaluation of the Creative Laboratory Experience Participants

Evaluators with the University of Alabama's Institute of Social Science Research are assisting in developing a qualitative and quantitative data-gathering process for measuring the success of the Course, Curriculum, and Laboratory Improvement project. Multiple respondents will be used for most assessments including student, mentor, and instructor assessments, and multiple measurement techniques will be employed including self-report surveys, enrollment/demographic information, and interviews. Surveys will include both closed-ended and open-ended items, generating quantitative and qualitative data. The University of Alabama Teaching Evaluation Form, which includes rating scales for the instructor's communication skills and preparedness for class, as well as questions about the course requirements, assignments, and other materials and overall ratings of the course and instructor, will also be used. The expected outcomes for this project over the long term include (a) developing a laboratory to exercise creativity to give students experience in creating a functional yet aesthetic product; (b) increasing enthusiasm for the major and establishing networks between faculty members and classmates; (c) increasing awareness of the importance of skills that make up the creative process (idea generation, design aspects, costs, influence of different perspectives, importance of balance between function and aesthetics); and (d) demonstrating an approach to problem solving that is not captured by a single process but involves a variety of methods to arrive at an answer.

In addition to addressing the specific objectives and expected outcomes for the project, other interesting questions can be addressed through the evaluation activities. Examples of these issues include the following:

- Does the creative exercise appeal to particular types of students, such as students typically underrepresented in engineering (e.g., females, minorities)?
- How is interest in the creative exercises related to performance in the course and overall academic performance?
- How does the mentor contribute to the overall quality of the students' experience with the creative exercise?
- How would the mentor describe the experience level, enthusiasm, and leadership skills of the students overall?
- What improvement in confidence is built in a student by exercising the creative process to problem solving?

Results and Conclusions

An array of active and collaborative learning instruments have been introduced into an introductory electrical and computer engineering course. These instruments were intended to assess specific course learning objectives and program outcome assessments assigned to this course within the curriculum. Additionally, many of the course learning objectives and program outcome assessments were new to this course.

Using an ECE Department standardized rubric, the assessment results demonstrate that these first-year students developed an understanding of this material comparable to that of more advanced students in the program. Additionally, we believe that the active and collaborative nature of these instruments assist greatly with student motivation and with retention within the program. As many of the students who ultimately succeed within our program identify themselves as "hands-on learners," we naturally expect that these instruments may be particularly effective throughout the curriculum. The program outcomes assessed as a part of this study are common across multiple engineering disciplines. It is therefore likely that the active and collaborative instruments employed here would be effective in other engineering disciplines under similar scenarios. Based on the results of this study, it is recommended that similar approaches to engaging engineering students be adopted to address student retention and student learning.

References

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