Paper ID #32099

Allowing Freshman Engineering Students to Encounter Multiple Disciplines: Discipline Oriented Labs in the First Semester Engineering Curriculum

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Abstract
Anderson University is a small liberal arts university established in the Church of God movement, located in Anderson, Indiana. The engineering program started in 2013, and now has ABET accredited majors in Mechanical, Electrical, and Computer Engineering. The first semester engineering course has undergone several changes since the program's inception, and has evolved into three corequisite courses, accompanied by a 2-hour recitation section.

The first semester engineering curriculum consists of a 1-hour lecture course (ENGR 2001), a 2-hour ME lab course (ENGR 2002), and a 2-hour ECE lab course (ENGR 2003). Providing these two lab courses allows students to gain basic understanding of the engineering disciplines offered by the university and affords them tools for exploration of their practice. While lab courses of this sort are not entirely unique to the Anderson University first semester engineering program, some of the mechanisms and course structure differ from other programs. Students also meet for a two-hour recitation section in the evenings, which allows them to get tutoring for Calculus and Chemistry, as well as engage in engineering group projects with their cohort.

The current formulation of the first semester courses has been offered for two consecutive years. This work presents the course content with an emphasis on lab instruction, course learning outcomes, and assessment results for the first two years, along with lessons learned.

Introduction

The engineering program at Anderson University is in its first decade, having started in 2013, and now features ABET accredited majors in Mechanical, Electrical, and Computer Engineering. Anderson is a small, Christian liberal arts university, affiliated with the Church of God denomination. One of the hallmark principles of the program is to introduce students to discipline related skills and equipment on day one, instead of waiting until upper level courses. Based on this concept, there has been a desire to integrate this introduction to tools and facilities into the first semester engineering program in order to equip students for exploration of the engineering disciplines available at the institution. The first semester engineering experience has thus evolved into a 1-hour lecture course (ENGR 2001) two rigorous 2-hour lab courses covering Mechanical Engineering (ENGR 2002) and Electrical and Computer Engineering (ENGR 2003) material, combined with a 2-hour recitation section each week.

Before elaborating on the course design, it is important to discuss some important constraints that inform the design problem presented by the institution's history as a liberal arts focused school. First, all majors are faced with credit limitations in order to complete both the major and liberal arts curriculum in 120 total credit hours. This prevents significant additional course material from being added. A second constraint is that all labs and courses at the institution are taught by faculty, not by lab or graduate assistants. This presents a challenge in delivering content without overloading faculty. A third constraint is that required courses may be offered only during the hours of 8AM-3PM, or after 6PM to accommodate the large number of student athletes on campus.

Beyond constraints, there are two desired “soft” objectives for the first semester of freshman engineering. The first is to promote a cohesive cohort among the first-year engineering students. The second is to foster meaningful relationships between faculty and students. One way that this can be achieved is by applying intentionality into individualized lab instruction with faculty. While these objectives are not directly measurable, they inform the design of the course sequence. We feel that this development of community within the engineering cohort and between students and faculty are encouraged by our approach to the first semester, and with continued refinement may positively impact retention.

Significant research has been conducted across many engineering programs at many universities to integrate labs and projects into the first semester of engineering. Most of the universities who have successfully integrated labs into their first semester of engineering are very large research-oriented universities with significant resources, which differs from the work described in this paper. A few notable examples of the inclusion of labs in the first-year curriculum are surveyed here. Ohio State reports the use of hands on labs integrated with a semester project, as early as 2001, and continuing to present [1]-[3]. At Louisiana Tech, the engineering program has leveraged a student owned lab (which they call “Living with the Lab”) to improve hands-on experience and affect growth in retention [4], and several other universities have successfully adopted similar strategies [5]. The University of Wisconsin-Platteville has developed a course in which “students rotate through short, hands-on modules for each engineering discipline on our campus, as a means of gaining an active introduction to each discipline” [6], [7]. NYU has developed hands-on experiences including giving students introduction and access to the university’s makerspace [8].

Building upon past work and leveraging some of the constraints at Anderson University, we have developed a somewhat novel approach, to which we now shift our focus. The first year for the course structure discussed was Fall 2018, and significant refinements were made for Fall 2019, outlined in the lessons learned and discussion section at the end of the paper.

Course Design

The primary lecture course, ENGR 2001: Introduction to Engineering, serves to provide students with a background in the engineering design process, project management, engineering ethics, and written communication. This course is similar to many such introductory engineering courses, but only meets for 1 hour per week. In addition to the lecture course, students meet in several 2-hour evening recitation sections. These sections are led by other undergraduate engineering students and provide an opportunity for first semester students to get tutoring for Calculus and Chemistry, as well as collaborate with their cohort.

Associated with this course is a semester long project that students complete in groups. For the past two years, the project has been a well-defined roller coaster design project involving iterative design. Prior to the current formulation of the course, the project took many other shapes, including more open-ended projects. Informed by past experiences, the roller coaster project was chosen to allow students to focus on project management, teamwork, and the engineering design process. This project is most similar to work done at Ohio State [2], [3]. One difference from the work at Ohio State is that students may use recitation time rather than using lab time to explore the design of the roller coaster and the majority of labs are not focused on facilitating the semester project. The application of a semester project in an introductory engineering course is not novel and is not discussed further in this work.

The lab courses are both 2-hour sections that meets weekly and is led by a faculty member. Students work in pairs to complete laboratories, but are expected to complete quizzes, lab reports, and skills exams independently. In the mechanical engineering laboratory, ENGR 2002, the focus is on an introduction to computer-aided design, measurement, unit conversions, and hands-on fabrication methods. The first few weeks reinforce unit manipulation and conversions that would have first been introduced in high school, and we move quickly to appropriate measurement techniques and the corresponding concepts of precision and accuracy in measurement. Following a workplace safety and personal protective equipment introduction, we incorporated various engineering concepts, such as stress and strain, heat transfer, and fluid drag forces, into lessons that required actual application of these concepts. The student fabricated an I-beam using milling techniques, measured their beams for accuracy and precision, and tested their strength in bending. Welding was used as an example of heat transfer, and the students operated a wind tunnel and measured objects to calculate drag coefficients from experiments. Measurement and units were also reinforced through the use of computer-aided design software. Students were able to realize their CAD designs in actual objects through both laser-cutting and 3D printing. The fabrication methods they learned in 2002 could also be applied to the 2001 project. In an effort to be intentional in lab instruction, student competency exams have been introduced, which allow students to meet with the faculty member and practice until they are able to complete the skills exams [9]. To ensure that each student was able to perform the base skills of the laboratory, skills exams were given as a midterm and final that required proper measurement technique, appropriate knowledge of unit conversions, and a basic understanding of the underlying mechanical principles behind the technology used.

ENGR 2003, the electrical and computer engineering laboratory, focuses on a hands-on introduction to circuits and embedded systems. The course iteratively builds on knowledge from week to week by incorporating new equipment into labs. Due to the nature of the course, the semester starts with electrical fundamentals such as bread boarding, components, and electrical equipment. The semester progresses into transistor logic, Boolean logic, and then embedded systems to demonstrate the relation. The semester ends with an embedded system that introduces students to Linux, Python, and GPIO interfacing. Two skills exams are given over the semester, the first requires competency in breadboarding a circuit and measuring features of a waveform. The second requires students be able to implement a simple python program that utilizes GPIO pins. Both exams must be passed without error but can be taken as many times as the student needs to pass the exam. The retakes are similar in nature, but not duplicated.

The following course outcomes are covered across the three courses. The course in which each outcome is covered is noted in parentheses next to the outcome.

Table 1: Course learning outcomes for the corequisite engineering courses in this work.

1. Demonstrate an understanding of precision and accuracy. (2002)	2. Ability to differentiate between ME, EE, and CpE (2001)
3. Able to write reports in LATEX (2001)	4. Able to convert between units (2001, 2002)
5. Operates effectively as a team player (2001)	6. Makes ethical decisions (2001)
7. Performs computer aided drafting (2002)	8. Proficiency in measurement techniques (2002)
9. Safely operates metal and wood tools (2002)	10. Able to design and 3D print parts (2002)
11. Prototypes and tests simple circuits (2003)	12. Identifies rudimentary electronic components (2003)
13. Exercises and demonstrates problem solving skills in a laboratory setting (2002,2003)	14. Writes simple programs in Python (2003)
15. Employs the engineering design process to solve a real-world problem (2001)	16. Join an engineering professional society (2001)

Assessment

To directly assess student achievement of learning outcomes, course instructors chose performance indicators (PIs), in the form of graded course artifacts, mapped to course outcomes and set a benchmark indicating achievement. There is typically more than one PI per outcome. Instructors provide the minimum grade possible, maximum grade possible, and mastering score, often around 80% of the available maximum score. For each student score, a value p is found by the equation $p = (score - mastering)/\Delta$, where $\Delta = max - mastering$. This value is clipped so that $p \in [-1,1]$, so that a value of 1 means the student scored the maximum possible, and a value of -1 means that a student scored at or below $mastering - \Delta$ (equal to 60% if the mastering benchmark is 80%). After this is completed for every student, the average across all student PI results linked to the same course outcome is computed, and this result is reported in Table 2.

Table 2: Assessment results.

Outcome	2017	2018	2019	Outcome	2017	2018	2019
1	-0.44	0.33	1.00	**9**	1.00	0.90	1.00
2	DNE	1.00	0.86	**10**	DNE	0.63	1.00
3	-0.08	0.44	0.69	**11**	0.50	0.81	0.27
4	-0.47	0.11	0.47	**12**	0.48	0.42	-0.47
5	0.08	0.11	0.51	**13**	0.55	0.65	1.00
6	DNE	0.49	0.61	**14**	-0.06	0.40	0.48
7	DNE	0.62	1.00	**15**	DNE	0.18	0.43
8	0.53	0.78	-0.48	**16**	DNE	1.00	1.00

Values of DNE indicate content not covered in the previous course formulation. From the data shown in Table 2, it can be seen that the change in model seems to have improved student achievement. While improvement in achievement of course outcomes is not uniform, there was a marked increase in the performance metrics over the three consecutive years.

Lessons Learned and Discussion

Retention of first year engineering students isn't directly related to the course instruction, but the two are likely linked. Since the changes to the curriculum are very recent, the retention to second semester is considered as a metric. In Figure 1, the retention data is shown. The primary axis bar chart shows retention to second semester, and the average high school GPA (normalized to 4.0 scale) and MATH SAT score (normalized to 800) is reported, demonstrating that incoming freshman cohorts are roughly identical. There appears to be a large jump in retention to second semester in the 2019 cohort, even though their incoming indicators are nearly the same as previous years. One contributing factor could be the redesign and refinement of the first semester engineering curriculum.

In addition to the change in model between 2017 and 2018, the following refinements were made to course instruction between the 2018 and 2019 offerings.

1. In 2019, the Mechanical Engineering laboratory was taught by an ME faculty member, while in 2018 it was taught by an ECE faculty member
2. The semester project was improved, allowing students to work on design for longer and in a more iterative approach.
3. Latex instruction started on day one of lab, and was improved in lecture section
4. Weekly labs were incorporated for both ME and ECE starting in 2018
5. Increased expectation of student effort and content mastery to prepare for program rigor

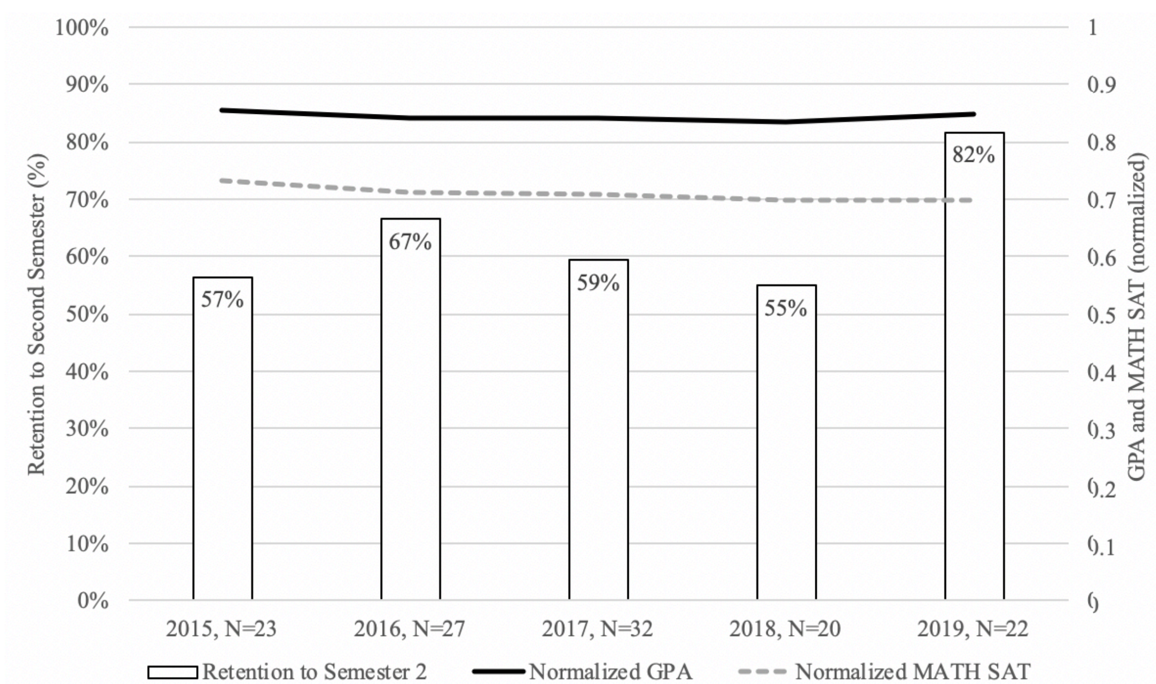

Figure 1: Retention data to second semester for cohorts 2015-2019.

The overwhelming majority of course outcomes saw improvement with the change in model to three corequisite courses, even while academic rigor was increased. The only outcomes to see a decrease are (8) demonstrates proficiency in measurement techniques and (12) identifies rudimentary electronic components. This is likely due to a new emphasis on deep mastery of these topics, motivated on the previous successes. For example, students are now required to read a micrometer to the 10 thousandths place in accuracy whereas in previous years they only needed to know how to use digital calipers properly. In the ECE lab, instead of only being able to identify the components, students were required to know more intricacies, such as energy storage in the magnetic field in an inductor, or electric field for a capacitor.

Through the course design process, two important lessons have emerged: that students connect with the promotion of collaboration in the lecture, lab, and recitations, and that the facilitation of hands on experience is preferred. Achievement of course outcomes and retention data suggest that this change in course model has been successful in allowing students to encounter different disciplines and grow in understanding of the engineering profession.

References

[1] R.J. Frueler, A.W. Fentiman, J.T. Demel, R.J. Gustafson, J.A. Merrill. "Developing and Implementing Hands-on Laboratory Exercises and Design Projects for First Year Engineering Students." *Proceedings of the 2001 American Society for Engineering Education Annual Conference & Exposition*, 2001.

[2] C.A. Whitfield, R.J. Frueler, Y. Allam, E.A. Ritter. "An Overview of Highly Successful First-year Engineering Cornerstone Design Projects." *Proceedings of the 17th International Conference on Engineering Education*, 2011.

[3] N.R. Sattele, K.M. Kecskemety, K.A.A. Parris, "Analysis of the Entrepreneurial Mind-set Elements in Established First-year Engineering Labs: Analysis Process and Lessons Learned and Changes for the Future." *Proceedings of the 2019 American Society for Engineering Education Annual Conference & Exposition*, 2019.

[4] K. Crittenden, D. Hall, P. Brackin. "Living With the Lab: Sustainable Lab Experiences for Freshman Engineering Students." *Proceedings of the 2010 American Society for Engineering Education Annual Conference & Exposition*, 2010.

[5] G.W. Recktenwald. "Six Years of Living with the Lab." *Proceedings of the 2016 American Society for Engineering Education Annual Conference & Exposition*, 2016.

[6] H.T. Evenson. "A Hands-on, Introductory Course for First-year Engineering Students in Microsystems and Nanomaterials." *Proceedings of the 2013 American Society for Engineering Education Annual Conference & Exposition*, 2013.

[7] P. Parker. "Development and Assessment of a Revised Introductory Engineering Course." *Proceedings of the 2010 American Society for Engineering Education Annual Conference & Exposition*, 2010.

[8] J. Bringardner, G.W. Georgi, V. Bill. "From Design to Reality: Guiding First-Year Students from Design to Makerspace Reality." *2018 FYEE Conference,* 2018.

[9] B.D. McPheron, M.Z. McPheron, C.R. Thomas. "Does Performance-Based Assessment in an Introductory Circuits Laboratory Improve Student Learning?" *Proceedings of the 2017 American Society for Engineering Education Annual Conference & Exposition*, June 25-28, 2017.