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Implementing a Freshman Experience in Electrical Engineering

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Abstract:

This paper discusses the authors' experiences with a newly implemented freshman experience sequence in the EECS department at SDSU. Implementation of this experience was motivated by low retention rates for electrical engineering students. Students who failed to remain in EECS for their sophomore year apparently were handicapped by a lack of an intuitive feel for electrical engineering and a lack of understanding of how and why the various required courses would fit together to form a well-rounded curriculum.

To address these issues, EECS at SDSU is implementing a new FOCUSED (Focused Ongoing Concentrated Undergraduate Sequence in Engineering Design) in the Electrical Engineering program. Three years of our department-wide (both EE and CS) freshman robotics experience and two years of our EE specific EE 102 class have now been completed. Retention going into the sophomore year has dramatically improved and students appear to be better motivated. This paper discusses the motivation for the freshman experience, the design and implementation of the freshman experience, the increased retention numbers, the results of student surveys (after the freshman year and at the conclusion of the sophomore year), as well as future plans for this sequence.

Background and Motivation:

The Electrical Engineering (EE) program (in the Electrical Engineering and Computer Science (EECS) Department) at South Dakota State University (SDSU) has been concerned about low retention rates for several years. When interviewing qualified students who the faculty feel are capable of succeeding in electrical engineering and who are either changing out of the major or considering changing out, we see three recurring issues:

First, students begin their undergraduate careers with a distinct lack of understanding, or intuitive "feel" for electrical engineering. For many other disciplines it is relatively easy to relate subject matter to previous personal experiences of the students. For example, when discussing conservation of momentum, the basic ideas that heavy and/or fast objects are harder to stop than light or slow objects is something that students have personally experienced and the mathematical models serve to reinforce what they already "know". In electrical engineering, we do not have this advantage when describing the physics internal to our electrical devices so the math is not verifying a concept that they already understand. Instead, the math often appears as another layer of confusion rather than clarification.

A second problem is that undergraduate students do not typically realize that the various required courses have been selected for a reason, that all of these courses are related to each other, and that the courses work together to provide a solid background in electrical engineering. When struggling with a concept that they find difficult, a student often justifies a less dedicated approach based on the incorrect perception that this particular class or concept does not really matter or is not related to their career goals. For example, a student interested in a career in digital design might put in less effort and justify poor performance in the courses related to commercial power distribution. The student does not realize that these (and other) fields are interrelated: low-voltage, high-frequency signals traveling down a short printed-circuit board trace behave in a manner which is similar to that of lower frequency voltages being transmitted down a longer power line.

The biggest hurdle by far is an insufficient understanding of, or inadequate preparation in the mathematics required of electrical engineers. A distinction is made between these students who faculty feel could be successful in electrical engineering and those students who expressed an initial interest in the discipline but are incapable of or inadequately prepared to proceed with the course of study at the current time. Having previously observed a correlation between preparation in calculus and success in our electrical engineering curriculum, the department currently requires a grade of "C or better" in the second semester of calculus in order to enroll for the Circuits I class. Many of the students who do not meet this criteria change to other majors but a few do take remedial math courses and eventually succeed in our program. Our intent with this retention effort is focused on those students who we feel would be successful as evidenced by ability to earn the required grades in the freshman math classes.

In an effort to address these issues, we are implementing a new FOCUSED (Focused Ongoing Concentrated Undergraduate Sequence in Engineering Design) in the Electrical Engineering program. The purpose of FOCUSED is to combat the above apparent difficulties in teaching electrical engineering at the undergraduate level by providing an early, hands-on freshman seminar giving the student an intuitive feel for the concepts of electrical engineering and developing and emphasizing several common threads originating in that freshman class, continuing through the undergraduate core curriculum, and eventually connecting with aspects of the capstone senior design sequence.

The first stage of the FOCUSED concept is the *department*-wide freshman experience, GE109L which was first offered in the fall of 2010. The purpose is to both motivate EE and CS students to continue with their major as well as enable the department to connect with each student during the student's first year. Previously, due to the need to first develop a background in mathematics and science, electrical engineering students did not take an electrical engineering course until their sophomore year. It was not atypical for many students, at times close to 50%, to have switched to another major before attending their first electrical engineering class!

The second stage of the FOCUSED concept involves an EE *program* specific, required course in the spring semester of the freshman year, EE102. Note that CS students had been taking CS specific courses as freshman. EE102 seeks to expose undergraduate students to the continuity in

the electrical engineering program, motivate the students by giving future lab exercises a sense of purpose, more closely tie the various EE undergraduate classes to each other, and more closely tie the senior design experience to the rest of the undergraduate curriculum. This course has now been offered twice, in the spring of 2012 and 2013.

The third stage of the FOCUSED concept includes modifying a minimum of one lab or significant assignment in *at least* one of the required courses each semester of the sophomore and junior years. The selected assignment will be modified so as to provide a direct tie-in to an ongoing senior design project. The students who were exposed to these senior design projects as freshmen will be aware of the relevance of these modified assignments and have some assurance that they may have a chance to directly tie their sophomore and junior coursework to a senior design project.

As a part of this stage, we would strongly encourage faculty members to consider where their specific lessons fit into the overall scheme of our program and to select assignments, where possible, to emphasize the cohesive nature of our program. For example, after students learn the C programming language as freshmen they could be asked to solve an engineering problem using this language in several follow on classes. When a student is performing the op-amp lab in Electronics I, they would be reminded that they will likely need to amplify an input signal in the microcontrollers course and again in senior design.

The fourth part of the proposed plan would involve taking steps to ensure some continuity in the senior design projects which are offered each year. Students are typically allowed to select their project from a list of approved projects. We propose having at least three ongoing or recurring projects every year. Four possible choices would be: the robotics design competition, the electric ATV, the remote sensing project, and the new NSF-EPSCoR-PANS sponsored solar-car competition. We have had three of these projects in recent years, and all three have had proposed extensions for a second year project (although only one of the three was selected by students as a follow-up project last year). If at least one senior design team is working on these projects at any given time, the undergraduate students can be assured of continuity. In the event that one of these projects needs to be phased out (that is, replaced by another ongoing competition oriented project) the odds are that at least one of the three projects will survive for long enough to be observed as it evolves over a student's four or five year stay at SDSU.

This paper discusses our preliminary results after implementing the first two stages of our FOCUSED plan, the department-wide freshman seminar GE 109L and the EE specific EE 102 course. Retention numbers are discussed, as are the results of student surveys taken both at the end of the EE 102 class and at the end of the sophomore year. Detailed descriptions of both courses are given below.

GE 109L Freshman Experience:

Prior to the implementation of the FOCUSED concept, all engineering freshmen took an introduction to engineering course (GE 101). This course was not specific to any engineering discipline and purported to serve as a survey of the various engineering fields. Survey and anecdotal evidence indicated that this course actually hurt our EE retention numbers due, in part,

to the lack of EE-specific content. Students who had declared an EE major were also exposed to students from other engineering majors and discovered that the other students were actually taking (and enjoying) courses in their major/declared area of study. Since EE students would not take their first EE class until the sophomore year, they assumed that they were falling behind their colleagues.

Upon implementation of first stage of the FOCUSED concept, an EE and CS discipline specific lab section was added to the GE 101 course (later renumbered to GE 109L). While not having an EE prefix, this course was limited to students having declared an EE or CS major, and tailored to these students. Our goal for this course was to introduce students to the areas of EE and CS in a non-intimidating and fun manner. This course was loosely inspired by freshman design courses at the University of Maryland, College Park, where freshman engineering students competed in a hovercraft design contest[1, 2].

Initially, the lab portion of the GE 101/109L class met once per week for one hour. Students were divided into teams of (typically) two, and each team was loaned a CEENBoT[3] robotic platform (Figure 1) for the duration of the semester. Throughout the semester long course, the students became more familiar with the CEENBoT and investigated hardware and software additions to enable the CEENBoT to complete various tasks.

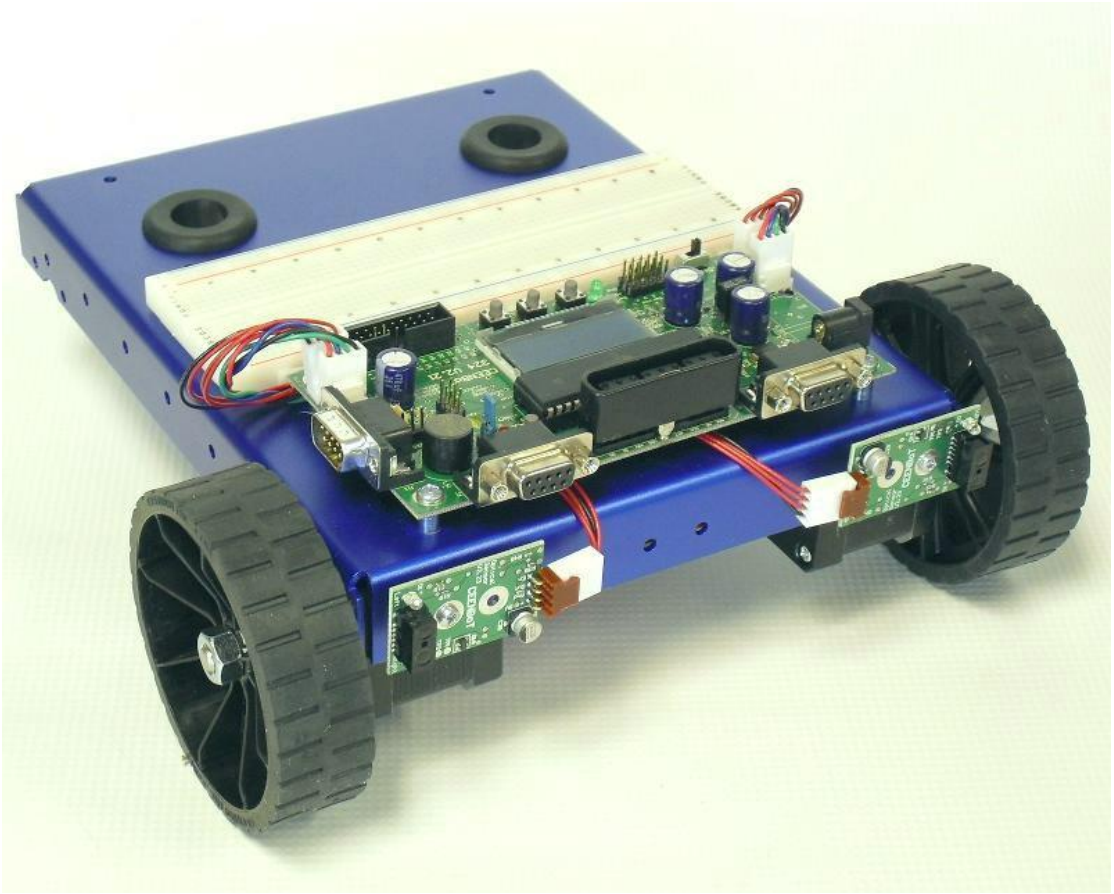

Figure 1. CEENBoT Robotics Platform (photo courtesy CEENBoT Inc.[3]).

Since this course is taken during the very first semester after students matriculate, there is no programing prerequisite. Rather, the students are presented with simple C functions or subroutines which, for example, cause a wheel to turn at a specified speed. The students download a program that calls these various functions and causes the robot to move forward an arbitrary distance. This is accomplished by first turning on both wheels with an arbitrary speed setting, then waiting a specified amount of time, and then turning off both wheels. For their first lab, the students are asked to make the robot stop after an instructor specified distance. It is fairly simple for even those students who have not programmed prior to the class to reverse engineer the function calls in order to change the stopping point. This can be done by changing the speed at which the wheels rotate, altering the amount of time that the wheels are allowed to run, or a combination. After that they use the engineering method of successive approximation (aka "trial and error") to cause the robot to stop exactly on the assigned stopping point. Within 45 minutes of being handed a CEENBoT, the students are empowered by successfully completing the first assignment. Electrical Engineering and/or Computer Science is now not only eminently do-able, but also quite a bit of fun. When these EE and CS majors take their new robots back to the dorms, it is now the declared ME and CE majors who are having second thoughts about their career choices!

As the semester progresses, the students are also taking their first C programming classes, so the robotics course reinforces and motivates the programming class even as the programming class removes some of the magic from the robotics experience. Subsequent software only labs turn the robot by spinning the wheels at different rates (or in different directions), ultimately navigating a specified roadway without running into any obstacles.

In later labs, students add hardware to the CEENBoT platform in order to allow the robot to respond to its environment. For example, a photo-resistor is added and students are asked to program the robot to drive towards the light, or to stop the robot when the downward facing sensor detects a strip of black tape on the white floor. A thermistor is added, and the student is asked to calibrate the sensor in order to display the sensed temperature in the included display. An ultrasonic distance sensor is incorporated, and the robot programmed to swerve to avoid obstacles or to stop a specified distance from a wall or other obstruction. An additional stepper motor is provided and the students incorporate that with some available output ports in order to raise a flag or to lower the temperature sensor into a container. By the end of the semester, the bare CEENBoT has been augmented as shown in Figure 2.

EE 102 Introduction to Electrical Engineering:

The second stage of the FOCUSED concept involves a *program* specific, required course in the spring semester of the freshman year, EE102, meeting once per week for two hours. The objectives of this course are to:

- Expose students to electronic circuits and devices without the mathematical rigor or theory which typically accompanies the subject matter.
- Make undergraduate students aware of the continuity in the electrical engineering

program.

- Motivate the students by giving undergraduate lab exercises a sense of purpose.
- Unify the various EE undergraduate classes to each other.
- Connect the senior design experience to the rest of the undergraduate curriculum.

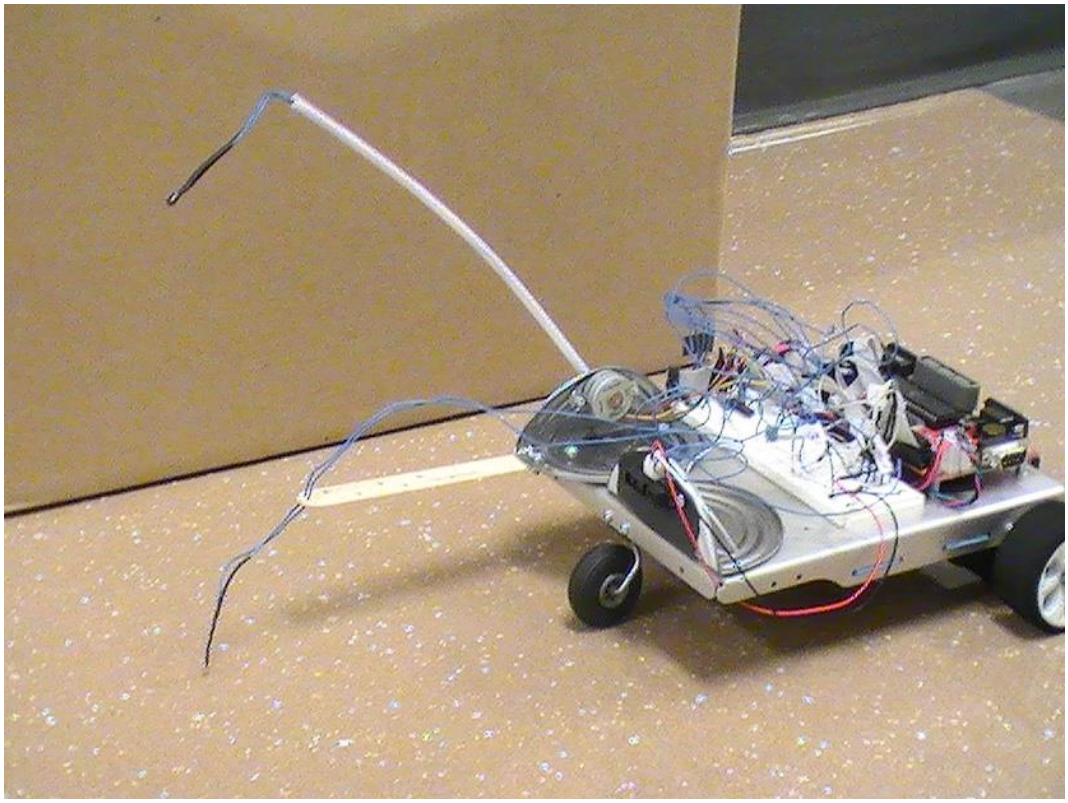

Figure 2. Fully Equipped CEENBoT.

Completing this course will provide students with a basic understanding and familiarity of laboratory equipment, prototyping methods, and basic device/ circuit functions. This course was taught for the first time in the spring of 2012, revised and offered again in the spring of 2013.

Several laboratory requirements were developed and incorporated:

- Labs written and structured so that students are able to reasonably complete the labs within the two hour period at a stress-free pace.
- Lab partners rotated each week. This helps students get to know each other and prevents students from being "stuck" with a lab partner they do not like.
- No do-nothing circuits. A blinking LED does little to inspire or relate to students.
- The lab manuals must include motivation and background relevant for the students and relate the circuits to systems found in student's lives.
- The textbook[4] shall be easy to read without *requiring* the mathematical or theoretical background not yet achieved by the students. However, the textbook should also be of

sufficient detail and breadth such as to not be obsolete at the end of the course. The textbook should also be low cost.
- Lab manuals should use the same figures and nomenclature as the textbook; making it easy for the students to relate the book with the lab.
- The manuals should be written to be self-standing so as not to require any previous knowledge and include sufficient detail for the typical student to complete on their own.
- The labs should be written with a consistent format and structure (each should look identical).

The course begins with labs detailing the lab test equipment and basic circuits necessary for the balance of the course. Subsequent labs include more interesting circuits such as motor speed control, dusk to dawn light controllers, fan delay timers, and LED countdown timers. Basic design equations are presented, but students are not expected to derive these equations or even understand *why* the equation works. For example, a capacitive circuit is investigated and the relationships between the RC time constants and audio oscillator frequency were explored. Students follow the schematic to build the circuit on a breadboard and then use an oscilloscope and their ears to confirm the relationship. Students then change the circuit components to achieve a (different) specified behavior and demonstrate this to the instructor. Students are not expected to necessarily understand why the relationships hold, merely to observe the effect.

Retention rates before and after FOCUSED:

The retention data for electrical engineering students shown in Table 1 is based on data obtained from the registrar for declared majors, regardless of schedule. This data shows retention to have increased overall from 2007 to 2011 with a significant increase during the first year of our EE 102 course (the second year of our GE 109L course). This data may be somewhat misleading, in that it is not unheard of for a student to matriculate with a declared major of EE but never take any electrical engineering course. For example, of the 43 declared EE majors in the fall of 2010, only 32 actually signed up for the EE/CS section of GE 109L. Transfer students are not required to take this course, but this discrepancy seems higher than can be accounted for by transfer students alone.

Table 1. EE Retention Rates Based on Registrar Data.

Freshman Year	Freshman Enrollment	Returning Sophomores	Retention Rate
2011	36	26	72%
2010	43	27	63%
2009	57	34	60%
2008	48	33	69%
2007	38	20	53%

Table 2 shows retention data based on our actual count of declared EE majors in the GE 109L course. Unfortunately, this data does not go back as far as the Table 1 data, so it is difficult to make a statistically valid comparison of our retention rates before and after the initial

implementation of the FOCUSED concept. While the data for 2012 does not initially indicate a gain in retention (compared to the years prior to implementing our changes), more detailed review of the individual students involved shows that of the 15 students that did not make it into the sophomore year, 8 of these did not meet the math prerequisite for EE 220. It is suspected that most of these students will not continue with the program, although some do retake the calculus course and eventually succeed in our program. Three additional students had not yet enrolled at the start of the Fall 2013 semester, but indicated an intent to continue with the program when contacted earlier in the summer. The remaining four students could not be reached for comment, and unfortunately, similar data for prior years is not available.

Table 2. EE Retention Rates Based on Class Enrollment.

Freshman Year	EE Majors in GE109L	EE Majors in EE220 in following year	Retention Rate
2012	43	28	65%
2011	24	22	92%
2010	32	29	91%

Survey Information:

Anecdotal information, obtained by surveying spring 2013 EE 102 students at the conclusion of EE 102 and also by surveying spring 2012 EE 102 students at the end of their sophomore year, lends the following conclusions:

- A near universal agreement that EE 102 improved student's comfort level with laboratory equipment (DMM, scopes, signal generators, power supplies, and protoboards).
- EE 102 improved student's intent and comfort level in continuing with the EE program.
- EE 102 helped 2 students out of class of 36 realize that EE was not a good fit.
- The majority of EE 102 students would recommend this course.
- After the sophomore year, the results are somewhat more mixed but still overly positive with regards to the benefit of the 102 class in preparing students for future classes.

Conclusions

Two of the four stages of the FOCUSED concept have been implemented. Sufficient and consistent enrollment data necessary to judge the concept is not yet available. However, student survey data clearly indicates that GE109L and EE102 improve student's level of comfort and desire to continue in the EE program. Improved methods of tracking enrollment are necessary to analyze retention. When a student changes majors at SDSU, they do so by contacting the new program office and initiating the change. They are not required to communicate with the old program or department. The gaps in our data above indicate a need to go to further efforts to contact more of these students to find out exactly why they are leaving the program.

While the results of the portions of FOCUSED that have been implemented to date will not be

conclusively determined for several more years, preliminary data indicates that the remaining two phases should be implemented. Surveys should be continued through the senior year to judge the effectiveness of the entire program, and stronger efforts should be made to interview students who leave the program.

GE109L and EE102 obviously led to freshmen students interacting with the faculty teaching these classes, but the sequence also led to increased freshman involvement as evidenced by attendance at EE department social events and technical presentations. This in turn led to increased interaction with other EE faculty, fulfilling one of the goals for initiating the freshman sequence.

Future Work:

Improved surveys and other methods to collect more relevant data need to be developed. The freshman experience courses should continue to be improved based on student feedback. The remaining two phases of the FOCUSED concept should be implemented.

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