AN ABSTRACT OF THE THESIS OF

Matthew W. Shuman for the degree of Master of Science in Electrical and Computer Engineering on September 18th, 2008

Title: A Comprehensive Integration of First Year Engineering Education

Abstract approved:

Roger Traylor

Retention of engineering students is a problem for many universities, especially during the first year. The problem of introducing students to engineering while increasing retention rates has recently been addressed by many different universities. Implementing novel lab structures, adjusting the lecture to incorporate more effective teaching techniques, and using orientation programs to build learning communities are all different methods being used. In September 2006 a freshman mentor program was started for Electrical and Computer Engineering (ECE) students at Oregon State University (OSU) to improve retention rates by increasing self-efficacy and developing learning communities. This mentoring program uses a trained cohort of undergraduate freshman mentors to connect a Platform for Learning (PFL) with three terms of lectures and labs during the first year of ECE education. This approach changes a sequence of three distinct courses into a comprehensive integration of technical experiences. Survey data collected throughout the program tracks changes in learning self-efficacy and learning community development. Results from the mentor program indicate a positive effect on students’ self perceived communication, time management, resource location, problem solving, and stress management skills. These improvements should translate into increased retention rates as these students continue their engineering education.
A Comprehensive Integration of First Year Engineering Education

by

Matthew W. Shuman

A THESIS
Submitted to
Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Presented September 18, 2008
Commencement June 2009

APPROVED:

______________________________
Major Professor, representing Electrical and Computer Engineering

______________________________
Director of the School of Electrical Engineering and Computer Science

______________________________
Dean of the Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

______________________________
Matthew W. Shuman, Author
I would like to acknowledge the role models in my life that have given me the skills that made success at OSU possible. My father, Tom Shuman, taught me engineering courage by fixing the family car and constructing household improvements. My mother, Jean Ottaway, taught me how to see a need and fix it without being told, in a word, self-sufficiency. My sister, Lynn Shuman, has been a supportive partner in a challenging life. Grandma Gleo, Gleo Shuman, showed me organizational skills. Grandma Michael, Clara Ottaway, taught me how to be gracious through her consistent example. Grandpa Tree, Hollis Ottaway, gave me leadership skills that have been valuable in graduate school and his career with Oregon State University has been an influential inspiration.

I would also like to acknowledge people at OSU that have made my graduate work possible. Terri Fiez has built a solid PFL, TekBots. Roger Traylor has been a great role model for teaching. Donald Heer has worked diligently and created an environment to learn engineering at OSU. Lastly, the undergraduate engineering students have shown me how to surpass conventional limits and truly achieve the amazing.
CONTRIBUTION OF AUTHORS

Ding Luo generated exceptional statistical analysis of the survey results. Jace Akerlund provided a role in the generation and refinement of the freshman mentor program and paper. Roger Traylor provided insightful advice and guidance in the revision and refinement of this thesis.
TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preface</td>
<td>1</td>
</tr>
<tr>
<td>A Comprehensive Integration of First Year Engineering Education</td>
<td>2</td>
</tr>
<tr>
<td>I. Introduction</td>
<td>3</td>
</tr>
<tr>
<td>II. Proposed First Year Curriculum</td>
<td>4</td>
</tr>
<tr>
<td>A. Platform for Learning</td>
<td>6</td>
</tr>
<tr>
<td>B. Freshman Mentor Program</td>
<td>9</td>
</tr>
<tr>
<td>C. Specific Solution Used</td>
<td>10</td>
</tr>
<tr>
<td>1. ECE 111 – Introduction to ECE: Tools</td>
<td>10</td>
</tr>
<tr>
<td>2. ECE 112 – Introduction to ECE: Skills</td>
<td>11</td>
</tr>
<tr>
<td>3. ECE 271/272 – Digital Logic Design</td>
<td>12</td>
</tr>
<tr>
<td>III. Data Collection</td>
<td>13</td>
</tr>
<tr>
<td>IV. Results</td>
<td>14</td>
</tr>
<tr>
<td>A. First T-Test</td>
<td>16</td>
</tr>
<tr>
<td>B. Second T-Test</td>
<td>17</td>
</tr>
<tr>
<td>C. Last T-Test</td>
<td>17</td>
</tr>
<tr>
<td>V. Conclusions</td>
<td>18</td>
</tr>
<tr>
<td>VI. Future Work</td>
<td>19</td>
</tr>
<tr>
<td>VII. References</td>
<td>21</td>
</tr>
<tr>
<td>A Manipulative Rich, Design Based Approach to First Year Electrical Engineering Education</td>
<td>24</td>
</tr>
</tbody>
</table>
TABLE OF CONTENTS (Continued)

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Introduction</td>
<td>24</td>
</tr>
<tr>
<td>II. Platform for Learning</td>
<td>25</td>
</tr>
<tr>
<td>III. Educational Objectives</td>
<td>27</td>
</tr>
<tr>
<td>IV. First Year Program</td>
<td>28</td>
</tr>
<tr>
<td>A. Overview</td>
<td>28</td>
</tr>
<tr>
<td>B. ECE 111</td>
<td>31</td>
</tr>
<tr>
<td>C. ECE 112</td>
<td>33</td>
</tr>
<tr>
<td>D. ECE 272</td>
<td>35</td>
</tr>
<tr>
<td>V. Results</td>
<td>37</td>
</tr>
<tr>
<td>VI. Conclusion</td>
<td>38</td>
</tr>
<tr>
<td>VII. Future Work</td>
<td>38</td>
</tr>
<tr>
<td>VIII. References</td>
<td>40</td>
</tr>
</tbody>
</table>

Work in Progress: Improving Self-Efficacy with a Freshman Mentor Program  

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Background and Introduction</td>
<td>42</td>
</tr>
<tr>
<td>II. Proposed Approach</td>
<td>44</td>
</tr>
<tr>
<td>III. Freshman Mentor Structure</td>
<td>45</td>
</tr>
<tr>
<td>IV. Platform for Learning</td>
<td>45</td>
</tr>
<tr>
<td>V. Preliminary Results</td>
<td>46</td>
</tr>
<tr>
<td>VI. Conclusion</td>
<td>47</td>
</tr>
<tr>
<td>VII. Future Work</td>
<td>47</td>
</tr>
</tbody>
</table>
TABLE OF CONTENTS (Continued)

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIII. References</td>
<td>48</td>
</tr>
<tr>
<td>Work in Progress: Implementing a Freshman Mentor Program</td>
<td>49</td>
</tr>
<tr>
<td>I. Introduction</td>
<td>50</td>
</tr>
<tr>
<td>II. Freshman Mentor Program</td>
<td>50</td>
</tr>
<tr>
<td>III. Lab Environment</td>
<td>52</td>
</tr>
<tr>
<td>IV. Mentor Empowerment</td>
<td>53</td>
</tr>
<tr>
<td>V. Results</td>
<td>54</td>
</tr>
<tr>
<td>VI. Conclusion</td>
<td>54</td>
</tr>
<tr>
<td>VII. Future Work</td>
<td>55</td>
</tr>
<tr>
<td>VIII. References</td>
<td>55</td>
</tr>
<tr>
<td>Overall Conclusion</td>
<td>56</td>
</tr>
</tbody>
</table>
LIST OF FIGURES

Figure

1.1: Organization of the first year curriculum................................................... 6
1.2: Evolution of TekBot control through the curriculum ......................... 8
1.3: Usage of the freshman mentor lounge during fall term of 2007 .......... 19
2.1: Model showing lecture and lab enhancement ........................................ 27
2.2: Model showing the progression of design competence ....................... 29
2.3: A senior project that used prior design knowledge .............................. 30
2.4: Microcontroller manipulative used in ECE 111 ................................. 31
2.5: TekBot manipulative used in ECE 112 .............................................. 35
2.6: CPLD-based TekBot manipulative used for ECE 272 ...................... 36
2.7: Procedure to improve the platform for learning ................................. 39
4.1: Student engineering experience distribution chart ....................... 52
LIST OF TABLES

Table

1.1: Elements common to Platforms for Learning.................................................... 7
1.2: Statements used in the survey................................................................. 14
1.3: Legend used to decode T-Test percentages ........................................... 15
1.4: Comparison of first year to second year ............................................... 15
1.5: Results from paired tagged surveys ...................................................... 16
1.6: Results from all surveys......................................................................... 17
1.7: Results comparing the first and second year progress............................. 18
2.1: Distinctives common to all PFL ....................................................... 26
2.2: Clarification of PFL Objectives ............................................................ 28
2.3: Survey results for the freshman year program....................................... 37
3.1: Preliminary Self-Efficacy Survey Results............................................... 46
Dedication

This paper is dedicated to my past teachers. Your patience, sacrifice, and commitment have made the world a much better place.
PREFACE

The first section, “A Comprehensive Integration of First Year Engineering Education”, is being submitted for publication to “IEEE Transactions on Education”. It is intended to be a summary of my work in the school of Electrical Engineering and Computer Science (EECS) over the past two years. The three following papers are accepted by the “Frontiers in Education” (FIE) conference. They were submitted in March 2008 and document the progress of my work from Fall 2007 to Winter 2008. The FIE papers will be presented at the conference in October 2008. Each FIE paper describes an aspect of the IEEE paper and gives more background information than the space in journal articles allow. These FIE papers have been revised after publication to develop a polished and complete thesis. This thesis documents, analyzes and provides conclusions to improving core factors that influence the retention of desirable students in the rapidly changing field of Electrical and Computer Engineering.
A COMPREHENSIVE INTEGRATION OF FIRST YEAR ENGINEERING EDUCATION

Matthew Shuman, Roger Traylor, Ding Luo, Donald Heer, and Terri Fiez
School of Electrical Engineering and Computer Science
Oregon State University
Corvallis, OR 97330

Abstract – Retention of engineering students is a problem for many universities, especially during the first year. The problem of introducing students to engineering while increasing retention rates has recently been addressed by many different universities. Implementing novel lab structures, adjusting the lecture to incorporate more effective teaching techniques, and using orientation programs to build learning communities are all different methods being used. In September 2006 a freshman mentor program was started for Electrical and Computer Engineering (ECE) students at Oregon State University (OSU) to improve retention rates by increasing self-efficacy and developing learning communities. This mentoring program uses a trained cohort of undergraduate freshman mentors to connect a Platform for Learning (PFL) with three terms of lectures and labs during the first year of ECE education. This approach changes a sequence of three distinct courses into a comprehensive integration of technical experiences. Survey data collected throughout the program tracks changes in learning self-efficacy and learning community development. Results from the mentor program indicate a positive
effect on students’ self perceived communication, time management, resource location, problem solving, and stress management skills. These improvements should translate into increased retention rates as these students continue their engineering education.

Key Words – First Year Program, Engineering Education, Electrical Computer Engineering, Platform for Learning, TekBots, Learning Communities, Self-Efficacy, Retention

I. Introduction

The first year engineering curriculum is a special focus of engineering education due to the importance of addressing the transition from a general education to a specific field of study. Not only are students transitioning education styles but engineering colleges are being requested to produce a new type of engineer [1]. Leah Jamieson, President of IEEE, presents one of these requests during her keynote speech at DesignCon 2007. The request calls for a need to add other additional abilities and skills to the engineering skills traditionally required to be taught in the curriculum. These new traits are innovation, leadership, decision making, and an ability to recognize and manage change. These necessary additions enable future engineering graduates to apply current knowledge based on societal demands. An excerpt from her speech asks how these traits can be integrated within an engineering curriculum.

“An alternative proposal is to turn the curriculum inside out. The challenge is that we still need to teach engineering—technical and engineering skills—but now we
need to teach this other stuff, and I contend that most of that “other stuff” is hard to teach in a traditional classroom. You do not envision a class on innovation; you do not envision a class on lifelong learning. So the question becomes, is there a way to turn the curriculum inside out; to integrate these other abilities so deeply that in fact they go along with the learning of the engineering? [2]”

Universities have responded to the challenge and are educating engineers, in higher numbers and with an increased emphasis on design. Learning communities build a more welcoming environment to retain incoming engineering students, 10% higher than the historical average [3]. Design skills are promoted through the restructuring of lectures, tutorials, and small projects [4]. New design experiences in a year long sequence of courses teach fundamental skills and abilities that are necessary for engineering innovation and design [5]. The main challenge is still increasing the design skills of incoming students, while increasing the retention rate.

II.  Proposed First Year Curriculum

For several years now, a new first year curriculum has been employed at OSU. Its primary goal was to improve learning by infusing design and innovation into the curriculum and by integrating multiple methods for student instruction. Lecture and lab are common methods of teaching, but this new curriculum includes a freshman mentor program and PFL. Every term has four major components; lecture, lab, freshman mentors, and a PFL. The PFL is used in the lab to help build a foundation to help develop future design skills. Freshman mentors are used by the lecture and lab to help improve a connection between different aspects of the course.
Figure 1.1 depicts the relationship of how all of these work together over the course of the year. New engineering theories are presented in lecture and the students gain hands-on perspective by experientially revisiting those topics in the lab. Both lecture and lab have supporting structure of a PFL helping improve topical alignment and give a sense of context to the course material.

The mentoring program implemented at OSU is conceptually based and received guidance from the mentoring program used at University of Nebraska’s Peter Kiewit Institute. They realized an increased retention rate due to their hierarchical approach to mentoring students [6]. They used a counseling assistant to lead pod leaders that met with four to five students once a week. The counseling assistant saw all seventy students in lab every week. The major changes made for the OSU mentoring program adjust the scale of the mentor program to be more suitable for a medium sized engineering program of 140 students. The freshman mentoring program uses peer mentorship throughout the year, to further unite lecture, lab, and PFL. These mentors become a “glue” that ensures communities built and design concepts learned in prior courses are transferred and utilized in future labs. This was traditionally difficult because laboratory assistants varied each term. The freshman mentors give continuity in lab to three discrete terms of the first year program.
A. Platform for Learning

The OSU ECE curriculum is supported by a PFL. A PFL is any device, project, or idea that is used to connect multiple courses. A business plan could become a PFL for curriculum in a college of business. Students would learn accounting by developing financial documents for their proposed business, and could learn tax law by investigating regulations pertinent to their business plan. A PFL motivates learning and gives context to discrete topics within a given curriculum.

In 2000, OSU began creating a solution to the need for improved learning as well as more design, leadership, and innovation in ECE by creating a PFL called a TekBot [7]. The TekBot PFL was inspired from an intellectually substantive introductory ECE course used at Carnegie Mellon University [8]. Their course used a robotic system to motivate learning basic electrical engineering concepts by using a tangible manipulative. By our definition, PFLs have several core concepts, shown in Table 1.1 [9]:

![Figure 1.1: Organization of the first year curriculum](image.png)
Table 1.1: Elements common to Platforms for Learning

<table>
<thead>
<tr>
<th>Ownership</th>
<th>Each student owns the platform and tools. Personal ownership helps the student take responsibility for their equipment and education.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuity</td>
<td>A PFL provides topical continuity through the entire curriculum.</td>
</tr>
<tr>
<td>Context</td>
<td>A PFL provides a real-world context to place abstract lecture topics.</td>
</tr>
<tr>
<td>Fun Factor</td>
<td>Through engaging hands-on experiences students have fun!</td>
</tr>
<tr>
<td>Hands-on Learning</td>
<td>Hands-on experiments improve learning and comprehension of engineering theories [10].</td>
</tr>
</tbody>
</table>

Concepts in lecture are demonstrated in lab and the relevant robotic hardware is added to the student’s TekBot. As new theories and ideas are learned in lecture, new hardware is added to or replaces the previous hardware. Three different approaches to controlling a bumping robot are explored over three terms in this fashion. The third method is used in the third year of the ECE curriculum, but it shows a connection from the first year applications to the more advanced applications within the computer architecture course.

Notice the similarity between the four systems in Figure 1.2. Students learn the fundamentals of design by using a microcontroller as a black box. They read inputs and control outputs to begin understanding design and improving their self-efficacy. This introduction is modified in ECE 112 when an analog controlled bumping robot is built by using analog comparators to look at the voltage across capacitors that are discharged when bumping into a wall. Again the same structure is leveraged in the third term by building a digitally controlled bumping robot by using a complex programmable logic device (CPLD) to replace the prior analog board. The same sensors are used to detect the wall while a state machine is used to control TekBot
motion. Two years later the bumping robot familiarity is leveraged while using computer architecture knowledge. A microcontroller bumping robot is built by using an 8-bit microcontroller to replace the prior CPLD. Again the same sensors are used except the operation is controlled through software interrupts.

![Evolution of TekBot control through the curriculum](image)

**Figure 1.2: Evolution of TekBot control through the curriculum**

The TekBot is a mature PFL after seven years of development and has been joined by a number of other PFLs. Every summer undergraduate students are employed with the development of PFL hardware, software, manuals, and laboratories. Thirteen different courses are connected to PFLs within the engineering curriculum, with hardware ranging from digital signal processors to Bluetooth modules to field programmable gate arrays. Four other universities are also using TekBot PFLs to meet their educational needs. [11, 12, 13, 14]
B. Freshman Mentor Program

A freshman mentoring program started in the Fall of 2006. Initially, a single graduate student attempted to mentor 140 students during 2006-2007. The high student to mentor ratio, lack of time, difference in educational levels between the mentor and students, and not having the mentor in each lab section prevented the desired mentoring environment from forming. Four modifications to the program were made to remove these deficiencies.

1. The mentors should be of similar educational status. An appropriate undergraduate is a better suited peer mentor than a graduate student.
2. Each of the seven labs should be lead by a mentor, ensuring the students to see their mentor every week.
3. The student to mentor ratio should be close to twenty to one, ensured by having one mentor per lab section.
4. Mentors should have a common mentoring lounge to hold office hours and “hang out” with students.

Six undergraduate mentors joined the graduate student coordinator in mentoring the entire freshman ECE class throughout all three terms. Weekly duties carried out by all seven mentors for the entire year included: holding three office hours, leading a laboratory section, organizing study sessions for students, grading homework, and hanging out with students. Specific freshman mentor duties for each term are outlined in the following sections describing the courses in the first year program.
The freshman mentors were also given a small office to turn into a lounge. The layout of this room was intended to create an open and inviting refuge where students can come eat lunch, talk to their mentors, and receive help with their coursework. This room is intentionally small to make a more comfortable atmosphere than a typical classroom or study hall provides.

A desktop computer in the lounge holds a database that is updated with information about student visits. Mentor interactions with students are anonymously logged. The reason for the student visit, be it a lecture, lab, extracurricular, or social question is stored into a mentor database for later review.

C. Specific Solution Used

1. **ECE 111 – Introduction to ECE: Tools**

ECE 111 is the first ECE introductory course, held during fall term. Lecture covers the engineering history, ethics, study skills, and the basics of microcontroller usage, but not architecture, per se. The microcontroller is treated as a “black box” that simply reads inputs and can control outputs. Engineering ethics and history are discussed using case studies of historical engineering mistakes. Study skills cover scheduling courses for graduation and interviewing practicing engineers. The lecture spends a week on the basics needed to understand programming, implementation, and current applications for microcontrollers.

ECE 111 lab provides hands-on design experience. A freshman mentor and two undergraduate assistants lead a weekly two-hour lab of twenty students. Mentors are equipped with the knowledge necessary to help the students use microcontrollers
as a “black box”. Communicating this knowledge to the students is facilitated due to the closeness in age and experience of the mentors and students. The beginning four weeks of lab cover basic skills needed for the final design project, such as soldering, reading schematics, and programming a microcontroller. Students can choose from four different project ideas for their final design project; tachometer, range finder, inclinometer, or a project of their own design. Each project reads a sensor, processes the input, and displays the output using an LED display. These projects are intended to be open-ended and difficult. Having a student to lab assistant ratio of seven to one allows for students to receive enough assistance to succeed in this early challenge.

2. **ECE 112 – Introduction to ECE: Skills**

The second course in the first year series focuses on fundamental topics of circuit analysis within the core of ECE. Voltage and current are explained and Ohm’s Law is used to analyze resistors. Kirchhoff’s voltage law and current law are used to analyze diodes and transistors. Some of these techniques were used in ECE 111 lab. This gives context to the application of these theories being explored in more depth in ECE 112 lecture.

Freshman mentors organize weekly homework help sessions in a lecture hall. The function of the mentors is not to answer individual student questions, but to help students form study groups. Mentors assist and provide helpful hints only if the entire study group needs assistance.
Freshman mentors also staff these labs. Often, students specifically enroll in a lab to keep the same mentor from the prior term. Mentors go through weekly training to understand the technical theories and demonstrations that are possible with the hardware for the current week. Possible hardware modifications to the lab are discussed during these meetings. For example, by swapping a single resistor in the analog control board the capacitor charge rate is modified, which increases the turning accuracy.

3. **ECE 271/272 – Digital Logic Design**

ECE 271 is the final course of the first year program and covers digital logic. Digital circuit analysis, minimization, and design are introduced using the following topics: Number systems, Boolean algebra, circuit minimization with Karnaugh maps, flip flops, counters, and state machine design.

The lab is numbered ECE 272 to allow for Computer Science students to take the lecture without the lab. The lab uses a CPLD to replace the analog controller used in ECE 112. Advantages and disadvantages of digital logic versus analog circuitry become apparent as the students implement the theory presented in the lecture to program the CPLD. The greater precision of the CPLD plus its inherent capabilities, entice the more capable and creative students to greater levels of creativity and innovation. One student interfaced their TekBot to an infrared television remote, using the volume and channel buttons on the remote to drive the TekBot.
III. Data Collection

To determine the effect of the freshman mentor program on retention, we measure two of the constituent components that comprise retention. These components are learning communities and self-efficacy. Self-efficacy can be further separated into four parts: mastery experiences, vicarious experiences, social persuasion, and physiological state. At least once a term a voluntary survey is given to the students. The survey has twenty-one statements that specifically measure the development of learning communities and self-efficacy. The survey questions are listed in Table 1.2. Five questions that target components of retention are questions 12 and 18 through 21. Question 12 looks at the development of learning communities. Question 18 looks at the mastery experience component of self-efficacy. Question 19 probes for vicarious experience. Question 20 looks at social persuasion. Lastly, question 21 looks at the student’s physiological state. The survey questions originated from prior research in the school of EECS at OSU into the transfer of self-efficacy in teaching assistants to their students. Each survey question is ranked by the student on a confidence level from 0 – 100, with a higher score indicating more agreement with the statement. Students had the option of choosing a 5 digit number to tag each survey. The “tag” lets future analysis track changes in the self-efficacy of the same students throughout the year.
Table 1.2: Statements used in the survey

<table>
<thead>
<tr>
<th>#</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I can understand the topics in my engineering classes so that I am prepared for the next courses.</td>
</tr>
<tr>
<td>2</td>
<td>I am able to build relationships with role models in the engineering field who will help me succeed in my degree.</td>
</tr>
<tr>
<td>3</td>
<td>I can earn the grades and GPA I need to stay in engineering.</td>
</tr>
<tr>
<td>4</td>
<td>I can motivate myself to overcome the obstacles to completing my engineering degree.</td>
</tr>
<tr>
<td>5</td>
<td>I can do hands-on tasks such as making measurements, soldering, and using equipment to succeed in engineering lab courses.</td>
</tr>
<tr>
<td>6</td>
<td>I can bounce back even if I get a bad grade on a homework or exam.</td>
</tr>
<tr>
<td>7</td>
<td>I can choose to study even if my friends are doing other fun activities.</td>
</tr>
<tr>
<td>8</td>
<td>I am able to get answers to my questions when I feel intimidated or ‘stupid’ for not understanding.</td>
</tr>
<tr>
<td>9</td>
<td>I can accurately solve abstract problems in my homework.</td>
</tr>
<tr>
<td>10</td>
<td>I can compete with the other students in my classes and do well compared to them.</td>
</tr>
<tr>
<td>11</td>
<td>I am able to solve problems that I don’t initially know the answer to.</td>
</tr>
<tr>
<td>12</td>
<td>I am able to interact with other students in my classes and form study groups with them.</td>
</tr>
<tr>
<td>13</td>
<td>I can manage my time and tasks so that I get my class work done.</td>
</tr>
<tr>
<td>14</td>
<td>I am able to keep up with my studies even when the courses are fast paced.</td>
</tr>
<tr>
<td>15</td>
<td>I am able to find a place that’s good for me to study.</td>
</tr>
<tr>
<td>16</td>
<td>I am confident that I can gain admission to engineering pro school.</td>
</tr>
<tr>
<td>17</td>
<td>I can quickly use the computer to solve homework problems.</td>
</tr>
<tr>
<td>18</td>
<td>I have experienced success in doing engineering-related activities.</td>
</tr>
<tr>
<td>19</td>
<td>I have had a role model who was an engineer who made me think that I could be one, too.</td>
</tr>
<tr>
<td>20</td>
<td>I have received encouragement from others to become an engineer.</td>
</tr>
<tr>
<td>21</td>
<td>I feel relaxed and positive when I think about doing engineering-related activities.</td>
</tr>
</tbody>
</table>

IV. Results

The analysis of the surveys uses a T-Test to find statistical differences in self-efficacy between ECE 111 and ECE 272. The T-Test is a common analysis technique that compares the mean, standard deviation, and sample size of surveys [15]. Traditional survey results only report the mean and maybe the sample size. This leaves
a question as to whether the effects measured were actually significant. The T-Test removes guesswork from the analysis and provides a quantitative score to determine statistical certainty in the differences between survey results. Only T-Test results of 95% and higher are considered statistically different, indicating that the changes made between the first and second year are valid. The legend in Table 1.3 relates confidence percentages to significance.

Table 1.3: Legend used to decode T-Test percentages

<table>
<thead>
<tr>
<th>T-Test Result</th>
<th>Statistical Certainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 95%</td>
<td>No Significant Change</td>
</tr>
<tr>
<td>95% - 97.5%</td>
<td>Significant</td>
</tr>
<tr>
<td>98% - 99%</td>
<td>More Significant</td>
</tr>
<tr>
<td>99% - 99.5%</td>
<td>Very Significant</td>
</tr>
</tbody>
</table>

In Table 1.4, the major differences between the first and second year of the freshman mentoring program can be seen. Note that the same number of people were hired to work in the labs each year. The major differences are employee training and resource allocation.

Table 1.4: Comparison of first year to second year

<table>
<thead>
<tr>
<th></th>
<th>2006 - 2007</th>
<th>2007 - 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graduate Student</td>
<td>1 Freshman Mentor</td>
<td>1 Freshman Mentor Coordinator</td>
</tr>
<tr>
<td>Freshman Mentors</td>
<td>0 Freshman Mentors</td>
<td>6 Freshman Mentors</td>
</tr>
<tr>
<td>Undergraduate TA</td>
<td>15 Teaching Assistants</td>
<td>9 Teaching Assistants</td>
</tr>
<tr>
<td>Extra Resources</td>
<td>None</td>
<td>Freshman Mentor Lounge</td>
</tr>
</tbody>
</table>
A. First T-Test

The results from the tagged population T-Test are shown in Table 1.5. This T-Test compares changes in survey results throughout the year for students that were voluntarily “tagged”. The tag limits the analysis to students that filled out voluntary surveys during all three terms. Analyzing students that fill out surveys during all three terms modifies the population of the analysis towards reliable students, but the following results are still significant for that population. Another note is that the small sample size is accounted for in the T-Test results. The only significant result from this comparison is shown in Table 1.5.

<table>
<thead>
<tr>
<th>#</th>
<th>Statement</th>
<th>2006 - 2007</th>
<th>2007 - 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>I feel relaxed and positive when I think about doing engineering-related activities.</td>
<td>Significant Decrease</td>
<td>No Significant Change</td>
</tr>
</tbody>
</table>

The first observation to make from Table 1.5 is that twenty out of twenty-one of our survey items yielded no significant change, due to the small sample size of tagged surveys. This indicates while the mean of survey results may have fluctuated, no valid conclusions can be formed. Secondly, a significant decrease in student attitudes towards engineering during the first year is not present during the second year. The amount of staff in the lab did not change, just the number of trained mentors. This T-Test indicates that the revised freshman mentor program prevented a significant decrease in the physiological component of self-efficacy from appearing in the second year.
B. Second T-Test

A different set of T-Tests analyzes all surveys, regardless of “tag”, from the first year with 126 total student surveys and the second year with 176 total student surveys. Table 1.6 lists all statistically significant results in these new survey populations. The results from question 12 indicate that students feel more comfortable in forming their own learning communities. Question 15 is linked to the development of the freshman mentor lounge, which addresses the social persuasion component of self-efficacy.

Table 1.6: Results from all surveys

<table>
<thead>
<tr>
<th>#</th>
<th>Statement</th>
<th>2006 - 2007</th>
<th>2007 - 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>I am able to solve problems that I don’t initially know the answer to.</td>
<td>No Significant Change</td>
<td>Significant Increase</td>
</tr>
<tr>
<td>12</td>
<td>I am able to interact with other students in my classes and form study groups with them.</td>
<td>No Significant Change</td>
<td>Very Significant Increase</td>
</tr>
<tr>
<td>13</td>
<td>I can manage my time and tasks so that I get my class work done.</td>
<td>No Significant Change</td>
<td>More Significant Increase</td>
</tr>
<tr>
<td>15</td>
<td>I am able to find a place that’s good for me to study.</td>
<td>No Significant Change</td>
<td>More Significant Increase</td>
</tr>
</tbody>
</table>

C. Last T-Test

The final T-Test directly compares the same untagged population as Table 1.6 but focuses on the change in the mean results during 2006 – 2007 to the change in mean results during 2007 – 2008. The two items of improvement in Table 1.7 indicate the impact that a properly staffed and equipped mentoring program can have on a first year experience. Students can use the lounge to improve time management skills, while becoming more relaxed and comfortable with engineering activities.
Table 1.7: Results comparing the first and second year progress

<table>
<thead>
<tr>
<th>#</th>
<th>Statement</th>
<th>2006 - 2007 Change</th>
<th>2007 - 2008 Change</th>
<th>Significance of Change Between First and Second Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>I can manage my time and tasks so that I get my class work done.</td>
<td>-8%</td>
<td>10.33%</td>
<td>Significant Increase</td>
</tr>
<tr>
<td>21</td>
<td>I feel relaxed and positive when I think about doing engineering-related activities.</td>
<td>-9.67%</td>
<td>4.44%</td>
<td>Significant Increase</td>
</tr>
</tbody>
</table>

V. Conclusions

The combination of a lecture and lab that build on a PFL clearly shows benefits from using the freshman mentor program. Students go to the freshman mentor lounge to receive help and learn skills necessary to succeed at ECE. This mentoring provides help that improves self-efficacy. Logged student usage of the freshman mentor lounge shows that students visit the lounge when coursework becomes stressful. The graph in Figure 1.3 shows usage during Fall 2007. 68 visits to the freshman lounge were logged during a design project during weeks 8-10. Each of these visits gave students an opportunity to learn from the mentors and get help to overcome their challenge, improving all four components of their self-efficacy. Some of these improvements have already been shown to be statistically significant by collecting self-efficacy surveys and using the T-Test to isolate significant results.
The mentor program has neutralized a negative trend that impacted the physiological state of the students during 2006 - 2007. In summary, one statistically significant negative result during the first year was changed to six significantly positive results in the second year through the improvements to the ECE freshman year experience.

VI. Future Work

Two main areas are being developed. First of all, the Computer Science (CS) department is also implementing a first year program similar to ECE. The CS department at OSU is creating a PFL and freshman mentor program during next
school year. The platform will be an open source Ultra Mobile Personal Computer (UMPC) that is being designed by undergraduate ECE student workers. This platform will help provide a tangible outlet for CS theories and applications. Target CS topics include Java, C, and assembly programming, networking, and operating systems. The CS mentor program will have five undergraduates that follow a similar structure as the ECE mentors. Survey data will be collected and analyzed to compare progress of the two mentoring programs.

Secondly, four new ECE freshman mentors are going through a more rigorous training schedule before beginning to mentor students during the next school year. The mentors are offered summer internships before they begin mentoring during the school year. Summer internship training focuses on designing projects and current teaching techniques.

Lastly, results comparing the past two years of mentoring programs will be used in the future to further refine mentor training techniques and the structure of the freshman mentor program.
VII. References


A MANIPULATIVE RICH, DESIGN BASED APPROACH TO FIRST YEAR ELECTRICAL ENGINEERING EDUCATION
Matthew Shuman, Donald Heer, Terri S. Fiez
Oregon State University

Abstract – Impartation of innovative engineering design skills has been identified as an important goal for engineering educators. Some universities choose to delay the design content of their curriculum until the senior year, when the students can utilize the engineering concepts learned in lectures. This delay is unnecessary as the skills needed for innovative design can be learned independently from the engineering theories being employed. The first year Electrical and Computer Engineering (ECE) curriculum at Oregon State University (OSU) introduces three design oriented courses, which combine a manipulative rich laboratory with traditional lecture based method of instruction. These first year courses explore the core topics of design fundamentals, circuit analysis, and digital logic design.

Key Words – TekBots, Design, Engineering Education, Freshman Year, Electrical Engineering, Platform for Learning

I. Introduction

The first year of an engineering education is important. Incoming students are introduced to a completely new style of learning. This first year also sets a precedent
for the remaining years as an engineering student. Not only is the year an important transition, but certain requirements must be addressed by the curriculum.

Accreditation Board for Engineering and Technology (ABET) requirements add a traditional challenge to planning a first year curriculum. Additional requirements are also being suggested to help new engineering graduates adapt to future demands. In her keynote speech at DesignCon 2007, Leah Jamieson brings attention to traditional and additional requirements for engineering educators. She describes a need to add other additional abilities and traits, such as innovation, leadership, decision making, and an ability to recognize and manage change [1]. An excerpt from her speech outlines an alternative approach to curriculum design.

“An alternative proposal is to turn the curriculum inside out. The challenge is that we still need to teach engineering – technical and engineering skills – but now we need to teach this other stuff, and I contend that most of that “other stuff” is hard to each in a traditional classroom. You do not envision a class on innovation; you do not envision a class on lifelong learning. So the question becomes, is there a way to turn the curriculum inside out; to integrate these other abilities so deeply that in fact they go along with the learning of the engineering? [1]”

II. Platform for Learning

A platform for learning (PFL) is defined as a common unifying object or experience that unites various classes into a curriculum sequence [2]. A PFL provides a foundation that is used to develop skills necessary for engineering students. At OSU, development of PFLs began in 2001 and the resulting platforms developed have gone
through several iterations to improve their effectiveness. For instance, a preassembled motor control board is now supplied to the students instead of having them solder it together. Testing and hands-on learning with the motor control board still occurs in lab, but the students have more time to experiment and understand the circuit elements.

In 2001, OSU began creating a solution to the need for teaching our students more design skills and innovation by creating a PFL called a TekBot [2]. The inspiration for the TekBot came from an intellectually substantive introductory ECE course used at Carnegie Mellon University. Their course used a simple robotic system to provide a tangible manipulative to motivate understanding basic electrical engineering concepts [3]. Our differing needs and the deficiencies we noted motivated the design of a new PFL.

All PFLs have several core distinctives that are listed in table 2.1 [4]:

<table>
<thead>
<tr>
<th>Ownership</th>
<th>Each student owns platform and tools. Personal ownership helps the student take responsibility for their equipment and education.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuity</td>
<td>A PFL provides topical continuity through the entire curriculum.</td>
</tr>
<tr>
<td>Context</td>
<td>A PFL provides a real-world context to place abstract lecture topics.</td>
</tr>
<tr>
<td>Fun Factor</td>
<td>Through engaging hands-on experiences students have fun!</td>
</tr>
<tr>
<td>Hands-on Learning</td>
<td>Hands-on experiments improve learning and comprehension of engineering theories [5].</td>
</tr>
</tbody>
</table>
III. Educational Objectives

Figure 2.1: Model showing lecture and lab enhancement

Figure 2.1 shows how a PFL addresses both ABET mandates shown as the core of the pyramid and requirements beyond ABET. Depth, breadth, and traditional engineering fundamentals required by ABET are taught in lecture. Experiences in lab provide opportunities for innovation and hands-on learning. A PFL encompasses lab and lecture by providing a common object to illustrate theory and to experience the manifestations of it in a real-world object. This connection meets ABET requirements, while also adding design, innovation, professionalism, and community [4]. The interpreted requirements that Figure 2.1 depict are clarified in Table 2.2.
Table 2.2: Clarification of PFL Objectives

<table>
<thead>
<tr>
<th>Objective</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth</td>
<td>The ability to identify, formulate, analyze, and solve electrical and computer engineering problems by applying fundamental mathematics and engineering theory.</td>
</tr>
<tr>
<td>Breadth</td>
<td>A base of understanding at a systems level as well as at a component level. This includes comprehension of the global and local consequences that ECE solutions create.</td>
</tr>
<tr>
<td>Troubleshooting</td>
<td>A developed and practiced skill by which a student approaches the isolation, diagnosis, and resolution of engineering problems.</td>
</tr>
<tr>
<td>Community</td>
<td>The ability to responsibly build realtionships, learn from, teach, and lead engineering teams.</td>
</tr>
<tr>
<td>Professionalism</td>
<td>The skills necessary for being able to effectively work in a modern workplace. This includes effective communication, responsible teamwork, and an understanding of engineering ethics.</td>
</tr>
<tr>
<td>Innovation</td>
<td>The capability by which ideas are created, improved upon, and transformed into engineering products.</td>
</tr>
</tbody>
</table>

**IV. First Year Program**

**A. Overview**

The first year ECE experience at OSU consists of three courses which all use a PFL and a freshman mentor program. Freshman mentors are a set of constant peer instructors that are only a year or two older than the incoming students. Mentors are employed through all three introductory courses.
Each course provides a unique insight into the field of electrical and computer engineering. The introductory course, ECE 111, teaches engineering ethics, the basics of microcontroller usage, and begins explaining the design process. ECE 112, the second course in the series, covers the application of Kirchhoff’s voltage and current laws to actual design problems embodied in the TekBot PFL. The final course in the first year program, ECE 271, teaches digital logic design and the tools needed to solve control problems digitally. The lab for this course, ECE 272, gives students an opportunity to implement those designs using digital logic. Again, this lab is provided a common link to the design environment in ECE 111 and ECE 112 by the PFL. A progression of growing design capability is shown in Figure 2.2. Furthermore, the growing capital of design competence gained in the first year program is utilized further in many downstream ECE courses that use the TekBot PFL.

Figure 2.2: Model showing the progression of design competence
Skills gained using the TekBot PFL become a springboard for senior design projects. A high percentage of senior design projects use ideas and design skills acquired while learning with a TekBot PFL. An example of a senior project that most apparently used TekBot skills and hardware was a modified TekBot that found and sorted balls based upon color [6], Figure 2.3.

![Figure 2.3: A senior project that used prior design knowledge](image)

The TekBot PFL has been used at Oregon State University for over seven years, and during this time the platform has also spread to other schools. In Oregon, Linn Benton and Umpqua Community Colleges are using TekBots in their curriculums. George Fox University used the TekBot PFL to infuse design into their freshman year as well [7]. The University of Nebraska [8], Texas A&M University, Rochester Institute of Technology [9], Iowa State University, and Fukuoka Institute of Technology in Japan have used the TekBot platform to develop engineering curricula fitted to their needs.
B. ECE 111

The initial first-year ECE course, ECE 111, has a lecture and lab. Lecture covers ethics, student skills, and the basics of microcontroller usage, but not architecture, per se. When covering ethics, the traditional approach of case studies is used as well as ethical applications to the student experience with discussions of academic dishonesty. Student skills include scheduling courses, interviewing practicing engineers, and developing a plan for graduation.

Lab for ECE 111 is taught by freshman mentors with groups of 25 students per section. Two hour labs provide students an opportunity to form community groups, build relationships with freshman mentors, and gain hands-on learning with the manipulative for ECE 111. The microcontroller and PCB used are shown in Figure 2.4. The multitude of designs possible with this board makes it a good tool to teach design skills without the cost of an expensive development board. In fact, this board is so cheap, all of the students own two.

Figure 2.4: Microcontroller manipulative used in ECE 111
This manipulative also provides skills necessary to the construction of electrical engineering prototypes. These skills include component identification, soldering, breadboarding, and troubleshooting. Instruction is provided by a freshman lab manual, which is used for the entire year. The freshman mentors also provide accessible support to the students.

The initial projects for the lab are structured and limited. Students calculate how to correctly limit current through an LED with assistance from their classmates and mentors. A microcontroller is then programmed to blink the LED at a certain rate, or to be controlled by a small switch. The last defined project uses pre-coded C language functions to read an analog-to-digital converter and control the number of LEDs that are lit.

About halfway through the term, students are given a choice of four open ended final project ideas. While minimum requirements are set, the projects are allowed to become as ambitious as is reasonable. The available project choices include: a tachometer, a digital range finder, an inclinometer, or a project of their own choosing that gets instructor approval.

Each project must use an input sensor. The tachometer counts how many magnets pass a reed switch in a given second and then displays the result to a one digit LED display. The digital range finder reads an analog signal from an IR sensor to find the distance to the nearest object and displays the result on a one digit LED display. The inclinometer also reads an analog input from an accelerometer to find the angle of an axis relative to gravity and display the result on a two digit LED display.
The dynamic range of difficulty of the projects is from simply interesting to quite difficult. Experienced students can challenge themselves with more challenging projects that have more digits or advanced features. Inexperienced students can choose less difficult projects that let them feel successful in their first engineering project. The ECE freshman mentors and TAs that staff this lab enable this final project to be a success.

**C. ECE 112**

The second ECE course focuses on the fundamental topics of circuit analysis used in electrical engineering. Current and voltage are formally defined for the students. Their past experience with LED biasing allows them to grasp more of what the terms “current through the LED” and “voltage drop across the LED” really describe. The lecture covers Kirchhoff’s laws, circuit simulation in SPICE, diode and transistor circuits, simple logic gate formation with transistors, and logic minimization.

The lab for ECE 112 introduces the TekBot PFL, shown in Figure 2.5. The labs for the course are divided into four sections: battery charger board assembly, experiments with resistors, bipolar junction transistor analysis, and analog controller board assembly. The charger board introduces the idea that complex circuits are usually composed of several functional blocks, each of which performs a specific task. The bridge rectifier functional block allows for the use of AC or DC wall warts. The voltage regulator enables higher voltage wall warts to be used without damaging the
charger. The block diagram for the charger introduces the students to a way to partition a complex system by decomposing it into comprehensible subsections.

The idea of breaking up a system into functional blocks is repeated with the motor controller board. A logic gate is introduced as current sequencer to an H-bridge. An H-bridge allows for bidirectional control of motors.

Students are also taught how to troubleshoot and verify functionality of their board using the provided test pads on the board. While building the charger board students verify each functional block immediately after assembly. After the block is tested and works correctly the student begins to build the next block. This helps empower the student to fix problems as they arise, as well as build troubleshooting skills.

Another board that is built in ECE 112 is the analog controller. Blocks are again used to describe operation of this system. A ramp generator block generates timing signals for the right and left switches of the TekBot. Four tunable voltages are set by potentiometers. Lastly, comparators are used to compare a voltage set by a potentiometer and the RC ramp generator. This provides timing control that is fed to the motor controller board and controls the amount of time that the TekBot reverses and turns after bumping into an object.
Figure 2.5: TekBot manipulative used in ECE 112

D. ECE 272

The final course in the ECE first year program is ECE 271. This course covers the analysis, synthesis, and minimization of digital logic by introducing the following topics: number systems, Boolean algebra, circuit minimization with Karnaugh maps, flip flops, counters and state machine design. The lab for this course, ECE 272, uses a complex programmable logic device (CPLD) shown in Figure 2.6. This manipulative, which is yet another component of the TekBot PFL, is used as a replacement for the analog controller used in ECE 112. The removal of the old board and installation of the digital logic board comes with a discussion that covers how an engineering problem has many solutions. Students learn that their TekBot can be driven by different methods of control, each with its own costs and benefits. An analog control
board is less expensive. A digital logic board is more precise and can interface to infrared devices, such as a television remote.

![CPLD-based TekBot manipulative used for ECE 272](image)

Figure 2.6: CPLD-based TekBot manipulative used for ECE 272

The ECE 272 lab begins with an overview of the new board. A quick scan of the schematic shows the students that they already have some common knowledge to leverage. There are 3.3 and 5.0 volt regulators and LEDs that have been used in ECE 111 and ECE 112. The first lab begins with using buttons to control LEDs, just as in ECE 111.

As the labs move forward, they mirror the lecture topics and give students an opportunity to gain hands on experience and increase their depth of the knowledge. The last lab becomes a final project with two options. The first is building an IR-controlled TekBot. The second option is to combine previous designs and make a tethered TekBot that automatically reacts to walls and displays the current action with an LED display.
V. Results

A voluntary survey is given multiple times a year, at least once per term. Survey questions pertain to different aspects of self-efficacy. All questions are rated between 0 and 100 with a higher score correlating to a stronger agreement with the survey question.

Table 2.3: Survey results for the freshman year program

<table>
<thead>
<tr>
<th>Question</th>
<th>ECE 111 Pre</th>
<th>ECE 112 Pre</th>
<th>ECE 112 Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>I do more than what is required in lab and create new projects with my lab materials.</td>
<td>42.9</td>
<td>58.6</td>
<td>61.2</td>
</tr>
<tr>
<td>I have a role model who helped me engineer something creative this term.</td>
<td>22.0</td>
<td>48.7</td>
<td>52.2</td>
</tr>
<tr>
<td>I have experienced success in doing engineering related activities.</td>
<td>57.3</td>
<td>80.5</td>
<td>81.0</td>
</tr>
</tbody>
</table>

The first survey question probes for improvements in student innovation within lab. The ability to stretch the platform and their own skills beyond the required level indicates how students have increased their ability to innovate.

The second survey question is used to determine the effect that laboratory assistants and the freshman mentor have on innovation. Teaching creativity is difficult, but this indicates that students believe they are becoming creative engineers.

The last question tries to determine if the PFL increases student confidence by giving them early successes in engineering. Creating successful experiences in engineering are a valuable component to developing the incoming engineers.
Results from these survey questions are very positive. Many incoming students answered zero for the pre-ECE 111 questions. By the end of ECE 112 those students have worked with freshman mentors and found role models, pushing that result up to 52.2. Another insightful note is that the exciting labs enticed general engineering students to begin ECE. Our enrollment numbers actually went up slightly from ECE 111 to ECE 112.

**VI. Conclusion**

Students who are to be the engineers of the future have peripheral needs that surpass the ability to work difficult math problems and quote engineering theories. Peripheral skills also need to be taught, and using a PFL to introduce design content into an engineering curriculum achieves this. Our survey results show that students respond positively to the PFL and freshman mentor approach to ECE education. The core concepts of a PFL, ownership, continuity, context, fun factor, and hands-on learning, provide both confidence and familiarity with a wide variety of electrical engineering topics, improving the delicate art of design.

**VII. Future Work**

Future goals for utilizing manipulative rich environments are to improve upon learning outcomes while minimizing unnecessary cost, both time and financial. The concept of partitioning systems is going to become more of an important focus of design. The most notable change for next year will be the use of simulation to check designs in ECE 272 before implementation in the CPLD. This will enable students to
develop and debug their logic design, without the complexities inherent in hardware implementation.

The PFLs in use at OSU are in a constant process of improvement. Figure 2.7 shows how the forward movement of the platforms progress. PFL development for a course takes place during the summer with instructor guidance and exceptional students that have first hand knowledge of the platform’s performance during the prior iteration. Students that worked on developing the PFL are then encouraged to assist in the laboratory teaching during the next course offering. New students and teaching assistants evaluate strengths and weaknesses of the revised course, in order to focus development efforts that will happen during the next summer.

Figure 2.7: Procedure to improve the platform for learning.


**VIII. References**


[7] Spivey, Gary; Bader, Jefferey; Ninteman, Neal, "Work In Progress - building MatBot - a platform for freshman robotics with use throughout the engineering curriculum," Frontiers in education conference - global engineering:
knowledge without borders, opportunities without passports, 2007. FIE '07.
37th annual, vol., no., pp.S1J-12-S1J-13, 10-13 Oct. 2007

[8] (2008, March). Engineering Nebraska Summer 2006 Website, University of
Nebraska-Lincoln, Lincoln, Nebraska, [Online], Available:
“http://engineering.unl.edu/publications/ENonline/Summer06/02.shtml”

[9] (2008, March), RIT News and Events Newsletter, Rochester Institute of
2007/Dec01/NandE_12_06_07.pdf”
Abstract – Transitioning from high school to a university setting is difficult, and when combined with the academic stresses of an engineering program, low undergraduate retention rates are a common problem. A solution to the retention problem is to create a curriculum that can improve self-efficacy while teaching engineering basics. Most current methods to increase self-efficacy include mentorship programs, addressing different learning pedagogies, and creating separate learning communities. However, execution of these methods is prohibitive when educating large numbers of students. This paper describes a method of increasing self-efficacy in a large class setting with a goal of improving retention rates. A preliminary self-efficacy survey shows an improvement in self-efficacy as a response to our work.

Key Words – TekBots, Mentorship, Engineering Education, Freshman, Self-Efficacy

I. Background and Introduction

Self-efficacy is an established indicator for modeling social learning and has been leveraged for more than thirty years [1]. Leveraging these social learning concepts is imperative for improving the retention and development of incoming
engineering students [2]. The process of a student leaving an engineering program often begins with an event that creates doubt about a student’s ability to succeed in engineering. After this initial event, the doubt grows with each future struggle. Eventually, the attraction of engineering is outweighed by another option with more perceived ability for success, and the student changes majors to the new perceived best option. This doubt in perceived ability to succeed in engineering is an example of low self-efficacy [2]. To retain engineering students, approaches need to be taken to improve self-efficacy while not sacrificing program goals and standards.

There are four components that constitute self-efficacy: mastery experiences, vicarious experiences, social persuasions, and physiological states [3]. The majority of mentoring methods that address self-efficacy include; specialty mentoring programs [4], and general orientation programs [5].

An example of a specialty mentoring program is the GUIDE program implemented at Michigan Tech University. They team 10 students with 10 peer mentors [4]. This program has had success improving the social persuasion component of self-efficacy, but the one to one ratio of mentors to students is not easily scaled to 150 students.

The University of Pittsburgh has implemented a general peer mentor program that guides close to 400 students in general engineering [5]. While this program has had positive results in social persuasion, it does not offer engineering mastery experiences for students.
The School of Electrical Engineering and Computer Science (EECS) at Oregon State University (OSU) has 150 incoming freshman students each year with a broad distribution in baseline engineering experience. The large number of students coupled with a varied skill set requires an approach that is highly scalable and adaptable to individual student needs. Existing programs found in literature do not meet these requirements.

II. Proposed Approach

Our proposed approach to improve engineering undergraduate retention rates is to implement a freshman mentor program that uses all four sources of self-efficacy theory [3]. This program was first created in 2006, and is utilized over a one year period with the entire incoming Electrical and Computer Engineering (ECE) freshman class. Each of the seven ECE mentors lead a lab section of twenty students and help maximize the impact of the TekBots Platform for Learning (PFL) [6].

Mentors are selected for their abilities to improve self-efficacy of students in their lab. Some mentors have an encouraging personality and are able to persuade students to keep trying engineering. Four of the mentors won a national robotics competition, The University Rover Challenge, granting a vicarious experience in engineering success to their students. The PFL that exist in each of the students’ labs throughout the year give students an opportunity to generate mastery experiences. Lastly mentors are encouraged to create events that are of personal interest to them in hopes of reducing stress and improving the physiological state within ECE students. Video game tournaments, outdoor games, study sessions, and robotics club activities
have all been used to increase student interest in engineering while providing relaxation from the stresses of lectures and assignments.

**III. Freshman Mentor Structure**

An efficient structure within our freshman mentor program is crucial to improving student self-efficacy. At OSU we employ a freshman mentor coordinator who is a graduate student, whose primary goal is to create a positive atmosphere to train the undergraduate freshman mentors. All mentors commit for an entire year and are given access to a room dedicated for their base of operations, the freshman mentor lounge. Mentors hold weekly office hours in the lounge, and student visits are recorded into a database creating a useful anonymous log of lounge usage. Responsibilities of the mentors include grading homework, laboratories, and midterms for freshman courses. This alerts mentors to poor student performance so they can discreetly encourage the student to drop by the lounge for assistance. All grading information remains confidential, only known to the mentor and the class instructor. Lastly, the mentoring program is self-sustaining. Mentors are responsible for encouraging appropriate students to apply to become mentors, recommending applicants, and giving preliminary interviews for mentoring positions in the following year.

**IV. Platform for Learning**

A PFL is defined as a common unifying object or experience that unites various classes into a curriculum sequence [2]. A PFL provides a foundation that is
used to develop skills necessary for engineering students. At OSU, development of a PFL began in 2001, and the resulting platforms have gone through several iterations to improve their effectiveness. For instance, a preassembled motor control board is now supplied to the students instead of having them solder it together. Testing and hands-on-learning with the motor control board still occur in lab, but the students have more time to experiment and understand the circuit elements.

V. Preliminary Results

A voluntary survey is given to the students three times a year, once a term with questions pertaining to different aspects of self-efficacy. All questions are rated between 0 and 100 with a higher score correlating to a stronger agreement with the survey question. Current results are shown in Table 3.1. A third column will be added to this table during the next term.

<table>
<thead>
<tr>
<th>Question</th>
<th>1st Term</th>
<th>2nd Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>I have experienced success in doing engineering related activities.</td>
<td>57.3</td>
<td>81.0</td>
</tr>
<tr>
<td>I have had a role model who was an engineer who made me think that I could be one, too.</td>
<td>22.0</td>
<td>52.2</td>
</tr>
</tbody>
</table>

The first question gauges how students rate their mastery experience to date and the second question measures if students have a source for vicarious experiences. These results show that students are getting opportunities to do engineering and that
they are receiving support from their role models. Current results do not show a noticeable increase in the other two sources of self-efficacy.

**VI. Conclusion**

Improving self-efficacy will result in better undergraduate engineering retention. Self-efficacy is composed of four components: mastery experiences, vicarious experiences, social persuasion, and physiological state. The current mentoring methods do not address all the components of self-efficacy. The synergy of a freshman mentor program with a PFL is designed to improve all four components, and already has shown positive results for half of them. The self-efficacy survey results show an improvement during the beginning of the second term. These students now eat lunch, study, or work on independent extra projects in the lounge with guidance from a mentor. While the program is not yet complete, it promises to be a positive and self sustaining resource for a large school to implement in efforts to retain and develop a diverse student body of different entry skill levels.

**VII. Future Work**

Future work includes creating on-campus partnerships with STEM researchers, researchers in the studies of self-efficacy models and measurement tools, and faculty in the OSU Center for Teaching and Learning. A more complete study and analysis of self-efficacy survey data will be explored as well. The program will be expanded in the next year to include Computer Science students.
VIII. References


WORK IN PROGRESS: IMPLEMENTING A FRESHMAN MENTOR PROGRAM
Matthew Shuman, Jace Akerlund, Donald Heer, Terri Fiez
Oregon State University

Abstract – Creating positive learning communities that engage incoming engineering students with varying degrees of engineering experience poses a challenge to universities with high enrollments. Many schools have a general university-wide orientation program for every student. Other universities address only a distinct subset of students in their mentorship programs. In September 2006, a solution was started at Oregon State University (OSU) which was to implement a mentor program for the entire freshman Electrical and Computer Engineering (ECE) class. Evaluation tools for the freshman mentor program consist of student retention rate records, a freshman mentor database, and a survey to track growth in our mentoring effectiveness within the student body. Future goals of the program will include increasing student involvement with academic clubs and implementing novel structures to increase retention.

Key Words – Electrical Engineering, Mentorship, Engineering Education, Freshman, Self-Efficacy
I. Introduction

Mentoring programs are a common solution to student retention problems in universities. Scope and approach in these programs is extremely varied. The University of Tennessee implemented a mentor program they call “Engage”. The Engage program combines five basic engineering courses into two team-taught courses. The courses include design teams, each of which has an upperclassmen coach. Results from this program have indicated improved retention rates and increased preparedness for students entering their desired major engineering department [1].

The University of Nebraska began a “pod-based” mentoring program in Fall 2005, which serves as a model for OSU’s mentoring program. Their plan used an off-campus retreat, student support communities called pods, a graduate student counseling assistant, and more immediate feedback to the instructor about student misconceptions in an attempt to reduce the attrition rate during the freshman year. The counseling assistant led labs for the seventy students and was successful in influencing students during the weekly laboratory. Their efforts were rewarded and the attrition rate lowered from a historical average of 33% to 20% [2].

II. Freshman Mentor Program

The mentoring approach started at OSU’s ECE program in Fall 2006 uses a variation of the program started at University of Nebraska’s Peter Kiewit Institute [2]. Four main features have been modified to suit our needs. First, instead of a single
counseling assistant, a freshman mentor coordinator is employed to lead six other undergraduate freshman mentors for the entire year. Second is that mentors are hired to lead a lab section during each of the three terms in the freshman year. Next, mentors are trained to properly interact with different student skill levels. The last change is that our mentor program must be self sustainable.

The freshman mentor coordinator is a graduate student that completed his or her undergraduate degree at OSU. This is critical to success as the graduate student has taken the undergraduate labs and is very comfortable with the material. The coordinator then handpicks the other undergraduate mentors, one for each lab section. Each mentor is selected for their ability to serve as a role model for engineering success. Half of the mentors are chosen for their engineering passion and lead by example. The other half are chosen for their outgoing personalities and ability to guide students via positive encouragement and rapport. The ‘chemistry’ of the team is designed for a balance of those two teaching styles.

Each mentor is employed as a lead teaching assistant for a lab section of an ECE class during all three terms of the freshman year. Mentors also hold weekly office hours in a dedicated room called the freshman mentor lounge. This opportunity to lead a section of 20 students and become involved in student instruction and assessment creates a genuine sense of ownership for student retention and development.

The layout of the freshman mentor lounge intends to create an open and inviting refuge where students can come eat lunch, talk to their mentors, and receive
help with their coursework. Such a layout creates a more comfortable atmosphere than a classroom or study hall. Lastly, a desktop computer holds a database that is updated with logged information about when student visits happen. Mentor interactions with students are logged, whether due to a lecture, lab, extracurricular, or social question into a mentor database. The information gathered can help in the analysis of course difficulty, because students tend to come to mentors for help as coursework becomes more difficult. The mentor database has recorded 304 interactions with 88 of our 176 incoming students in just 20 weeks of logging visits.

III. Lab Environment

Varying levels of engineering experience within the incoming freshman class present difficulties when mentoring or planning laboratories. The experience levels of incoming freshman can be characterized by a bell curve with three distinct regions, as is shown in Figure 4.1. Region 1 represents the students that have no prior electronics experience. Region 2 is the largest group and has students with little or moderate electronics experience. Region 3 represents students with significant electronics
experience. A static lab can only target a specific portion of this distribution. Students from the third region find these static labs lack innovation and excitement, and often complain about the labs being “too easy”. Students from the first region contrarily find the labs “too difficult” and are required, in some cases, to play “catch-up” with the rest of the students.

The solution is to employ a dynamic, project-based lab which can offer extra challenges to adjust the difficulty of each project to suit the needs of each student. The freshman mentor facilitates this dynamic challenge within the lab. These dynamic labs have been crucial in the motivation and engagement of experienced students.

Sustainability of the mentor program is key to its continuation. Hiring appropriate undergraduates that have already completed their freshman courses as peer mentors creates natural learning communities within the incoming student body. Mentors quickly become role models for the students as shown by a survey given to the students during the beginning of every term. As mentor positions become available they are advertised, and current mentors encourage appropriate students to apply. After the applications have been received, the mentors are then asked who they think best fits as a freshman mentor for the following year. Mentors are ideally suited for this task because they have known the students for an entire year and best know the requirements to become a future mentor.

IV. Mentor Empowerment

Freshman mentors are encouraged to create activities and groups to help improve student involvement, camaraderie, and interest in electrical engineering. Video game
tournaments, study sessions, outdoor games, extra lab time, and other activities have been created by the mentors in efforts to better connect to the students and streamline operation of the freshman year courses.

A direct result of this encouragement is the new OSU Robotics Club. This club was founded by the freshman mentor coordinator, and three other freshman mentors quickly became involved. Student involvement has already increased and there are currently 45 members involved in the club.

V. Results

A voluntary anonymous survey is given to students once a term during their freshman year. Students are asked to rate the accuracy of a list of statements on a scale from 0 to 100. Preliminary results have been very positive. Students rated the question “I have a role model who helped me engineer something creative this term” at an average of 22.0 during the beginning of the first term. By the end of the second trimester the average rating rose to 52.2.

VI. Conclusion

This mentoring program has been a valuable resource in increasing the retention of undergraduate students. Students enjoy the consistency of the mentor role models. This program has become a valuable asset in growing the ability of our students at all incoming experience levels. Overall student enjoyment of the labs themselves has also increased as student initiated projects and innovations have become commonplace in and outside the lab.
VII. Future Work

Future ideas for the mentoring program include creating new student involvement structures, such as student competitions, innovation challenges, engineering workshops, or community building activities.

VIII. References


OVERALL CONCLUSION

This thesis has explored the challenge of retaining Electrical and Computer Engineering students. Oregon State University is under pressure to graduate more engineers of that have a higher level of design experience. This stress has helped develop PFLs and a freshman mentor program.

The freshman mentor program has become valuable in increasing retention of undergraduate students. The mentors are critical to assisting students that want extra help and challenging students that want extra work. The mentors add a dynamic element to lab that helps retain students of varying levels of engineering experience.

Our efforts to improve retention have focused on maintaining a high self-efficacy in our students. The combination of the TekBot PFL and the freshman mentor program address all four components of self-efficacy. Voluntary survey results already indicate an improvement in developing learning communities and half of the components of self-efficacy.

Manipulatives used in the first year of Electrical and Computer Engineering allow for the instruction of peripheral skills. Students gain an ability to build, analyze, and design engineering projects through a sequence of lectures, labs, and manipulatives.

Assessing the progression of self-efficacy is accomplished by survey data and logged data from the freshman mentor database. Results have shown that problems exist in hands-on labs without the proper support structure provided by trained
freshman mentors. These problems are counteracted and even reversed when the freshman mentors are utilized properly in the laboratory.

Initial survey data shows that the synergy of PFLs and freshman mentors have had a significant benefit to the increase of student self-efficacy. This improvement will be linked with the retention rates of students as they progress through the engineering curriculum during the following years. Labs that use a PFL, while being staffed by freshman mentors have a positive effect on self-efficacy. The self-efficacy assessment surveys and analysis techniques developed to assess this improvement verifies that this program has a real and significant benefit to the retention of Electrical and Computer Engineering undergraduate students.