I, Whitney Gaskins, hereby submit this original work as part of the requirements for the degree of Doctor of Philosophy in Biomedical Engineering.

It is entitled:
Changing the Learning Environment in the College of Engineering and Applied Science: The impact of Educational Training on Future Faculty and Student-Centered Pedagogy on Undergraduate Students.

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Changing the Learning Environment in the College of Engineering and Applied Science: The impact of Educational Training on Future Faculty and Student-Centered Pedagogy on Undergraduate Students.

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ABSTRACT

Over the past 20 years there have been many changes to the primary and secondary educational system that have impacted students, teachers, and post-secondary institutions across the United States of America. One of the most important is the large number of standardized tests students are required to take to show adequate performance in school. Students think differently because they are taught differently due to this focus on standardized testing, thus changing the skill sets students acquire in secondary school. This presents a critical problem for colleges and universities, as they now are using practices for and have expectations of these students that are unrealistic for the changing times. High dropout rates in the College of Engineering have been attributed to the cultural atmosphere of the institution. Students have reported a low sense of belonging and low relatability to course material.

This study developed a “preparing the future” faculty program that gave graduate students at the University of Cincinnati a unique training experience that helped them understand the students they will educate. They received educational training, developed from a future educator’s curriculum that covered classroom management, standards, and pedagogy. Graduate students who participated in the training program reported increases in self-efficacy and student understanding.

To reduce negative experiences and increase motivation, Challenge Based Learning (CBL) was introduced in an undergraduate Basic Electric Circuits (BEC) course. CBL is a structured model for course content with a foundation in problem-based learning. CBL offers general concepts from which students derive the challenges they will address. Results show an improved classroom experience for students who were taught with CBL.
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Chapter 1: Introduction

Over the past 20 years there have been many changes to the primary and secondary educational system that have impacted students, teachers, and post-secondary institutions across the United States of America. Policy and legislation affecting the education system has changed, technology used in the classroom has changed, and, due to the policy changes and available technology, the teaching methodologies have also changed (Culp, 2005). Teachers are now under different type of pressure than previously in trying to meet the demands of these changing standards (Dee and Jacob, 2010; Reback, Rockoff, and Schwartz, 2011). Students think differently, which has changed the skill sets students are equipped with once they leave the secondary school environment (Healy, 2011). Generally, post-secondary educational institutions are not aware of the changes made to the secondary education system and, importantly, do not understand how these changes affect their students as they matriculate into a college environment (Anderson et al., 2011). Colleges and universities have managed to stay “unchanged” and “unaffected” by K-12 educational policy and continued the same teaching methodologies and practices for the past 50 years, especially colleges of engineering and applied sciences (Wilson et al., 2010; Taylor, 2010). There have been many attempts at post-secondary educational reform, but none has become a national movement. The absence of a national consensus for addressing the changes in the educational makeup of graduating high school students presents a critical problem for college and universities when educating these students, as they now are using practices with and have expectations of students that are unrealistic for the changing times.
Assessment of Primary and Secondary Education

Standardized Testing

Standardized tests are used to measure learning outcomes required by the federal legislation to assess K-12 teaching effectiveness in each state (No Child Left Behind Act, 2001). States use test scores to compare schools within districts as well as between districts (Chatterji, 2003). Students complete two types of standardized tests: norm-referenced tests and criterion-referenced tests. Norm-referenced tests compare student performance to students in the same state, sometimes nationally (Gronlund, 2003). Criterion-referenced tests compare student performance to a specific area or region (Borich and Tombari, 2004). States and school districts have noted that standardized tests do not assess all learning outcomes, but standardized testing is the measure that is predominantly used in every state to assess student performance (Mitchell, 1997).

To ensure proper testing, schools implement an average of 27 standardized tests from beginning primary school throughout secondary school. In some states students take two times the number of exams compared to prior to 2001. The increase in testing has primed students to believe that exams are the proper measure of success. This increase in testing has also placed teachers under pressure to show high student performance outcomes.

To meet state and federal requirements, K-12 school districts have started using teaching strategies to help students become better test takers (Popham, 2000). Some of the teaching strategies include a review of test content, only covering content that will appear on exams and after school programs to review actual test material. There are even cases of teachers doing in class practice sessions (Popham, 2000). To meet the necessary criteria and to show high performance, studies have shown that teachers will change their teaching methodologies as well as their lesson plans to be more
aligned with tested material (Earl et. al., 2003). In the United States there have been over 100 reported cases where teachers and administrators gave students the correct answers to test questions or engaged in systemic practices of altering student answers prior to tests being graded (Goodnough, 1999; Simmer, 2000).

Figure 1: Number of Standardized Tests Administered by State (figure created using data from time4learning.com)

Figure 2: Number of Standardized Tests Administered in Primary and Secondary School by State (figure created using data from time4learning.com)
Standardized testing has the potential to help teachers assess student performance. The change in teaching methodologies and the emphasis on high performance on the standardized tests corruptions the useful of exam scores (Popham, 2001). Burger and Krueger (2003) stated the predictive validity of a standardized test is compromised when “teaching to the test” techniques are employed.

Standardized tests also have some documented negative effects on students (Sacks, 2000). One negative effect of teaching to the test is the “dumbing down effect” (Sacks, 2000). “Dumbing down” is defined as lowering the general level of intelligence. Higher order thinking skills are affected by the increased focus on standardized testing due to teachers spending the majority of their time on subjects that are tested (Herman, 1992). Research has shown that the increased focus on tested subjects has not affected learning for the students, even when test scores are increased (Shepard, 2000; Smith and Fey, 2000). Studies have shown that students are more proficient in test taking strategies as opposed to the material on the exam (Neil, 2003). Students have been evaluated and asked to explain their answers. Many of the students were unable to comprehend what they had just reviewed; they were able to select the correct answer based off strategies they learned from their teachers. When students move from primary and secondary education, they will be required to think critically and to gain a deep understanding of the material, especially in the STEM fields. Currently students may be lacking the skills needed to succeed due to emphasis on testing.

Another negative effect of teaching to the test is the narrowing of curriculum. To ensure students are high performers, the depth of instruction on subjects is lessened. Some subjects, such as physical education, music, and drama, have a decreased amount of time in the school day to give students more time to review tested subjects such as math, writing, and reading.

Last, teaching to the test gives students the impression that they are prepared to take college-level courses due to high performance outcomes on standardized tests. Communication and research
skills like public speaking, presenting research, conducting the scientific method and following the engineering design process are neglected when teachers are focused on testing, but these skills are needed in higher education (Volante, 2004). For students seeking careers in STEM fields, teaching to the test hinders the critical thinking that is vital for those disciplines.

**Why the Rise in Standardized Testing**

In the United States the federal role in education is limited because the Tenth Amendment states “education is the responsibility of the State.” However, in 2001 the federal government passed the No Child Left Behind Act (NCLB) that changed the educational system by mandating measurable progress hence the increase in standardized testing (NCLB Act, 2001).

The primary purpose of NCLB Act is to ensure that students in every public school achieve specific learning goals while being educated in safe classrooms by well-prepared and qualified teachers (NCLB Act, 2001). The Act strives to close achievement gaps between underrepresented and socio-economically disadvantaged students. Part of NCLB Act required schools to reach 100 percent proficiency on standardized testing in a 12 year time frame. Each state is responsible for developing benchmarks for math and reading proficiency. Each student and district must make Adequate Yearly Progress (AYP). AYP is the measure by which schools, districts, and states are held accountable for student performance under Title I of NCLB Act. States use standardized assessments in order to measure AYP. Schools and districts that meet the yearly goal are considered distinguished and in some states win a distinguished school award. When schools are unable to meet AYP two years in a row they are considered “in need of improvement.” If the school fails to meet AYP goals for three years in a row, children are eligible for additional activities, like free tutoring and after-school instruction. Parents can move their child from a school that is failing to meet AYP to a higher-performing school within the
district. Schools that are labeled Title I, schools with high poverty, and students who are academically behind are given federal funds to use toward improvements.

**Positive Consequences of NCLB Act**

To encourage scientifically based teaching strategies, NCLB Act funds instructional programs that have been researched and proven to be successful. NCLB Act is working to ensure that students are educated with proven teaching methods.

NCLB Act also puts emphasis on the quality of the teacher. NCLB provides funding for teachers to become better instructors. Under NCLB Act, all teachers must be licensed to teach, hold at least a bachelor’s degree, and be highly qualified in the subject they are teaching.

**Unintended Negative Consequences of NCLB Act**

Administrators and teachers focused their efforts on meeting NCLB Act criteria. The change increased pressure on teachers to decrease achievement gaps and increase student performance (Anthes, 2002). Studies have shown that teachers will tailor their teaching efforts to improve test scores in order to increase student performance outcomes (Earl et. al., 2003). In the United States there have been over 100 reported cases where teachers and administrators gave students the correct answers to test questions or engaged in systemic practices of altering student answers prior to tests being graded (Goodnough, 1999; Simner, 2000).

**Steps to correct Unintended Negatives**

The Blueprint for Education Reform of 2010 (US Department of Education, 2010) provides waivers to states as they work to achieve the goals stated in the NCLB Act. According to whitehouse.gov
these waivers give states the flexibility needed to increase student achievement outcomes, improve school accountability, and increase teacher effectiveness.

According to www2.ed.gov states receiving waivers must develop a plan to ensure students succeed above the standards described in NCLB Act addressing three main areas:

1. *Preparing students for college and careers:* States must have already adopted college- and career-ready standards in reading and math that raise the achievement of all students, including English language Learners and students with disabilities. Additionally, the state must create a plan to help schools and districts implement those standards and administer statewide tests to measure progress.
2. *Hold schools accountable for making progress:* States must establish an accountability system that recognizes and rewards both high-performing schools as well as those that are making significant gains in improving student achievement, and they must develop targeted strategies to turn around the lowest performing schools and help groups of students with the greatest needs.
3. *Improving teacher and principal effectiveness:* States must set guidelines for teacher and principal evaluation and support systems, developed with input from educators and principals. Evaluation systems should assess performance using factors beyond test scores—such as principal observation, peer review, student work, and/or parent and student feedback—and provide teachers both with constructive advice for improving and support in doing so.

**Impact on Post-Secondary Education**

**Critical Thinking**

NCLB Act has put into place a structure that causes students to be tested frequently, causing testing fatigue as well as a “teaching to the test” teaching methodology. Many students believe that the only measure of success is performance on exams. When students move to a college environment they are forced into a different learning environment of a type that they have not seen or experienced since they started their educational career at age 5. In college, students are responsible for learning material more deeply.

Critical thinking is defined as the learning of complex, abstract concepts (Elder and Paul, 2004). Critical thinking is a skill that is thought to be developed in college classrooms; however research has
shown that critical thinking is not part of the college classroom environment. Cognitive skills are
developed when participating in activities or doing “hands-on” work. In most college classrooms
students do not participate in activities to learn, studies have shown they sit through lectures (Elder and
Paul, 2004). Students enter college without the skill of critical thinking, and leave college without it as
well.

Students focus on what will allow them to achieve high grades. In many cases, colleges and
universities use exams to measure student performance. This type of testing emphasizes recall of
memorized factual information rather than intellectual challenge, further adding to students’ beliefs of
success as measured by exam grades. Even with the lack of critical thinking assessment, a 1972 study of
40,000 faculty members by the American Council on Education found that 97 percent of the
respondents indicated the most important goal of undergraduate education was to foster students’
ability to think critically (Elder and Paul, 2004).

Teaching Quality

NCLB Act also puts emphasis on the quality of teacher, but in the university setting there are no
requirements for professors to teach besides earning a higher education degree. In some institutions,
this could be a master’s degree, but in most it is a doctorate. Without the attention to quality in
teaching, many students experience classroom environments that are not conducive to effective
learning.

This lack of pedagogical training for Science, Technology, Engineering, and Mathematics (STEM)
doctoral students may be due to lack of utilizing research centered on learning. Traditionally professors
 teach the way they were taught even though research has indicated better methodologies for college
student development (Bransford et al., 2004). The diversity in the college has also changed. Students
no longer come from the same backgrounds as the professors and the lack of understanding each other
has changed the learning experience in colleges. It is time to use research to develop professional training and teach not only graduate students but faculty members how to educate.

New faculty members often are unprepared for the position’s roles and responsibilities due to the lack of training received in their graduate training (Austin, 2002; Boice, 1992; Olsen, 1993; Crawford and Olsen, 1998; Rice, 1996; Sorcinelli, 1992). One of the main responsibilities of new faculty members is teaching (Boice, 1992). When graduate students are hired they are expected to be ready to teach (Seidel, Benassi and Richards, 1999). Even with the demand for educators graduate training has not incorporated training in the curriculum. Teaching certifications are not a requirement to teach in the post-secondary environment. Graduate students in STEM fields have little to no teaching experience, while others may serve as teaching assistants in one or two different courses where their main responsibility is grading papers. Graduate advisors as well as new faculty both agreed that the graduate training they received was not suitable to be effective educators (Seidel, Benassi and Richards, 1999). In a longitudinal study graduate students reported that during their graduate studies the importance of teaching was not emphasized and often times felt they received contradictory statements regarding its importance (Austin, 2002).

The Preparing Future Faculty (PFF) program was launched in 1993 by the Association of American Colleges and Universities (AACandU) and the Council of Graduate Schools (CGS) to develop new models of doctoral preparation for faculty careers. Although PFF programs have been developed to help graduate students with all aspects of a future faculty career, this training has not yet recognized the importance of teaching. The lack of focus on teaching affects graduate students’ teaching self-efficacy.
Teaching Self-Efficacy

According to Bandura (1977), self-efficacy is "the belief in one’s capabilities to organize and execute the courses of action required to manage prospective situations." It has also been defined as the belief that one can succeed in a particular field or domain.

Teaching Efficacy Belief is a teacher’s belief in his or her own ability to teach, called personal teaching efficacy, and to have students learn, called teaching outcome expectancy. Teaching Efficacy Belief was initially described in the Rand Corporation evaluations of Title III-funded projects (Berman and McLaughlin, 1977).

Research has shown that self-efficacy or the belief in oneself affects learning and behavior. Research in education and psychology show that self-efficacy affects performance and the ability to succeed. The Organization for Economic Cooperation and Development (OECD)’s Teaching and Learning International Survey (TALIS) explored teachers’ reported self-efficacy (OECD, 2005). The OECD study found that teachers with a high sense of self-efficacy persist longer when not reaching a desired outcome and strive to become better in their work. They found that teachers with a high sense of self-efficacy will be more creative and innovate to reach a desired goal. Guskey and Passaro (1994) found that teachers with a high self-efficacy can motivate students in learning even when a student is disinterested (Guskey and Passaro, 1994). Research has found positive correlations between teacher’s self-efficacy and student performance and achievement (Anderson, Greene, and Loewen, 1988; Ashton and Webb, 1986; Moore and Esselman, 1994; Midgley, Feldlaufer, and Eccles, 1989; Ross, Hogaboam-Gray, and Hannay, 2001).
Technology

Technological advances have had an impact on teaching methods and the profession as a whole. Technology is becoming more advanced every day. Many schools have new technology that teachers use. New teachers may be acclimated to new technology, where seasoned teachers may have to go through Professional Development (PD) to ensure they are learning about new technology and how to use new technological advancements in the classroom.

Students now learn differently because they have been primed with technology to live in a faster-paced environment. In interviews conducted by Purcell et al. (2012) for Pew Research, teachers expressed their concern for student’s need for instant gratification, in which they called the “Wikipedia problem.” Currently students are accustomed to fast responses when looking for answers that they need to try or work hard is not the norm. Purcell (2012) found that 76 percent of teachers believed students had been conditioned by the Internet to find quick answers (Purcell et al., 2012). Their attention spans have decreased and they have become used to being entertained. With the use of video games and consumer internet, students are also used to learning visually. Purcell (2013) conducted a similar study with the common sense project to survey teachers about the effect of technology and the internet on students. Results were very similar to those of the Pew Research project, 71 percent of teachers believe that student attention spans are shorter (Purcell et al., 2013). Teachers also noted that students have a more difficult time communicating face to face. Of the 685 teachers surveyed, 60 percent think students’ oral and written communications have suffered (Purcell et al., 2013). From the same surveyed teachers, 50 percent stated that students are now struggling with critical thinking and their ability to do homework. Research conducted by Zimmerman and Christaki (2005) shows that the teachers’ perceptions could be accurate in sensing dwindling attention spans among students. They were able to show that attention spans are affected in mice when they are exposed to a large amount of digital stimulation. Their research has shown that teachers may have a more difficult time gaining the attention of their students do to the exposure to television, video games, and other digital media.

A recent survey by PBS Learning Media found that 74 percent of teachers incorporated devices such as tablets in their lessons. The survey also found that 69 percent of teachers using educational
technology said that it greatly enhances lessons and empowers them to teach as they have never been able to before.

With the use of technology, learning has become something that can be tailored and personalized to suit individual students’ unique learning needs. Colleges and universities have embraced new technology, but faculty and future faculty have not been trained on how to properly educate students or how to keep students motivated to learn in the classroom.

**Statement of the Problem**

The Cincinnati Engineering Enhanced Math and Science Program (CEEMS) works to connect the students’ motivation to what they are learning with the use of Challenge Based Learning (CBL). The CBL methodology, proposed by Apple Computer Inc., employs a multidisciplinary approach in encouraging students to use their knowledge and technology to solve real-world problems (Johnson et al., 2009). Lectures are inefficient in promotion of thought (Bligh, 1998). This is a concern for students in colleges of engineering, as they are required to have the ability to think critically and solve problems as outlined in Accreditation Board for Engineering and Technology, Inc. (ABET) criteria. Research has shown that student-centered learning approaches are efficacious in improving student learning (Hightower, 2011). CBL is a pedagogy that uses the engineering design process (EDP) to enhance the process of learning while integrating technology.

In the CEEMS program, graduate students are provided with educational training, are taught the CBL method integrated with EDP, and how to support secondary school (middle and high school) math and science classrooms. Due to the effects of No Child Left Behind Act, current undergraduate students are educated differently in primary and secondary education than faculty. Understanding the K-12 environment is needed for future faculty success. The CEEMS program builds on PFF programs by
providing workshops for graduate students to learn about students, communication skills, teaching, and assessment. CEEMS provides an apprenticeship environment and is designed so that graduate students learn from educators. The CEEMS program developers took evidence from existing future faculty programs, along with results from self-efficacy studies, and developed a program that uses the best practices of each to help prepare graduate students for academia.

However, two gaps in knowledge exist: (a) it is unknown if educational training will improve graduate student instructors’ self-efficacy and thus improve undergraduate learning. (b) It is unknown if challenge based learning will improve student learning and experiences in post-secondary classrooms.

It is important to close these gap in knowledge because out of the potential causes of student success colleges and universities have direct influence on pedagogy used in the classrooms as well as the training that future faculty should receive. The continuation of these gaps in knowledge prevents university faculty members from understanding the effects of the college’s current academic practices on student learning outcomes.

Scope

The long-term goal of this research is to improve the learning environment for undergraduate students in colleges of engineering and applied sciences. The research includes:

1. Professional Development of Faculty and Graduate Students: Future faculty and faculty members have a direct influence on the environment and culture of the university. Research is needed to develop training and techniques that can improve the learning environment.
2. Assessment of Undergraduate Chronic Stress and its Sources: students in engineering or applied science fields may experience chronic stress inherent to the current practices in engineering and applied science academic programs. Research has shown chronic stress can have negative effects on students, such as impaired cognitive performance (Scott, 2011). Understanding how to reduce stress to increase student performance and experience.
3. Pedagogy: Implement new teaching strategies using research has shown to be effective in classrooms to improve student learning and performance in colleges of engineering.
Purpose of the Study

This study is intended to assess the improvement in undergraduate learning of engineering students that results from extending to postsecondary education the training and pedagogical methodologies that are extensively used in secondary education in the CEEMS-MSP project at the University of Cincinnati. Specifically, the study is structured to document:

1. The impact educational training has on graduate student instructors self-efficacy; and
2. The impact challenge-based learning has on student learning outcomes

This study is comprised of two specific aims:

**Specific Aim #1: Impact teaching self-efficacy of graduate students who are interested in pursuing careers in academia.** *This aim is based on the premise that graduate students who participate in the CEEMS-MSP Fellowship program will have an improved teaching self-efficacy due to the educational training received in the summer program at the University of Cincinnati. The teachers’ self-efficacy will be measured through surveys and weekly journals.*

**Specific Aim #2: Improve undergraduate student performance and experience by changing the teaching methods used in the Basic Electric Circuits course.** *Students will be taught using the challenge-based learning (CBL) approach as outlined by CEEMS. Students taking the Basic Electric Circuits course will be monitored through their test scores and surveys.*

The objective of Specific Aim #1 is to identify whether educational training will improve teaching self-efficacy of future faculty. The rationale behind this aim is that teachers with a higher self-efficacy provide better classroom experiences to students, which can affect student performance and learning. Recent research has shown that teachers who have formal educational training have high teaching self-efficacy. High teaching self-efficacy of the teacher has shown to increase student performance and
experience. When this aim has been achieved, it is expected that the educational training provided to the graduate students will improve their teaching self-efficacy and help prepare them to be effective educators in the classroom. The approach will measure self-efficacy prior to the educational training and monitor its progress/changes throughout the training program.

The objective of Specific Aim #2 is to improve student performance, learning, and experience by changing the pedagogy used in a Basic Electric Circuits Course. The rationale behind this aim is that typical engineering classrooms tend to be impersonal, competitive, and authoritarian. This type of environment is believed to discourage students, particularly those who lack confidence in their ability to succeed in engineering. Recent research has shown engineering students leave college due to negative experiences that impact performance and learning. The working hypothesis is that using Challenge Based Learning, as described by CEEMS, will have a positive impact on students’ experience, performance, and learning. The classroom environment will become more student-centered, which will engage the student to play an active role in learning. This in turn will increase student performance and experience. The approach will be to monitor the students in the Basic Electric Circuits course. Students’ grades and responses to a satisfaction survey will be compared to students taking the same Basic Electric Circuits course taught in a traditional lecture style format.

The study is structured to answer the following research questions:

1. Does teaching an engineering class improve teaching engineering self-efficacy?
2. How does educational training influence teaching self-efficacy?
3. Does using CBL in STEM classrooms improve student experience?
4. Does using CBL in STEM classrooms improve student performance?

**Intellectual Merit**

The proposed research is a novel approach for preparing future faculty by educating them about the secondary part of the K-12 education system to help graduate students understand their students’
previous learning environment. The project is also using an innovative pedagogy, Challenge Based Learning, to help students stay engaged in and take control of their learning.

**Broader Impact**

This proposed research is a first step in understanding what training is needed for future faculty to be better prepared for the classroom. This project will impact engineering education research by mapping a relationship between student learning, experience and performance from current engineering and applied science pedagogical practices.
Chapter 1 References


Chapter 2: Teaching Engineering Self-Efficacy

Introduction

The United States is the world leader in producing students with graduate degrees, especially in the fields of science, technology, engineering, and mathematics (STEM) (Duderstadt, 2000; National Science Foundation [NSF], 2006). Research universities are the primary sources for granting doctorate degrees, with 55 percent of doctorate degrees being earned in these institutions and more than 60 percent of faculty and professional staff being employed in STEM fields. Faculty members are expected to conduct research as well as to educate undergraduate students. However, graduate students are not themselves trained to educate students as part of their degree program. Researchers have noted that there is a lack of training for faculty responsibilities and expectations for doctoral students (Duderstadt, 2000; Prewitt, 2006; Wulff and Austin, 2004). This lack of training has a threefold effect: low teaching self-efficacy for graduate students, poor teaching preparedness for graduate students seeking careers in academia, and poor learning environments for the students they will teach.

Graduate education in science and engineering fields is highly decentralized, meaning most programs across the country do not have a standard for training (Fox, 2000). This is because teaching and learning vary by departments within institutions. Students mainly hold research assistantships (RAs), teaching assistantships (TAs), and fellowships (NSF, 2006). Graduate students who receive RA work solely on research for up to 20 hours a week, as opposed to taking on any teaching responsibilities. In addition, faculty members maintain their own labs where doctoral students conduct research, making science and engineering fields even more decentralized. It is also important to note that science and engineering doctoral students work closely with faculty members on funded research projects that generally end up being the student’s dissertation project. In the case of doctoral advising in engineering,
the doctoral student’s research advisor determines what work is considered sufficient for a Ph.D., and teaching is rarely, if ever, a requirement for the doctoral student (Fox, 2000; Fox, 2001). Graduate students who receive TAs traditionally spend little time teaching undergraduate students. TAs spend the majority of their time grading papers and/or answering questions for students after lecturing in recitation sessions or during designated office hours. However, when graduate students become faculty members, they take on teaching responsibilities for undergraduate students, and their lack of experience in this area has negative effects, not only on the new faculty member but also on the students. High dropout rates in engineering have been attributed to the negative cultural atmosphere of the institution (Astin and Astin, 1992; Astin, 1993; Buyer and Connolly, 2006; McGourty et al., 1999). Negative interactions experienced by students can be self-perceived or caused by actions from their professors or TAs. In large introductory classes it is typical for undergraduate students to spend more time with the TAs compared to the professors (Fagen and Suedkamp Wells, 2004; Golde and Dore, 2004). Since most graduate students and professors have never had formal pedagogical training, they tend to inadvertently create or perpetuate negative learning environments.

Scholars have researched doctoral student preparedness, and findings suggest that graduate students need better preparation for the academic environment, with a full scope of roles and responsibilities, including an emphasis on teaching. Most programs that prepare future faculty are seminar-based, with little or no hands-on experience in the classroom setting. These programs focus mainly on how responsibilities change at varying types of institutions. In many cases, enrolling in education classes was not part of the requirements to earn a Ph.D. (DeChenne et al., 2009; Golde and Dore, 2004; Piccinin and Fairweather, 1996; Rushin et al., 1997). There have been many programs developed to assist with graduate student training; however graduate students have indicated the lack of effectiveness especially when it comes to teaching (Burton, Bambery, and Harris-Boundy, 2005; Davis and Kring, 2001; Fagen and Suedkamp Wells, 2004; Luft et al., 2004; Prieto and Scheel, 2008).
The continuous cycle of inadequate training has a twofold effect. First, graduate students who aspire to work in academia have little experience, which leads to low teaching self-efficacy. Second, the lack of training negatively impacts learning environments for undergraduate students. Without a focus on teaching, undergraduate students continue to be a secondary priority of faculty members. Classrooms continue to be teacher-centered, as opposed to student-centered, environments. Universities lose sight of their primary objective, which is educating students (Zemsky, Wegner and Massy, 2005).

**Theoretical Framework**

**Historical Overview/Background of Preparing Future Faculty**

In 1993, the Preparing Future Faculty (PFF) program began as a national program. As stated on preparingfuturefaculty.org there are currently 45 doctoral degree-granting institutions and approximately 300 partner institutions involved in the program (www.preparing-faculty.org, 2008). The institutions involved in the PFF program work together to help potential junior faculty understand faculty roles and responsibilities. The program started as collaboration between the Association of American Colleges and Universities (AACandU) and the Council of Graduate Schools (CGS) program (www.preparing-faculty.org, 2008). The program was designed to help graduate students understand the responsibilities of faculty members as well as show those responsibilities at varying types of institutions (Gaff, Pruitt-Logan, and Weibl, 2000). With help from The Pew Charitable Trusts, the National Science Foundation, and The Atlantic Philanthropies, the program developed in four phases over the course of a decade.

PFF programs have three core features (Adams, 2002; Commander, Hart and Singer, 2000; DeNeef, 2002; Fagen and Suedkamp Wells, 2004), including:
• Training for faculty roles and responsibilities that include teaching, research, and service, emphasizing how the expectations for these responsibilities often differ in different campus settings.
• Mentorship and reflective feedback, not only for their research activities, but also for their teaching and service activities.
• Overview of cluster institutions. Within the cluster, the partners work together to provide experiences that will allow the participating graduate students to learn about the roles and responsibilities of faculty members at each institution.

PFF programs have provided the foundation of practice upon which a growing body of scholarly literature on faculty development efforts rests. It has become clear through the body of literature that PFF programs do little to prepare future faculty for teaching responsibilities, and, as a result, most new faculty members struggle (Rice et al., 2000). Given the longevity of PFF programs and the extensive body of research documenting their effectiveness (Golde, 2008), it is critical that the teaching responsibilities of future faculty members is highlighted and included in PFF programs.

Nontraditional Faculty Preparation Programs

The Graduates STEM fellows in K-12 Education (GK-12) program was a nationally NSF-sponsored program that allowed graduate students to work in Kindergarten through 12th grade (K-12) classroom environments (NSF Graduate STEM fellows in K-12 Education [GK-12], 2013). Each state, including the District of Columbia and Puerto Rico, had at least one GK-12 program. The program started in 1999 and ended in 2011 (NSF GK-12, 2013). The GK-12 Program supported fellowships and training for graduate students through interactions with teachers and students in K-12 schools. Graduate fellows could improve communication and teaching skills while enriching STEM content and instruction for their K-12 partners (NSF GK-12, 2013). Expected outcomes for graduate fellows included: enhanced understanding of their own research subject area; including its societal and global contexts and improved communication skills of STEM subjects with technical and non-technical audiences; leadership; team building; and teaching capabilities (NSF GK-12, 2013). Fellows participate in training sessions that are designed to improve teaching skills in the areas of instructional techniques, student
cognition, classroom management strategies, student diversity and equity issues, and how to develop age-appropriate lessons and activities. Although it was reported that fellows were participating in various professional-development activities, NSF’s review of fellows’ project responses did not find consistent evidence (Gamse et al., 2010).

**Teachers’ Sense of Efficacy**

Historically, graduate students are underprepared to be effective in a classroom setting (Rice et al., 2000). The focus throughout a master’s program is to become more focused in a field of study, as opposed to the broad understanding that is gained in undergraduate studies. As doctoral students, they are trained and expected to become a subject matter expert in their particular discipline. Little time and energy is given to preparing these students to become effective teachers. Until most recently, “developing the capacity for teaching and learning about fundamental professional concepts and principles remain accidental occurrences” (Gaff, Pruitt-Logan, and Wiebl, 2000). Yet, in order to achieve tenure, professors must show that they are effective teachers within the classroom, with a proven track record of success. The conversation around PFF has continued to grow in relevance and, as a result, has led to a calling for more research into the relationship of faculty preparedness / effectiveness and student performance.

Teaching engineering self-efficacy is defined as teachers’ personal belief in their ability to positively affect students’ learning of engineering. Teacher self-efficacy has a direct impact on student learning (Tschannen-Moran and Hoy, 2001). A strong, self-efficacious faculty member generally has high-achieving students (Tschannen-Moran and Hoy, 2001). Thus, over the past 30 years, there has been a greater focus on the relationship between teacher self-efficacy and student experience.

Bandura (1977, 1997) theorized four sources of efficacy expectations: social persuasion, psychological and emotional states, vicarious experiences, and mastery experiences. The most powerful
source of efficacy expectations is mastery experiences. As teachers gain a greater understanding of and sense of achievement in their teaching experiences, their belief in their own ability to educate students in future classes will subsequently increase. Similarly, lack of positive results in their current teaching experiences will negatively affect their belief in their ability to achieve the best results in future classrooms.

Heppner found that 75 percent of the influence on efficacy, as noted by graduate students, came in the form of verbal feedback from their students (Heppner, 1994). Graduate students noted the need to become more knowledgeable and to develop more personal relationships with students to develop students’ critical thinking in the subject matter as a step towards improving their mastery experience. In a national survey, Prieto and Myers (1999) found that graduate students who were given formal teacher training had higher self-efficacy than those who received no specific teacher training. Therefore, some form of educational training is a critical component of graduate student success in the classroom.

When teachers have a high sense of self-efficacy, they are more creative in their work, intensify their efforts when their performances fall short of their goals, and persist longer. Teachers’ sense of self-efficacy can thus influence the learning and motivation of students, even if students are unmotivated or considered difficult (Guskey and Passaro, 1994). Studies have found a positive relationship between teachers’ efficacy beliefs and several student cognitive outcomes, such as achievement (e.g., Anderson, Greene, and Loewen, 1988; Ashton and Webb, 1986; Moore and Esselman, 1994) and performance and skills (Midgley, Feldlaufer, and Eccles, 1989; Ross, Hogaboam-Gray, and Hannay, 2001). Studies conducted by Ashton and Webb (1986) have shown positive correlations between levels of teacher self-efficacy and student performance.
What is the Cincinnati Engineering Enhanced Math and Science (CEEMS) Program?

The Cincinnati Engineering Enhanced Mathematics and Science (CEEMS) Program is led by the University of Cincinnati in partnership with 14 school districts. CEEMS works to meet the growing need for engineering-educated teachers who are equipped to provide learners with opportunities to achieve the recently-revised Ohio New Learning Standards juxtaposed with Universal skills (21st Century Learning Skills). To address this need, CEEMS offers professional development pathways for teacher preparedness.

The vision for CEEMS is to establish a cadre of teachers, some new to the teaching profession and others experienced in the classroom, who will implement, through teaching and learning, the explicit authentic articulation of engineering with science and mathematics in Grade 7-12 classrooms. The goals of the CEEMS program are to:

1. Improve 7-12 science and mathematics achievement to prepare for and increase interest in the college study of engineering or other STEM careers.
2. Develop mathematics and science teacher knowledge of engineering and the engineering design and challenge-based instruction process through explicit training and classroom implementation support.
3. Recruit engineering undergraduates as science or mathematics teachers through involvement in teaching experiences with younger college students in the schools and through a defined licensure program.
4. Build a sustainable education licensure STEM degree-granting infrastructure to positively impact the entire region.

In 2013, CEEMS added graduate fellows to the program for two reasons: 1) the fellows would assist teachers and review unit template development, work with resource team members to ensure the engineering design process is included in all unit implementation, and provide insight to teachers on relevant research; and 2) the fellows would gain experience in STEM disciplines to acquire additional skills to broadly prepare them for professional and scientific careers in the 21st century. Graduate
students especially in STEM fields are in need of training that will help them communicate not only to
the research community but also students. As graduate students bring their research and practices into
the K-12 classroom, they gain skills which enable them to explain science to people of all ages, ranging
from students to teachers. By training graduate students, the CEEMS program also inspires
transformation in the undergraduate learning environment to stimulate interest in engineering among
students. Due to the high correlation between teacher self-efficacy and student performance
(Tschannen-Moran and Hoy, 2001), the CEEMS program developed a training program designed to
increase graduate fellows’ self-efficacy.

**Difference in CEEMS Versus PFF**

PFF programs are traditionally seminar-based and focus on preparing graduate students for
academic careers at postsecondary institutions. These programs help graduate students conduct
productive job searches and achieve early career success while providing professional development that
does not extend time-to-degree. The CEEMS program, however, builds on PFF programs by providing
workshops for graduate students to learn about students, communication skills, teaching and
assessment of learning. The CEEMS program provides an apprenticeship environment and is designed
so that graduate students learn from K-12 educators. The CEEMS program developers took evidence
from the GK-12 program, along with results from self-efficacy studies, and developed a program that
used the best practices of each to help prepare graduate students for academia.

The CEEMS fellowship program consists of the following three components:

1. Educational seminars: training tools for fellows to learn about the K-12 educational system,
pedagogy, learning, students, and assessment of learning;
2. Apprenticeship: each fellow is paired with a team of experts that includes members of the
resource team (retired professional engineering, science and K-12 education specialists) and
K-12 teachers, and fellows shadow teachers and resource team members by spending an
average of 10 hours a week in K-12 classrooms. The intent behind graduate students
observing a K-12 classroom is to observe theories learned in educational seminars used in a
real classroom environment, gain a better understanding of the state of education and the environments their future students will come from, and enhance their teaching; and
3. Teaching experience: each fellow teaches in an undergraduate classroom to gain hands-on experience to supplement seminars about teaching and education.

Importance of the CEEMS Program

Teachers are believed to be a significant determining factor in the overall classroom success of their students. It is believed that teachers are a contributing factor in students not connecting with the school environment, which can lead to them leaving school. Student belief in teacher knowledge and ability is directly related to student learning (McGlone and Anderson, 1973). As the number of negative interactions with teachers increases, student achievement decreases. Conversely, as teachers’ capability is validated, student performance also improves (McGlone and Anderson, 1973). The CEEMS program is intended to equip graduate students with the appropriate skills and teaching experience to increase graduate students’ teaching self-efficacy, which translates to more positive interactions with students to improve student achievement.

Research Questions

The study was designed to investigate if providing educational training to graduate students interested in pursuing careers in academia would improve teaching engineering self-efficacy. In particular, the research questions are:

1. Does a teaching experience improve teaching engineering self-efficacy?
2. How does educational training influence teaching self-efficacy?

Gaining an initial understanding of these questions will provide a basis to develop strategies to improve graduate student training that better prepares future faculty for teaching responsibility.
Experimental Design

Justification of Methods

The Qualitative Approach

The advantage of qualitative research is that it provides detailed information on people, programs, or events in a natural context (Creswell, 1998; Yin, 1994). The approach is also used to identify and describe complex interactions and interrelationships among students and teachers.

The Quantitative Approach

This study was an exploration-of-consequences experimental study. In this study, the author investigated the influence of educational training on graduate student self-efficacy. Participants were divided into two groups: an experimental group and a control group. The control group consisted of graduate students who had an interest in teaching and aspired to work in academia but had no prior educational training. The experimental group consisted of the CEEMS fellows. Data was collected from scores on the teaching engineering self-efficacy survey.

Framework of Data Collection

Students

CEEMS Fellows:

Four fellows of the University of Cincinnati CEEMS program participated in the educational training provided during the summer program. CEEMS fellows were selected because they have an interest in an academic career. For the purpose of this study, each fellow is named as follows: Fellow 1, Fellow 2, Fellow 3, and Fellow 4.
Fellow 1 has a Bachelor of Arts in Mathematics and prior to the CEEMS program worked for 2 years as a GK-12 fellow and had taken a formal teacher quarter-long teacher preparation program and two quarter long teaching practicum at a high school developing, teaching and documenting one curricular lesson and assisting a teacher for 10 hours/week in the classroom. Fellow 2 has a Bachelor of Science degree in Chemical Engineering. Prior to the CEEMS program Fellow 2 served as a mentor/tutor for the public school system supervising and coordinating daily tutoring activities. Fellow 3 has a Bachelor of Science degree in Biotechnology and prior to the CEEMS program had worked as a tutor for undergraduate students. Fellow 4 has a Bachelor of Science degree in Chemical Engineering. Prior to the CEEMS program, Fellow 4 volunteered as a junior high school basketball coach.

Untrained Graduate Instructors:

Graduate students in the University of Cincinnati’s College of Engineering and Applied Science served as the control group for this study. Four untrained graduate instructors were selected to participate because of their desire to be future educators. A call for instructors was sent to the entire graduate student population matriculating at the University of Cincinnati’s College of Engineering and Applied Science. Applicants were then divided into two categories based on their application: interest in an academic career and no interest in an academic career. From the pool of graduate students interested in a career in academia, four students were selected to be instructors based on responses from interviews. These untrained graduate instructors followed the current process for teaching responsibilities of graduate students at the University of Cincinnati.

**Educational Training**

During the summer, the CEEMS fellows enrolled in a 3-credit-hour course in which they learned about the CEEMS program and how they would assist with its mission. The fellows discussed effective
teaching methods, with a focus on teaching K-12 math and science. Topics included instructional approaches and best teaching practices in teaching middle and high school students, creating course content, defining learning outcomes, conducting effective assessments, polishing presentation skills, encouraging active learning, managing student projects and teams, understanding standards used in school systems, and conducting research in engineering education. CEEMS fellows learned how to incorporate seminar topics to create a challenge based learning (CBL) classroom that incorporates engineering to help K-12 math and science educators better implement and teach engineering design process. Each fellow created a syllabus and course materials for the undergraduate course they taught in the fall, which was included in each fellow’s teaching portfolio (see Appendix for the syllabus).

As part of the course requirements, fellows completed homework assignments along with weekly reflections. Analysis of the reflections was used to identify themes and categories related to the fellows’ experience as well as quality of the course content. Reflections were collected via SurveyMonkey every Friday during the nine weeks of the summer course. These reflections were analyzed using an inductive approach (Thomas, 2006).

In addition to the 3-credit-hour course, each fellow worked with a group of six middle school and high school math and science teachers, not only to advise on engineering content used in the classroom settings, but also to learn about the classroom environments in which they would teach. Fellows were also partnered with CEEMS Resource Team members. Each team consisted of individuals with the following qualifications:

- An experienced 7-12 science or math teacher specialist
- An engineer or scientist, and
- An educator with expertise in curriculum and/or assessment (see Appendix for Resource Team member qualifications).
Fall Teaching Experience

CEEMS fellows and untrained graduate instructors taught different sections of the Basic Electric Circuits (BEC) course. The untrained graduate instructors taught section 2 and the CEEMS fellows taught section 1. Section 1 had 27 students and section 2 had 26 students from the Department of Biomedical, Chemical and Environmental Engineering.

Each class section was assigned an assessor, who monitored the classroom and provided feedback to CEEMS fellows and untrained graduate instructors. During the fall semester, CEEMS fellows continued to work with middle school and high school math and science teachers, spending an average of 10 hours per week in those classrooms.

Data Collection Procedure

The data collected during this study were obtained from the two groups of participants: CEEMS fellows and untrained graduate instructors. There were four CEEMS fellows and four untrained graduate instructors. The data obtained from the teaching engineering self-efficacy surveys, weekly reflections, teaching reflections, focus groups, and course evaluations were analyzed and compared using an inductive approach.

Data Sources

Teaching Self-Efficacy Survey (TESS)

For this study, teaching engineering self-efficacy was defined as teachers’ personal belief in their ability to positively affect students’ learning of engineering. Thus, the use of the TESS, as a teacher self-efficacy instrument tailored for the engineering teaching context, was expected to diagnose and clarify
the teacher’s self-efficacy system and to further understand teachers’ behaviors in class (Yoon and Griffin, 2012).

The subscales of the TESS are as follows:

1. Engineering Pedagogical Content Knowledge Self-efficacy,
2. Motivational Self-efficacy,
3. Instructional Self-efficacy,
4. Engagement Self-efficacy,
5. Disciplinary Self-efficacy, and
6. Outcome Expectancy.

Questions related to each subscale were designed to identify supports graduate students have and barriers they face when teaching engineering, which ultimately determines their teaching engineering self-efficacy. When analyzing the data, one would expect to find an increase in subscale averages as a graduate student gains more teaching experience through their academic career, indicating their engineering self-efficacy, feeling of inclusion, etc., increases as they progress through the program.

Participating graduate students completed the Teaching Engineering Self-Efficacy Survey (TESS) on the first day of class during the summer program, thereby establishing a baseline of the CEEMS fellows’ self-efficacy before the summer training began. Once participants completed the TESS, CEEMS fellows had an undergraduate teaching experience that included teaching a chapter of the BEC course offered in the summer at the University of Cincinnati through the College of Engineering and Applied Science. Students from the School of Energy, Environmental, Biological and Medical Engineering enrolled in BEC. Each fellow prepared a lecture using the *Fundamentals of Electric Circuits*, 5th Edition, textbook by Alexander and Sadiku, using their preferred teaching method. Each instructor chose direct instruction, using the lecture based format which is the traditional style most commonly used in college
courses. Once the lecture was developed, they presented it to the course instructor prior to presenting to the students.

Before the start of the fall semester, the untrained graduate instructors took the TESS. Each graduate instructor and CEEMS fellow taught BEC for three weeks during the fall semester. At the conclusion of the fall semester, the graduate instructors and CEEMS fellows reassessed self-efficacy using the TESS.

Weekly Reflections

CEEMS fellows participated in weekly reflections during the summer and fall semesters. These weekly reflections were used by the fellows to help make connections from what they learned in their educational training seminars and to help clarify connections between what they already knew and what they were learning. The reflections were guided with questions developed by the research evaluator to help the CEEMS fellows become active and aware learners. Each week, the fellows received a link from Survey Monkey to complete the reflection online.

Teaching Reflections

CEEMS fellows and untrained graduate instructors participated in a reflection upon completion of their three-week teaching experience during the fall semester. Through the teaching reflection, CEEMS fellows and graduate students could assess their conclusions, actions, and work process itself to further their personal and professional development.

Focus Groups

At the conclusion of the fall semester, CEEMS fellows and the untrained graduate students participated in a separate one-hour focus group to assess how they felt about teaching and their
teaching self-efficacy. The CEEMS project evaluator facilitated the focus group. Both focus groups were audiotaped and transcribed.

**Results**

**Analysis of Self-Efficacy Scores**

<table>
<thead>
<tr>
<th></th>
<th>Pre TESS</th>
<th>Post TESS</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CEEMS Fellow 1</strong></td>
<td>4.76</td>
<td>4.75</td>
<td>-0.01</td>
</tr>
<tr>
<td><strong>CEEMS Fellow 2</strong></td>
<td>5.32</td>
<td>5.42</td>
<td>0.10</td>
</tr>
<tr>
<td><strong>CEEMS Fellow 3</strong></td>
<td>2.76</td>
<td>3.44</td>
<td>0.34</td>
</tr>
<tr>
<td><strong>CEEMS Fellow 4</strong></td>
<td>4.95</td>
<td>5.29</td>
<td>0.68</td>
</tr>
</tbody>
</table>

Table 1 shows the CEEMS fellows’ TESS scores at the beginning of the summer semester compared to their TESS scores at the end of the summer semester. At the conclusion of the summer semester, 75 percent (3 out of 4) of the fellows had an increase in their overall teaching self-efficacy score and 25 percent (1 out of 4) had a decrease.

All four fellows had an increase in the Engineering Pedagogical Content Knowledge self-efficacy construct. The mean increase ranged from .05 to 1.29. Two fellows had a decrease in Motivation self-efficacy and two fellows’ scores remained the same. One fellow had a decrease in Instructional self-efficacy, two fellows had an increase and one fellow remained the same. Three fellows had the same Engagement self-efficacy score and one fellow had an increase. Two fellows had the same score for Discipline self-efficacy, one fellow had an increase and one fellow had a decrease. Two fellows had a decrease in Outcome expectancy self-efficacy and two fellows remained the same.

Table 2 outlines the changes in self-efficacy by construct. Fellow 1 had an overall decrease in the Teaching Engineering Self-Efficacy score from the start of the summer compared to the end of the
summer. Fellow 1’s scores for Instructional self-efficacy, Engagement self-efficacy, Disciplinary self-efficacy, and Outcome Expectancy remained the same.

Table 2: TESS Construct Scores at the Beginning of the Summer and TESS Construct Scores at the conclusion of the Summer

<table>
<thead>
<tr>
<th></th>
<th>Pre TESS</th>
<th>Post TESS</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CEEMS Fellow 1</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engineering Pedagogical Content Knowledge Self-efficacy</td>
<td>5.24</td>
<td>5.29</td>
<td>.05</td>
</tr>
<tr>
<td>Motivational Self-efficacy</td>
<td>4.50</td>
<td>4.00</td>
<td>-.50</td>
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<tr>
<td>Instructional Self-efficacy</td>
<td>5.20</td>
<td>5.20</td>
<td>.00</td>
</tr>
<tr>
<td>Engagement Self-efficacy</td>
<td>5.25</td>
<td>5.25</td>
<td>.00</td>
</tr>
<tr>
<td>Disciplinary Self-efficacy</td>
<td>3.17</td>
<td>3.17</td>
<td>.00</td>
</tr>
<tr>
<td>Outcome Expectancy</td>
<td>4.50</td>
<td>4.50</td>
<td>.00</td>
</tr>
<tr>
<td>Overall</td>
<td>4.73</td>
<td>4.71</td>
<td>-.02</td>
</tr>
<tr>
<td><strong>CEEMS Fellow 2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engineering Pedagogical Content Knowledge Self-efficacy</td>
<td>5.00</td>
<td>5.35</td>
<td>.35</td>
</tr>
<tr>
<td>Motivational Self-efficacy</td>
<td>5.67</td>
<td>5.67</td>
<td>.00</td>
</tr>
<tr>
<td>Instructional Self-efficacy</td>
<td>5.40</td>
<td>5.00</td>
<td>-.40</td>
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<tr>
<td>Engagement Self-efficacy</td>
<td>5.50</td>
<td>5.50</td>
<td>.00</td>
</tr>
<tr>
<td>Disciplinary Self-efficacy</td>
<td>5.67</td>
<td>5.50</td>
<td>-.17</td>
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<tr>
<td>Outcome Expectancy</td>
<td>6.00</td>
<td>5.67</td>
<td>-.33</td>
</tr>
<tr>
<td>Overall</td>
<td>5.32</td>
<td>5.42</td>
<td>.10</td>
</tr>
<tr>
<td><strong>CEEMS Fellow 3</strong></td>
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<tr>
<td>Engineering Pedagogical Content Knowledge Self-efficacy</td>
<td>2.29</td>
<td>3.59</td>
<td>1.29</td>
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<tr>
<td>Motivational Self-efficacy</td>
<td>4.67</td>
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<td>.00</td>
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<tr>
<td>Instructional Self-efficacy</td>
<td>2.60</td>
<td>3.40</td>
<td>.80</td>
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<td>Engagement Self-efficacy</td>
<td>3.25</td>
<td>3.75</td>
<td>.50</td>
</tr>
<tr>
<td>Disciplinary Self-efficacy</td>
<td>2.17</td>
<td>2.17</td>
<td>.00</td>
</tr>
<tr>
<td>Outcome Expectancy</td>
<td>3.50</td>
<td>3.50</td>
<td>.00</td>
</tr>
<tr>
<td>Overall</td>
<td>2.76</td>
<td>3.44</td>
<td>.68</td>
</tr>
<tr>
<td><strong>CEEMS Fellow 4</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engineering Pedagogical Content Knowledge Self-efficacy</td>
<td>4.82</td>
<td>5.53</td>
<td>.71</td>
</tr>
<tr>
<td>Motivational Self-efficacy</td>
<td>5.00</td>
<td>4.67</td>
<td>-.33</td>
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<tr>
<td>Instructional Self-efficacy</td>
<td>4.80</td>
<td>5.20</td>
<td>.40</td>
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<tr>
<td>Engagement Self-efficacy</td>
<td>5.25</td>
<td>5.25</td>
<td>.00</td>
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<tr>
<td>Disciplinary Self-efficacy</td>
<td>4.83</td>
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<td>.17</td>
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<tr>
<td>Outcome Expectancy</td>
<td>5.33</td>
<td>5.00</td>
<td>-.33</td>
</tr>
<tr>
<td>Overall</td>
<td>4.95</td>
<td>5.24</td>
<td>.29</td>
</tr>
</tbody>
</table>
Fellow 1 had an increase in Engineering Pedagogical Content Knowledge self-efficacy and a decrease in Motivational self-efficacy. The decrease in Motivational self-efficacy was greater than the increase in Engineering Pedagogical Content Knowledge self-efficacy; therefore fellow 1 had a decrease the overall Teaching Engineering Self-Efficacy score.

Fellow 2 had an overall increase in the Teaching Engineering Self-Efficacy score from the start of the summer compared to the end of the summer. Fellow 2 had a decrease in Instructional self-efficacy, Disciplinary self-efficacy, and Outcome Expectancy self-efficacy but had an increase in Engineering Pedagogical Content Knowledge self-efficacy. The score for Motivational self-efficacy remained the same. The increase in Engineering Pedagogical Content Knowledge score was greater than the decreases in Instructional, Disciplinary and Outcome Expectancy self-efficacy, which resulted in an increase in the overall Teaching Engineering Self-Efficacy score.

Fellow 3 had an overall increase in the Teaching Engineering Self-Efficacy score from the start of the summer compared to the end of the summer. Fellow 3 had an increase in Engineering Pedagogical Content Knowledge, Instructional, and Engagement self-efficacy and remained the same in Motivational, Disciplinary and Outcome Expectancy self-efficacy.

Fellow 4 had an overall increase in the Teaching Engineering Self-Efficacy score from the start of the summer compared to the end of the summer. Fellow 4 had an increase in Engineering Pedagogical Content Knowledge and Disciplinary self-efficacy, a decrease in Motivational and Outcome Expectancy self-efficacy, and remained the same in Engagement self-efficacy.

The Engineering Pedagogical Content Knowledge Self-Efficacy had a pattern of increase among all four fellows. The magnitude of increase was inconsistent; however the other five constructs of Teaching Engineering Self-Efficacy score did not show a pattern among fellows. This may be due to an
increase in comfort level with the material as well as increased ability to communicate complex topics for a general audience.

**Table 3: Pre TESS Scores from the Beginning of the Fall Semester and Post TESS Scores at the Conclusion of the Fall Semester**

<table>
<thead>
<tr>
<th>Fall Semester</th>
<th>Pre TESS</th>
<th>Post TESS</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEEMS Fellow 1</td>
<td>4.71</td>
<td>5.00</td>
<td>0.29</td>
</tr>
<tr>
<td>CEEMS Fellow 2</td>
<td>5.42</td>
<td>4.88</td>
<td>-0.54</td>
</tr>
<tr>
<td>CEEMS Fellow 3</td>
<td>5.24</td>
<td>5.29</td>
<td>0.05</td>
</tr>
<tr>
<td>CEEMS Fellow 4</td>
<td>3.44</td>
<td>5.56</td>
<td>2.12</td>
</tr>
<tr>
<td>Graduate Instructor 1</td>
<td>4.34</td>
<td>3.88</td>
<td>-0.46</td>
</tr>
<tr>
<td>Graduate Instructor 2</td>
<td>5.34</td>
<td>4.85</td>
<td>-0.49</td>
</tr>
<tr>
<td>Graduate Instructor 3</td>
<td>5.90</td>
<td>5.83</td>
<td>-0.07</td>
</tr>
<tr>
<td>Graduate Instructor 4</td>
<td>3.73</td>
<td>3.54</td>
<td>-0.19</td>
</tr>
</tbody>
</table>

Table 3 shows the TESS scores for the CEEMS fellows and graduate instructors at the beginning of the fall semester compared to their TESS scores at the end of the fall semester. At the conclusion of the fall semester, 75 percent (3 out of 4) of the fellows had an increase in their overall Teaching Engineering Self-Efficacy score and 25 percent (1 out of 4) had a decrease. All four graduate instructors showed a decrease in their Teaching Engineering Self-Efficacy scores from the start of the fall semester compared to the end of the fall semester. This may be due to the realization of teaching ability.

All four graduate instructors had a decrease in Motivational and Disciplinary self-efficacy. Three out of the four graduate instructors decreased in Engineering Pedagogical Content Knowledge and the same three instructors decreased in Instructional self-efficacy. The other graduate instructor’s scores remained the same in those categories. Two graduate instructors had a decrease in their Engagement self-efficacy, while the other two graduate instructors’ scores remained the same. Two graduate instructors’ Outcome Expectancy self-efficacy remained the same, one graduate instructor’s increased, and the other’s decreased.
Table 4 outlines the changes in self-efficacy by construct. Instructor 1 and instructor 4 had the same pattern of changes in self-efficacy constructs.

**Table 4: TESS Construct Scores at the Beginning of the Fall Semester and at the Conclusion of the Fall Semester**

<table>
<thead>
<tr>
<th></th>
<th>Pre TESS</th>
<th>Post TESS</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Untrained Graduate Instructor 1</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engineering Pedagogical Content Knowledge Self-efficacy</td>
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<td>3.94</td>
<td>-0.47</td>
</tr>
<tr>
<td>Motivational Self-efficacy</td>
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<td>4.33</td>
<td>-1.00</td>
</tr>
<tr>
<td>Instructional Self-efficacy</td>
<td>3.20</td>
<td>2.80</td>
<td>-0.40</td>
</tr>
<tr>
<td>Engagement Self-efficacy</td>
<td>5.75</td>
<td>4.50</td>
<td>-1.25</td>
</tr>
<tr>
<td>Disciplinary Self-efficacy</td>
<td>3.83</td>
<td>3.67</td>
<td>-0.17</td>
</tr>
<tr>
<td>Outcome Expectancy</td>
<td>4.17</td>
<td>4.17</td>
<td>0.00</td>
</tr>
<tr>
<td>Overall</td>
<td>4.34</td>
<td>3.88</td>
<td>-0.46</td>
</tr>
<tr>
<td><strong>Untrained Graduate Instructor 2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engineering Pedagogical Content Knowledge Self-efficacy</td>
<td>5.24</td>
<td>4.94</td>
<td>-0.29</td>
</tr>
<tr>
<td>Motivational Self-efficacy</td>
<td>5.00</td>
<td>3.67</td>
<td>-1.33</td>
</tr>
<tr>
<td>Instructional Self-efficacy</td>
<td>5.40</td>
<td>5.00</td>
<td>-0.40</td>
</tr>
<tr>
<td>Engagement Self-efficacy</td>
<td>5.25</td>
<td>5.25</td>
<td>0.00</td>
</tr>
<tr>
<td>Disciplinary Self-efficacy</td>
<td>5.17</td>
<td>4.83</td>
<td>-0.33</td>
</tr>
<tr>
<td>Outcome Expectancy</td>
<td>6.00</td>
<td>4.83</td>
<td>-1.17</td>
</tr>
<tr>
<td>Overall</td>
<td>5.34</td>
<td>4.85</td>
<td>-0.49</td>
</tr>
<tr>
<td><strong>Untrained Graduate Instructor 3</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engineering Pedagogical Content Knowledge Self-efficacy</td>
<td>6.00</td>
<td>6.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Motivational Self-efficacy</td>
<td>6.00</td>
<td>5.00</td>
<td>-1.00</td>
</tr>
<tr>
<td>Instructional Self-efficacy</td>
<td>6.00</td>
<td>6.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Engagement Self-efficacy</td>
<td>6.00</td>
<td>6.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Disciplinary Self-efficacy</td>
<td>6.00</td>
<td>5.67</td>
<td>-0.33</td>
</tr>
<tr>
<td>Outcome Expectancy</td>
<td>5.33</td>
<td>5.67</td>
<td>0.33</td>
</tr>
<tr>
<td>Overall</td>
<td>5.90</td>
<td>5.83</td>
<td>-0.07</td>
</tr>
<tr>
<td><strong>Untrained Graduate Instructor 4</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engineering Pedagogical Content Knowledge Self-efficacy</td>
<td>3.82</td>
<td>3.59</td>
<td>-0.24</td>
</tr>
<tr>
<td>Motivational Self-efficacy</td>
<td>4.00</td>
<td>3.67</td>
<td>-0.33</td>
</tr>
<tr>
<td>Instructional Self-efficacy</td>
<td>4.00</td>
<td>3.80</td>
<td>-0.20</td>
</tr>
<tr>
<td>Engagement Self-efficacy</td>
<td>4.00</td>
<td>3.75</td>
<td>-0.25</td>
</tr>
<tr>
<td>Disciplinary Self-efficacy</td>
<td>3.00</td>
<td>2.83</td>
<td>-0.17</td>
</tr>
<tr>
<td>Outcome Expectancy</td>
<td>3.67</td>
<td>3.67</td>
<td>0.00</td>
</tr>
<tr>
<td>Overall</td>
<td>3.73</td>
<td>3.54</td>
<td>-0.19</td>
</tr>
</tbody>
</table>
Both decreased in Engineering Pedagogical Content Knowledge, Motivational, Instructional, Engagement and Disciplinary self-efficacy and remained the same in Outcome Expectancy.

Instructor 2 decreased in Engineering Pedagogical Content Knowledge, Motivational, Instructional, Disciplinary, and Outcome Expectancy self-efficacy constructs and remained the same in Engagement self-efficacy.

Instructor 3 decreased in Motivational and Disciplinary self-efficacy and increased in Outcome Expectancy self-efficacy. Engineering Pedagogical Content Knowledge, Instructional and Engagement self-efficacy all remained the same.

### Table 5: CEEMS fellows TESS Scores from the Beginning of the Summer to the End of the Fall Semester

<table>
<thead>
<tr>
<th></th>
<th>Overall</th>
<th>Pre TESS</th>
<th>Post TESS</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEEMS Fellow 1</td>
<td>4.73</td>
<td>5.00</td>
<td></td>
<td>0.27</td>
</tr>
<tr>
<td>CEEMS Fellow 2</td>
<td>5.32</td>
<td>4.88</td>
<td></td>
<td>-0.44</td>
</tr>
<tr>
<td>CEEMS Fellow 3</td>
<td>4.95</td>
<td>5.29</td>
<td></td>
<td>0.34</td>
</tr>
<tr>
<td>CEEMS Fellow 4</td>
<td>2.76</td>
<td>5.56</td>
<td></td>
<td>2.80</td>
</tr>
</tbody>
</table>

From the beginning of the summer to the end of the fall semester, three fellows increased in overall self-efficacy. The magnitudes of the overall self-efficacy scores varied. Fellow 4’s overall self-efficacy doubled, as seen in Table 5. Fellow 2 had an overall self-efficacy score decrease and had the lowest self-efficacy score at the end of the fall semester, as compared to the other fellows. However, fellow 2’s overall self-efficacy score at the end of the fall semester was higher than the four graduate instructors’ overall self-efficacy scores.

Looking at the results from Tables 1 to 5 and analyzing the performance/input of each fellow individually, there were common learning gains from the CEEMS fellows program. The Engineering Pedagogical Content Knowledge Self-Efficacy construct had a pattern of increase among all four fellows. This may be due to an increase in comfort level with the material as well as increased ability to
communicate complex topics for a general audience. Each fellow showed a unique change among the constructs assessed and this may be due to prior experience in outreach, working with K-12 standards and teachers, or even personal experiences.

**Analysis of Weekly Reflections**

The weekly reflections were guided by the CEEMS project team through a series of questions sent weekly via Survey Monkey. CEEMS fellows used the weekly reflections to share and describe what they learned during the summer and fall semesters.

**Summer**

Group:

Several themes emerged from the summer weekly reflections: lesson planning, teaching effectiveness, and student misconceptions/teacher perceptions. Of the emerging themes, two were supported in literature: student misconceptions/teacher perceptions and teaching effectiveness. The student misconceptions/teacher perceptions theme was part of the seminar series the fellows attended in the summer; however, the impact of this seminar was explained in more detail in weekly reflections than any other seminar. Fellows expanded on how the misconception/perception seminar impacted them professionally as opposed to stating it was information learned in that week. Fellows indicated that the program helped them focus on teaching effectiveness. They learned how to enhance their teaching skill. Teaching Effectiveness is a consistent theme with the GK-12 program. Eighteen percent of GK-12 fellows responded that the program enhanced their ability to teach STEM research and concepts to undergraduate students, and 97 percent responded the GK-12 program enhanced their ability to teach STEM research and concepts to K-12 students (Gamse et al., 2010).
Lesson Planning

When the CEEMS fellows were asked what they had learned over the summer, many of the fellows responded that they had a better understanding of lesson planning. This may be due to the interaction with the K-12 teachers who were primarily concerned with developing 3 unit plans over the summer following a standard template. Select fellow comments are presented below:

Fellow #4, week 2: “I learned about some other teaching ideas that will help in creating lesson plans and writing questions that hit all stages of Blooms Taxonomy”

Fellow #1, week 7: “Lesson planning, specifically how to add more redesign to the lesson.”

Fellow #3, week 8: “Working with the teachers helps in learning lesson planning from people who consistently do it.”

Fellow #4, week 9: “I learned a lot about lesson planning and how to make innovative and creative lessons that will excite my students.”

Fellow #2, week 9: “I worked with the teachers in developing their units helped me in developing my lesson plan for ‘fundamentals of electric circuit’”

Teaching Effectiveness

Fellows mentioned that they learned new techniques to be effective in the classroom. The fellows felt that understanding the background of the school system and curriculum would help them be better teachers. This theme is consistent with workshops CEEMS fellows were required to attend as part of the educational training that discussed the American school system and standards. Fellows also interacted with K-12 teachers that were developing unit plans for the school year and this interaction may have taught the CEEMS fellows about teaching effectiveness. This finding was consistent with results from the GK-12 program (Gamse et al., 2010). Seventy-one percent of GK-12 fellows reported enhancement in their teaching skills. Select fellows feedback comments for this seminar are presented below:
Fellow 4, week 1: “I am also learning some techniques and strategies used in lesson planning and education. This information will help me in my teaching, allowing me to create more appropriate lessons for the students and helping me be a more effective teacher.”

Fellow 1, week 2: “Learning about the new math curriculum and how and why it was developed will help me in my teaching effectiveness.”

Fellow 3, week 3: “This background will help me to develop appropriate lessons that will push the students.”

Student Misconceptions and Teacher Perceptions

Fellows participated in two seminars that helped explain student misconceptions, with a special emphasis on math and science. The seminars went through a series of exercises to explain that students come into the classroom with beliefs and assumptions that are incorrect. The seminar gave different methods for the fellows to use to help their students to gain a better understanding of their background knowledge. Fellows also participated in a seminar on teacher perceptions that explained that their perceptions in the classroom can affect their students’ performance and learning. These seminars were conducted in week 2 of the summer training.

Fellow 2, week 2: “I learnt that students come into the class with preconceived notion and ideas about subjects. Those ideas are called misconceptions and it is the teacher’s responsibility to help the students construct new knowledge from experiences. The teacher should serve merely as a facilitator.”

Fellow 3, week 9: “Interacting with the teachers and getting to know the perceptions and misconceptions that students might have relating to a particular topic in class is something that'll help me to prepare myself better as a future teacher.”

Fellow 1, week 4: “This entire experience is helping me so much because it is correcting some misconceptions i had about teaching and curriculum in general.”

Individual:

Fellows 1 and 2 had additional themes that did not emerge as a group. Fellow 1 stated that seminars, homework, and experience were a waste of time. Seven out of the nine weeks there was a statement about disinterest in the program or the time commitment of the fellowship. This is not
consistent with the published literature. It is important to note that Fellow 1 stated learning outcomes throughout the summer experience despite the negative feelings towards the program. It is worth mentioning that fellow 1 had participated in a prior NSF GK-12 grant project at the University of Cincinnati and taken the teacher training and practicum program in middle and high school associated with it and completed a formal PFF course also. This experience may have influenced the perception that participation in the intensive CEEMS project was not of an added value. Comments received from the fellows as the weeks progressed are presented below:

Week 1: “Sorry it’s so short this week. 3.5 hours of straight lecture on things I already know is pretty rough. The homework we have been assigned seems a bit much to keep up with each week, and without any benefit. That’s just my opinion though.”

Week 2: “The homework about the people/groups was interesting, but the other homework this week seemed extremely unnecessary and nothing more than busy work. Busy work makes it feel like we have a lot of homework and that it’s pushing into research time (that isn’t the case, but because there is nothing to be had from completing the homework, it is just a waste of time). Sorry for being harsh!”

Week 3: “I still feel like there is too much homework to be useful. Regardless, the class was better this week.”

Week 4: “I feel like we are still wasting a lot of time in redundant classes and as members of groups we clearly don’t need to be participating in. A lot of the big questions are going unanswered and it often seems like there’s little effort made to actually educate. It seems like the CEEMS coursework (with the teachers) is more of a workshop than an educational experience (I do make a distinction; you can have either without the other). But I’m just complaining again.”

Week 7: “Still wasting a lot of time. A LOT. And we don’t really get much time with our teachers, nor have I formally met all of mine.”

Week 9: “I don’t feel like I learned very much at all through this summer. It felt like our goals were very unclear and we weren’t guided in any way. I still haven’t formally met my teachers; there may still be a teacher I haven’t met at all (whom I am working with). I don’t know for sure if it was just my focus on my defense, or if it was because of a failure to properly plan for graduate fellows, but I do not feel prepared for, or even informed about what is expected of us.”

Fellow 2 reflected on how the summer experience was helping professionally. Seven out of nine weeks, Fellow 2 commented about professional development and benefits of the CEEMS program. As can be seen below:
Week 1: “This experience is helping me professionally because as a PhD student, I am expected to be able to communicate my research area to people easily and eloquently in such a way that anyone would understand it. This opportunity with CEEMS will really help me sharpen my communication skills and particularly my teaching skill.”

Week 3: “This experience is helping me professionally to improve my teaching skill/style.”

Week 5: “This experience is helping me immensely professionally and personally because it has sharpened my communication and interpersonal skills.”

Week 6: “This experience is really helping me improve on my communications and interpersonal skills.”

Week 7: “So far, this has been a very rewarding experience for me.”

Week 7: “My experience in the CEEMS program has made me a better communicator and has helped me develop interpersonal skills.”

Week 8: “This whole experience has been greatly beneficial to me.”

Week 9: “This has been a very good experience for me.”

Fall

During the fall semester, fellows spent –between ten and twenty hours per week in K-12 classrooms as well as participated in the fall teaching of the BEC course. Throughout the reflections, two themes emerged from the group: understanding students and teaching style.

Understanding Students

Given the published literature, this theme is unique compared to other training programs. Fellows reflected that the experience enhanced their knowledge about students, as can be seen from their comments below:

Fellow 3, week 8: “It’s a great time spending with the students at school as I get to know their mindset and how they feel being taught in the CBL way. Also sitting in the classrooms of my cohorts while they’re teaching is helping me to learn the how to present yourself to the students as a teacher which I feel is going to help me in my future.”

Fellow 2, week 9: “I learned how to deal with setbacks in a lesson plan and how to adapt the lesson and time frame based on what is necessary for the students to learn everything they need to.”
Fellow 4, week 9: “I got some time to work with the students, helping me to understand where they come from and their background as I work in the classrooms.”

Teaching Style

An enhanced teaching skill was a theme that fellows from the GK-12 program had also developed (Gamse et al., 2010). Select fellow comments that lead to this conclusion are presented below this paragraph. This was an expected theme, due to CEEMS fellows spending time in K-12 environments similar to those of the GK-12 fellowship program.

Fellow 4, week 2: “The experience planning a lesson and teaching a classroom will help me become more comfortable in a teaching role.”

Fellow 4, week 10: “I learned a lot as I helped in the classroom. Working in the classroom on CBL projects is giving me experience working with kids and also teaching. I am learning through my observations of the teachers’ styles and methods of classroom management and teaching effectiveness so that I am able to meld these ideas into my own teaching style and ability.”

Fellow 2, week 3: “Working in classrooms allows me to see a lot of different teaching styles in practice so that I can adopt parts of them as I develop as a teacher.”

Fellow 1, week 11: “My first Club revealed that I need a board that everyone can see. I need to make little challenges that advanced students can work on. [Teacher] gave me a few ideas that will help me with this year specifically, but the concepts will stick with me throughout teaching.”

Individual:

Fellows 1 and 3 had a common theme emerge. Both reflected on Challenge Based Learning and its ineffectiveness in classrooms if the students are not motivated to learn as illustrated in their comments presented below this paragraph. This theme was unique.

Fellow 1: “There are a cluster of students who are still motivated by grades and to them CBL and EDP doesn’t make any sense.”

Fellow 1: “I learned how the CBL units could be enhanced for a better approach of the goal of this teaching pedagogy.”

Fellow 1: “In order to fully implement the CBL successfully, we should also do some psychological study on the students behavior towards this format of teaching in addition to the pre and post assessment that is there.”
Fellow 1: “Not every student is excited about CBL. In the end, they still care about grades.”

Fellow 1: “How to implement a *real* CBL lesson, or at least allow students to have some real choices. I feel like it's just another lesson for both students and teacher.”

Fellow 3: “I learned that not every student comes to the class to learn as I found some of them dosing off, or trying to be an element of disturbance. I'm trying to help them out learn and will find out how it goes.”

Fellow 3: “Our meeting with [teacher] was excellent in redefining our approach to CBL. His attitude that the students (undergrad and high school/middle school) have not developed the ability to think (define and solve their own problems) makes our approach to CBL much more reasonable.”

Fellow 3: “CBL requires the teachers to go out of the scope of the implemented unit or in other words make use of available theories which the students might not have been exposed yet; thereby making it difficult for them to grasp the lesson as a whole. The whole point of CBL is to help the students be intrigued by the challenge in front of them and then work gradually to find a solution. However, considering the situation of [teacher]’s, I realized in this case sometimes it could be necessary to teach the students the various other concepts and theories which are being used/applied in the present unit. Ex. The students had a hard time doing simple algebraic calculations which was mainly because they hadn't been taught to do such math yet, but that left many students unmotivated to work as they could get what was happening mathematically. I believe rather than moving from group to group explaining them the concepts which are being used, a class or two to teach the same math concepts being used in the unit, that would have a better learning impact on the students.”

Fellow 3: “...no matter if its blackboard teaching or CBL, there are still students who cannot relate to the topics taught in class and we need to find a reason for this and also a way to motivate them to participate and speak up.”

Fellow 2 had themes emerge that were separate from the themes that emerged from the group:

Interaction/Relating to Students and Classroom Management, as can be seen in their comments presented below this paragraph. Both themes were unique to the CEEMS program experience.

Interaction/Relating to Students

Fellow 2, week 2: “Everything so far, how to relate with students and teachers (good interpersonal skills)” – In response to question (What did you learn that will impact your teaching experience)

Fellow 2, week 9: “How to relate with and motivate students. Also, this week being my week of teaching basic electric circuits, I am learning how to adjust and improve my teaching style to be more interactive so that the students understand better and feel freer to ask questions.”
Fellow 2, week 11: “This experience is helping me interact and educate young people on the need for formal education and how they can make a difference in their world.”

Fellow 2, week 12: “I learnt how to make the students more interested in the content that is being taught.”

Classroom Management

Fellow 2, week 4: “I learnt how to relate with students and how to manage even the most difficult students.”

Fellow 2, week 10: “How to handle/manage difficult students... The way he is able to manage the students and get them to do what he needs them to do without so much noise and distractions is very commendable.”

Analysis of Teaching Reflection Survey

Fellows and untrained graduate instructors reflected on their teaching experiences. Each was required to answer three specific questions: “What do you think you did well?”; “What are your opportunities for improvement?” and “What did you learn?” CEEMS fellows reflected that the item they did well was interact and engage with the students. Each fellow reflected upon something different when asked about their opportunities for improvement. Each fellow also indicated that the CEEMS experience was valuable to their career professionally. They each stated an aspect of the program that was beneficial to them and their future teaching responsibilities.

Three out of four untrained graduate instructors reflected on the fall teaching experience. The instructors were asked the same three questions as the CEEMS fellows. There was no common theme when judging their teaching experience about what they did well. Two instructors stated they wanted to engage more with their students when asked for opportunities of improvement. The instructors had three themes emerge when asked what they had learned from the fall teaching experience. The first theme indicated was preparation needed to teach. Each instructor indicated an element of preparation needed to teach a classroom, either stating they now understood the time it takes to prepare a lecture or the thoughtfulness that is needed to make a lecture session follow a logical sequence. The second
theme that emerged was the willingness to teach again. Each fellow indicated that more teaching
experience would help them in the future. There was also a sense of excitement about teaching a class
again. The third theme was a new appreciation for teaching. They had a better understanding of the
student-teacher paradigm. These are presented for fellows and instructors, respectively, below.

CEEMS Fellows

Fellow 1

What do you think you did well? – “I think I related to and engaged my students well. I think I presented
the material in a manageable way, and provided good explanations. I think my CBL was a good idea -
linking the previous two lessons to a device that was applicable to their fields.”

What are your opportunities for improvement? – “I felt very unprofessional; I didn’t have my lesson
finished until I had to teach. On top of my procrastination (also aided by the late-term schedule change),
I missed a class. I feel terrible about it still. Finally, as a personal choice (one I will defend as a smart
move), I addressed the students very informally. The effort was to draw them back at the end of a
semester in a class that didn’t really apply to them, but still, it made me feel even more unprofessional.”

What did you learn? – “But seriously, being on the other side of the classroom is very interesting; it has
made me value learning opportunities a lot more, and has given me some experience to draw on for
teaching in a classroom later in life. It has given me something to add to my resume, but more than that;
it has given me experience preparing lessons, even in subjects I am relatively unfamiliar with. It also gave
me some background in the field I’m in! I am pursuing my PhD in EE, but hadn’t taken any of the
undergraduate EE classes. This was a nice informal introduction that allowed me to teach myself. As I said
before, education is about changing the way people think; this has certainly given me a better framework
for understanding electrical circuits, which will probably come up in my professional career.”

Fellow 2

What do you think you did well? – “Sometimes it’s really difficult to tell what you did well or not given
the circumstances, but I guess I’d say compared to my initial teaching in the summer, my communication
style and interaction with the students improved. I constantly tried to relate the content I was teaching
them (chap 6-8) to the challenge which was on energy storage device design.”

What are your opportunities for improvement? – “To have the students feedback will really help me
improve in my teaching. I can definitely improve on my organization of materials and also on depth of
material.”

What did you learn? - “I have learnt so many valuable things: 1) How to effectively interact with
students 2) How to improve my communication/interpersonal skills 3) How to conduct independent
research and study new materials on my own to be able to effectively teach others. 4) How to organize my thoughts in writing. 5) How to make better presentations.”

Fellow 3

What do you think you did well? – “Overall, I think I did a pretty good job to engage most of the students with me (the professor) which is not usually seen in normal blackboard style teaching.”

What are your opportunities for improvement? – “Getting to understand the learning capabilities and standards of all the students, I could tweak my lectures accordingly to suit a wider range of students. Although I didn’t feel that my lectures were complicated this time, but the failure from the part of the students to solve the problems I gave them in class made me think I could go more basic. Part of this also depends on how much they still remember the topics covered in the first exam which was necessary to understand the concepts I was teaching.”

What did you learn? - “Personally, I’ve learned that how just by remembering the names of the students and calling them by their names can convert a normal lecture to a much more interesting and engaging class. I think my students loved it when I called in with their names and sometimes as I forgot their names, I did apologize and asked for theirs again. Professionally, I’ve learned that no matter what, due to the past years of experience as students, no matter what, the students will go dumb in the morning in front of the teacher, even if they were talking vibrantly before the start of the class. Being a first time teaching experience, this was demotivating but I think I played along with the class really well to cope with this issue like the daily 5 min philosophies I used to share with them. Laughter Yoga therapy, The left brain and Right brain, the philosophy of being in the moment to get the best out of the lecture and my philosophy of being flexible like water to get the best out of CBL worked to get the students prepared for the next 45 min of class.”

Fellow 4

What do you think you did well? – “I think I moved at an appropriate pace and gave ample time for the students to ask questions. I also did a lot of example to try to explain the concepts and show how they apply.”

What are your opportunities for improvement? – “I think I sounded a little monotone and could be more dynamic at the board. I should also give more opportunities for the students to work in groups and present their findings to the class.”

What did you learn? – “Personally, I have learned a lot about what it takes to plan a class in terms of time and energy and how to manage that better. Professionally, I have gotten extremely valuable teaching experience in a college classroom that will help me become a better teacher in the future.”
Untrained graduate instructors

Instructor 1

What do you think you did well? – “I tried to answer the students questions (not always very well) and I tried to be quick to respond to emails/issues that arose during the class.”

What are your opportunities for improvement? - “Engage the class more -- Because I was not confident in my knowledge of the subject, I would not engage the class as much as I would have liked to. Instead of asking students to solve problems or work their way through problems, I worked through them with little interaction with the students. Employ alternative teaching methodologies to improve learning retention – I would like to investigate and employ alternative methods of teaching to help students better retain what they learn. Based on some of the exit tickets, students did not retain information that I had just lectured on, indicating to me that lecturing and writing on the board may not be the most effective teaching method for this particular subject.”

What did you learn? – “I have learned that I do enjoy teaching even though I find it to be very challenging! Even though I don't think I did a very good job with this course, I am motivated to continue to find opportunities to teach and improve my approaches/abilities. I enjoy engaging with students and I hope that in the future, I would structure my course to be able to maximize the amount of student/teacher interaction to further engage the students in the subject material.”

“This was a very humbling experience for me. I have a much greater respect for teachers/professors. I guess my take-away from this experience is that everyone has to start somewhere with teaching. I feel like I have a long way to go towards being an effective teacher, but I’m looking forward to continuing to hone my skills. Thanks for the opportunity”

Instructor 3

What do you think you did well? – “Yes I think I did well, because I can judge my performance with my inputs and also from the queries students asked in the class. As I took more classes I learned that there is a better mutual understanding between me and students. They were able to comprehend and understand my lectures and my explanations to their queries. I think I was able to clear their doubts.”

What are your opportunities for improvement? – “For improvements, I think as this was my first teaching experience it gave me a lot of insights from the point of view of a teacher. I think with experience and more teaching time, I would improve in understanding student queries in a more better way. I think judgment of class time and the amount of material to be covered with enough inputs to make the topic clear to students is very important for a teacher. I am sure with more teaching opportunities in future I will certainly improve on it.”

What did you learn? – “Personally I have learned that there is a big gap between a teacher's point of view and student's point of view toward a topic. Professionally I think it is very important for a teacher to think and teach from student level. I think while teaching a teacher should use his own experiences and difficulties faced as a student while learning the course. This would help in improved quality of teaching because a teacher would then prepare effectively for a class and would know in advance where students
might have difficulty in understanding complex topics. Also this would help a teacher in anticipating queries from students. I learned that while teaching the pace of the course and understanding of concepts by students in a class must be maintained within a balance considering time limitations.”

Instructor 4

What do you think you did well? – “I believe I explained concepts and example problems well. I also prepared well for the lectures and made sure I had a good understanding of everything in advance of class.”

What are your opportunities for improvement? – “I could improve the way I engage students during class. I attempted to engage students by asking targeted questions, but I feel like I can improve on this. I also need to improve the way I present material, I sometimes find myself slipping into monotone if I am not careful.”

What did you learn? – “I learned a number of things, most importantly being that I enjoy teaching and would like to continue it in the future. I also learned that traditional lecture format classes are not as effective as other formats. While I have never experienced other teaching styles, I am convinced traditional lectures are not the way to go. Professionally I learned the large time commitment that is required to teach, especially in preparation. I have a new appreciation for those that teach and the time they spend on the class. Finally I believe this experience will make me a better student, experiencing some student behavior as a teacher (whispering, coming late to class, technology use during class, etc) are far more disruptive for the teacher than I had thought as a student”.

Analysis of Focus Groups

Focus groups were used to gain a better understanding of the fall teaching experiences. Results are presented in this section for both fellows and instructors.

CEEMS Fellows

Q: How do you think the fall semester went?

Fellows stated they thought the semester was overall a good experience. They noted that times during the semester were busier than others due to the requirements of the fellowship.

“I thought it went well. It was a little busy. And trying to get everything like straightened out for the beginning of the year and at the end of the year, when I had exams and stuff and Thanksgiving and things like that. But I thought it went well.”
“I thought that was good. Like you say, the three weeks where you’re supposed to give lectures or [visiting] the schools and have our own academy classes, that was the most stressful one for me.”

“I think the weeks I taught, it was kind of hectic because I had to teach and also go to the schools I was working with. But I think other than that, it was okay.”

Q: How did it work with your CBL? What do you think happened?

Each fellow had a different experience when using the CBL method in their classroom. One fellow felt there was not enough time to implement a good challenge and another fellow stated that the execution of CBL could have been better, however both fellows stated that CBL helped the students understand why they were learning the material. A third fellow stated that the students were not engaged in CBL and felt that the students only cared about exams. Select fellow statements are presented below:

“I thought it worked okay. I mean, it was difficult to do CBL in the classrooms just based on the time frame we’re working with, us not being actual experts in the material.”

“I took it as basically letting the biomedical and chemical engineering students know why they’re learning electrical circuits. That was my main focus to understand. And I did pretty good on that, but basically coming up with a solution to a challenge that I gave to them, I might not have been successful in that the first two times. So maybe I will work on that the next time.”

“I think they were more concerned about the exams right? than the challenge-based learning part of it. Because they really wanted to practice problems because they had exams coming... so they wanted to know what the exam will be all about and what questions will be asked so they can pass the exams. The challenge was learning material.”

Q: How did you know your students were engaged?

Fellows judged their teaching based on student response. Each fellow thought their teaching experience was successful, due to the interaction they received in their classrooms, as illustrated from their statements below:
“Asking questions.”

“Usually I saw a number of students from the back coming to the front benches. And the positioning of people. For the first time after take classes, they say okay, you want the first benches started coming forward.”

Q: Do you think you learned anything for teaching the course?

Each fellow learned something different from the teaching experience. The items that fellows noted they learned were all teaching skills, as illustrated in the feedback comments presented below.

“Definitely. A lot of aspects there. Students at 9:00 a.m. in the morning and Friday would have a different impact than if you are teaching the students on a Monday. And then basic stuff. And then again, classroom management.”

“Hard work is in the prep... I actually began to appreciate how much time professors put into preparing lessons...”

“Classroom management and interaction.”

Q: How was it working with your K-12 teachers?

Fellows felt that shadowing the K-12 teachers was a beneficial experience. The fellows learned about students and their behavior, as illustrated by their statements below:

“It was something. And then staying in the classroom with the teachers also taught us lessons about how to be a good instructor. It was helpful, I would say, for me.”

“I also had a bit of a culture shock initially, but then I got used to it. And after discussing with the teachers, but yeah. It helped me to learn how to manage the students K through 12 and the students over here from the way I had my education.”

“It was good. It was a little hectic. But most of them seemed very excited. They seemed to enjoy the challenge-based stuff. They enjoyed doing the projects, I think, a lot.”

“I think for me, the first experience was like a shock, like culture shock kind of thing... So I think I really learned ______ managing people, not just the way I would stop growing up, like a different world of teacher-student relationship.”

Q: Do you think that your summer experience helped you, and if it did, how do you think it helped you?
Fellows indicated that the summer experience was beneficial to them. The summer teaching experience made them more prepared for the fall teaching experience, as illustrated by their statements below:

“I guess the summer experience helped more with being in the classroom. Because during that time we were working with the teacher, so we kind of go to see the project in development, so before going into classrooms.”

“So I think being in the classroom helped a little bit, being in the classroom in the summer, just because it wasn’t like we were walking in the first day of our class with no experience from a class teaching. So that helped a little bit.”

“I think I felt more relaxed in the classroom…”

Q: Do you think there’s anything we could have done as a project that could have helped you feel better or be more successful? Fellows responded as follows:

“The most helpful thing would have been more time. That’s obvious and you can’t control. It’s what you have to learn in a certain amount of time. But that’s with anything. If you have more time, you can be more creative in your approach. You can give your students more time to sort of develop mastery themselves.”

“I think experience like this and it was fast paced.”

Untrained Graduate Instructors

Q: How do you think the fall semester went?

Overall, the participants thought the summer was productive and effective. Participants noted that they felt the fall semester was a good teaching experience, as illustrated by the following statements:

“overall I think it went pretty well.”

“I enjoyed the experience.”

“…a good experience…”
“...it was a good experience overall.”

Q: What do you think you learned specifically?

Instructors noted two specific items they learned during the fall teaching experience: engagement is important in the classroom, and an understanding of how much time it took to prepare a lecture. These can be inferred from their following statements:

“I’ve learned that I think the best way to be a teacher is to be engaging with your students.”

“So I learned knowing the material and engaging the students is the best combination.”

“So things that I learned from that was how much preparation is required, like how many hours of preparation to get one hour of lecture in.”

“I would say for me it probably averaged about three hours of prep per hour of classwork.”

“I learned is the point of view like when you are a student in the class and there’s a different point of view you are giving, it’s the same thing from a student’s perspective and from a teacher’s perspective, the same thing.”

Q: Do you feel that you were prepared to teach?

The instructors felt prepared to teach, but the classroom experience changed their perspective, as illustrated by the following statements:

“Actually, I think it’s supposed to be easy for me, but it came to me as a challenge later on.”

“I’m feeling pretty confident about things, but then when you get up there and you’re writing it on the board, and they’re like, “Why did you just do that,” I’m like, “Oh, I don’t know.”

“I think the problem doesn’t just come from they’re not preparing us well enough. It’s from the top down. I mean they want faculty to be researchers first – at least this institution.”

Q: Did you feel comfortable with the way you were teaching?
Instructors felt comfortable with the lecture-style method because it was the method used when they were undergraduate students. Although the instructors felt comfortable, it was noted that it may not be the best method of teaching, as illustrated by the following statements:

“I mean it’s the traditional way and how I’ve been taught all through college.”

“Like I felt comfortable with the style because that’s what I’m used to seeing, but when you’re up there I’m like looking at all blank faces ‘cause they don’t understand or they can’t remember how I did three problems ago, and so for me I think it was okay, but for the students I think there are better ways that may be a little bit more uncomfortable for the teacher ‘cause you have to prepare, probably, more than what we prepared for now.”

Q: Do you feel this was a realistic experience in academia?

Instructors felt their fall teaching experience was a realistic experience. They noted that the teaching they delivered was similar to the teaching that was delivered to them, as illustrated by the following statements:

“Yeah, because most of these professors that I’ve had have been worse at teaching a particular course than I was.”

“I think the traditional way of teaching is really not good at all. It is actually very traditional because we are in a traditional time so we have to move and make lectures better for our students, because even from a teacher’s teaching point of view, I am not comfortable to just go and just write the steps and just be done with that... Like from my undergrad experience, the worst thing was this thing that teachers go over the steps on the board and they don’t carry on to explain the things, and that’s the same thing I’m doing to those students. I don’t want to do that same thing to them.”

How would you create the course now that you have had this experience?

Instructors noted that a good course starts with having a good textbook, but the text cannot be the center of the class, as illustrated by the following statements:

“Well, I think first of all finding a good textbook is a good starting point.”

“Well, I think some of my best courses have been courses where the textbook wasn’t the focus, but rather the supplement to what’s going on in the class.”
“I would find a textbook that would complement what I’m teaching in the course, but not have that be the focus because I didn’t read textbooks when I was an undergrad. None of my friends really read them very much, at least that I can remember. The main knowledge that we got was when we went to lecture and what we got from that.”

Do you want to be professors?

The fall teaching experience reinforced the idea of an academic career for two of the three instructors, as illustrated by the following statements:

“I enjoy teaching. I’m in research right now, and I get irritated because I don’t engage with people that often ’cause I’m just sitting at a bench. So if I were to go in academia I would want to teach for sure.”

“Yeah. I think it’s really good to be an instructor because it helps to basically improve the metrology of education.”

“I would like to, but I’m not really sure if I would be going to academia at this point because this was my first time [teaching].”

Discussion

The summer experience included the CEEMS fellows teaching for one week and educational training. The results from this experience impacted the CEEMS fellows’ TESS scores. Three CEEMS fellows had a TESS mean score increase and one had a TESS mean score decrease. After the fall semester, three of the fellows’ TESS means scores increased and one CEEMS fellow’s TESS score decreased. The increase in self-efficacy shows the impact of educational training and teaching experience. Since the majority of the CEEMS fellows’ TESS score increased, the program can serve as a good foundation for what is needed in preparing future faculty programs. The CEEMS fellow who showed a decrease at the end of training initially showed an increase in the summer. One of the three fellows who had a TESS score increase in the summer had a TESS mean score that decreased by the end of the fall. The decrease in TESS may be due to the fellow having a better understanding of his/her teaching responsibilities (Woolfolk and Hoy, 1990; Spector, 1990).
Each graduate instructor had a teaching experience of three weeks with no educational training; 100 percent of the graduate instructors had a mean TESS score decrease. The difference in the self-efficacy scores shows the longer the teaching experience, the more negative the influence on graduate student self-efficacy, if not reinforced with educational training and/or shadowing experience. The decrease also shows that graduate instructors had an inflated sense of teaching self-efficacy: they were overly confident in their teaching skills until they had a teaching experience. The realization of true ability from new faculty members is a factor in success. If a new faculty member thinks they can teach, but realize they have opportunities for improvement they originally did not understand, the faculty member may get frustrated. Frustration has been linked to poor performance (Waterhouse and Child, 1953). Poor teaching performance leads to negative classroom experience for undergraduates (Seymour and Hewitt, 1994). This cycle may be part of the high attrition rates in colleges of engineering.

CEEMS fellows had two themes from their weekly reflections supported by literature: student misconceptions/teacher perceptions and teaching effectiveness. The student misconception/teacher perception topic was a week-long topic covered as part of the seminar series the fellows attended in the summer; however, the impact of this seminar was reported in more detail in the fellow weekly reflections than any other seminar. Fellows expanded on how the misconception/perception seminar would continue to impact them professionally, as opposed to simply stating it was information learned in that week. Through the weekly reflections CEEMS fellows realized the importance of their role as teachers to dislodge misconceptions and control their perceptions to help the students learn. Sadler et al. (2013) found that teachers who could identify misconceptions had larger classroom gains. This finding suggests that a teacher’s ability to identify students’ most common misconceptions can positively impact student performance.
CEEMS fellows 1 and 2 had additional themes that did not emerge as a group. Fellow 1 stated that seminars, homework, and experience were a waste of time. Seven out of the nine weeks there was a statement about disinterest in the program or the time commitment of the fellowship. This is not consistent with the published literature. It is important to note that Fellow 1 stated learning outcomes throughout the summer experience despite the negative feelings towards the program. This theme is not consistent with literature. Research has shown that graduate students who participate in educational training feel the program is beneficial (Gamse et al., 2010). Fellow 1’s dissatisfaction may be due to other personal experiences that occurred concurrently with the training e.g. wedding preparation and/ or thesis defense. Fellow 1 has also worked for 2 years as a GK-12 fellow which included a two quarter long teaching practicum at a high school developing, teaching and documenting one curricular lesson and assisting a teacher for 10 hours/week in the classroom. Additionally the fellow had completed a PFF course. Fellow 2 reflected on how the summer experience was helping professionally. Seven out of nine weeks, Fellow 2 commented about professional development and benefits of the CEEMS program. This theme is consistent with literature. Fellows of the GK-12 program noted the experience helped with professional skills as well resume building (Gamse et al., 2010).

The CEEMS fellows also noted that the CEEMS program enhanced their teaching effectiveness. Teaching effectiveness was a theme that also emerged in the GK-12 program among the GK-12 fellows. Eighteen percent of GK-12 fellows responded that the program enhanced their ability to teach STEM research and concepts to undergraduate students and 97 percent responded the GK-12 program enhanced their ability to teach STEM research and concepts to K-12 students (Gamse et al., 2010).

During the fall semester, fellows spent between ten to twenty hours per week in K-12 classrooms as well as teaching for 3 weeks in the fall semester of the BEC course. During the fall the CEEMS fellows taught using CBL. Throughout the reflections, two themes emerged from the group:
understanding students and teaching style. Understanding students is a unique theme for participants of the CEEMS program. This theme has not been identified as a learning outcome in other PFF programs. Research has shown that understanding in schools requires strong, continuous relationships between teachers and students so they learn to “read” each other over time (Hargreaves, 2000). Teachers’ understanding of the student impacts student experience (Hargreaves, 2000). The second theme of teaching style is supported by literature on faculty development programs. Enhanced teaching skill was a theme that GK-12 fellows from the GK-12 program also developed (Gamse et al., 2010). This was an expected theme, due to CEEMS fellows spending time in K-12 environments similar to those in the GK-12 fellowship program.

Fellows 1 and 3 had a common theme emerge. Both reflected on CBL and its ineffectiveness in classrooms, especially if the students are not motivated to learn. This theme was unique and unsupported in literature. This may be due to the implementation of the pedagogy. CBL has not been widely used in post-secondary environments. Studies using PBL, a similar pedagogy, support an opposite theme, stating that PBL is an effective pedagogy to help motivate students to learn (Strobel and van Barneveld 2009).

Fellow 2 had themes emerge that were separate from the themes that emerged from the group: interaction/relating to students and classroom management. The GK-12 Program had a similar themes emerge, with 77 percent of GK-12 fellows understanding the importance of interaction/relating to students (Gamse et al., 2010). GK-12 fellows stated the program helped develop the skills needed to relate to students and manage a classroom (Gamse et al., 2010).

After the fall teaching experience, CEEMS fellows and graduate instructors provided a personal reflection about their experience. CEEMS fellows reflected that the item they did well was interact and engage with the students. The GK-12 Program had a similar theme emerge, with 77 percent of fellows
understanding the importance of interaction/relating to students (Gamse et al., 2010). Each fellow also indicated that the CEEMS experience was valuable to their career professionally. This theme was consistent with what was found in literature. Results from the GK-12 program indicate that GK-12 fellows felt the experience helped prepare them professionally (Gamse et al., 2010). Each CEEMS fellow reflected on something different when asked about their opportunities for improvement. They each stated an aspect of the program that was beneficial to them and future teaching responsibilities. The uniqueness of each fellows’ opportunities for improvement is understandable since self-reflection is tied to the individuals’ background and feeling about self. The graduate instructors were asked the same three questions as the CEEMS fellows. There was no common theme when judging the teaching experience of the graduate instructors. Two instructors stated they wanted to engage more with their students when asked for their opportunities for improvement. Since graduate instructors did not participate in the K-12 apprenticeship, the theme is consistent with literature. Literature states that spending time in the classroom help with student interaction (Gamse et al., 2010). The graduate instructors had three themes emerge when asked what they had learned from the fall teaching experience. The first theme indicated was the amount of preparation needed to teach. Each instructor indicated an element of preparation needed to teach a classroom, either stating they now understood the time it took to prepare a lecture or the thoughtfulness that is needed to make a lecture session follow a logical sequence. The second theme that emerged was the willingness to teach again. Each fellow indicated that more teaching experience will help them in the future. There was also a sense of excitement about teaching a class again. The third theme was a new appreciation for teaching. They had a better understanding of the student-teacher paradigm. These themes correspond to the decrease in overall TESS scores by showing that the graduate instructors better understood what was required of them to teach effectively (Woolfolk and Hoy, 1990; Spector, 1990).
Threats to Internal Validity

The major threat to the internal validity of this study was the possibility of a subject characteristics threat. Some examples of subject characteristics that might affect the results of this study included intelligence, attitude, stereotype threat, and socioeconomic status.

Threats to External Validity

The generalizability is limited. It is suggested that samples should be chosen in different types of schools with different demographics of students in various programs. It would be important to increase the number of participants and study them for a longer period of time to note the effects of the program over time.

Role

In the study, the researcher was an outsider and observed the teaching interactions in the classroom. Although the class was observed, the whole picture may not have been seen.

Generalization

Every graduate student is unique. However, the findings of the study provide a good suggestion for the implementation of a PFF program that has a shadowing component in the K-12 classroom environment. This study gives a good foundation for what program coordinators can expect to happen.

Limitations and Suggestions for Future Research

The study was conducted over two semesters. Each fellow and graduate student has the opportunity to teach for three weeks in the semester. Due to class limitations, fellows and graduate students were unable to teach a class for an entire semester on their own. In the future it would be
beneficial to conduct a study in which each fellow and graduate instructor taught a section of a course for a full semester.

In this study there were two groups of graduate students: CEEMS fellows and untrained graduate instructors. Due to the methodology used in this study, it is not clear which part of the CEEMS program contributed to the increase of teaching self-efficacy in the CEEMS fellows. Another study could be conducted with three groups of graduate students: fellows with educational training, fellows with apprenticeship experiences in K-12 classrooms, and untrained graduate instructors. Separating the CEEMS program into the two core components will help identify the element that has the most impact.

To make stronger statistical inferences, more fellows and graduate students are needed to participate in the study. The current study had four participants in each group. To make better generalizations, more participants would be needed.

**Conclusions**

Due to the increase in self-efficacy in CEEMS fellows and the emerging themes from reflections and focus groups, the CEEMS fellows’ training is a good foundation for future faculty training. It is important to note that teaching experiences are not enough to prepare graduate students for faculty positions. The teaching experience must be paired with training similar to that which is outlined in the CEEMS program.

The findings from this study show important learning outcomes for educators. Developing the educational training based on the CEEMS program for existing faculty would be beneficial to help make better learning environments. The current program is tailored for future faculty members, but current faculty members would also benefit from this pedagogical training.
Chapter 2 References


Chapter 3: Challenged Based Learning

Introduction

Cincinnati Engineering Enhanced Math and Science Program (CEEMS) works to connect the students’ motivation to what they are learning with the use of Challenge Based Learning (CBL). In the CEEMS program, teachers and graduate students are provided educational training, taught the CBL method, and how to use it to enhance student learning in secondary school math and science classrooms. Currently, the K-12 education system focuses on a series of standardized tests required to move to the next grade or to graduate (Kohn, 2000). It is believed that these changes have negatively affected student learning and motivation, which leads to high dropout rates (Harackiewicz et al., 2002).

The high dropout rates can be explained in part by the phenomenon of learned helplessness, which occurs when an animal is repeatedly subjected to an aversive stimulus that it cannot escape (Seligman, 1975). Eventually, the animal will stop trying to avoid the stimulus and behave as if it is utterly helpless to change the situation. Even when opportunities to escape are presented, this learned helplessness prevents any ameliorative action. A student who performs poorly on tests and assignments will quickly begin to feel that nothing that student does will have any effect on performance. When later faced with any type of related task, the student may experience a sense of helplessness, which is characterized by student passivity (Peterson, 1993) resulting from changes in cognition and emotion, a loss of motivation, and a reduction in behavioral agency (Gentile and Monaco, 1988; Peterson, 1993). Consequently, the students leave college.

Undergraduate engineering classrooms have been identified as environments where barriers to participation and persistence exist. More specifically, researchers have concluded that the typical
engineering classrooms tend to be impersonal, competitive, and authoritarian. This type of environment is believed to discourage students, particularly those who lack confidence in their abilities to succeed in engineering disciplines, from pursuing science-related majors (Milem and Astin, 1994). Seymour and Hewitt (1994) reported that of the 23 issues cited most frequently by students as problems in engineering majors, nine issues include poor teaching by science and engineering faculty members, lack of peer study group support, and a preference for the approaches used in teaching non-science and non-engineering courses.

In the freshman year of engineering it is important for students to participate in an active learning environment to foster a positive experience as the first year experience is linked to success and retention (Rugarcia et al., 2000; Besterfireld-Sacre, Atman, and Shuman, 1998). Research has shown the more positive and dynamic the first year experience for engineering freshman the more positive students’ attitudes, expectations, and skill level (Besterfireld-Sacre, Atman, and Shuman, 1998).

**Theoretical Framework**

**Direct Instruction**

Direct instruction is based on a teacher-centered classroom. The term *direct instruction* is defined by edglossary.org as: (1) instructional approaches that are structured, sequenced, and led by teachers, and/or (2) the presentation of academic content to students by teachers, such as in a lecture. Good (1979) explained direct instruction as an active teaching style where the teacher sets and explains all learning goals.

Lectures represent the dominant method of teaching in formal education. They have been identified with the higher education system for centuries and are still the preferred instructional method used today.
Teacher-centered instruction imposes a moratorium on students’ educational development by forcing them to assume a passive role as a student. The research has shown that lectures are as effective as other instructional methods in transmitting information to students; however, lectures are inefficient in promotion of thought (Bligh, 1998). This is a concern for students in the colleges of engineering and applied science, as they are required to have the ability to think critically and solve problems as outlined in the Accreditation Board for Engineering and Technology Inc. (ABET) criteria.

Bui and Alearo’s (2011) research also showed that students participating in the direct instruction method have more of a negative attitude towards science than nontraditional groups. In this research, CBL will be compared to the direct instruction method, lecturing, to investigate if these challenges can be overcome.

*Constructivism*

Constructivist theory is based on learners tying content to personal experiences or creating learning environments in which learners can identify content to context. What learners understand is a function of the content, the context, the activity of the learner, and the goals of the learner (Savery and Duffy, 1995). Creating authentic learning environments has the potential to increase student engagement and learning (Patrick and Yoon, 2004). In order for students to understand deeply they must learn new facts and link them to prior knowledge and understanding. Once students can link the knowledge they will be able to think critically (Marton and Booth, 1997). Research has shown the importance of students being able to apply theory knowledge in real-world applications, especially engineers. When students are able to apply knowledge, they are better equipped to solve problems as they arise in their discipline (Bransford and Vye, 1989).

Constructivism contains eight main instructional principles according to Savery and McDuffy (1995):
1. Anchor all learning activities to a larger task or problem. Learning must have a purpose that is meaningful.
2. Support the learner in developing ownership for the overall problem or task.
3. Design an authentic task.
4. Design the task and the learning environment to reflect the complexity of the environment the learner should be able to function in at the end of learning.
5. Give the learner ownership of the process used to develop a solution.
6. Design the learning environment to support and challenge the learner's thinking.
7. Encourage testing ideas against alternative views and alternative contexts.
8. Provide opportunity for and support reflection on both the content learned and the learning process.

**Definition of Project-Based Learning**

Project-based learning is grounded in constructivist theory, which allows students to be active, collaborative, reflective, and comparative in their learning experiences (Jonassen and Grabowski, 2003). Learning content through context is one of the 8 principles of constructivism (Hernandez-Ramos and De La Paz, 2009; Savery and Duffy, 1995). Constructivist thinking provides a building block for project-based learning pedagogy to engage.

Project-based learning is a model that organizes learning around projects (Thomas, 2000). A project is an extended, in-depth investigation of a topic, and involves conducting research on phenomena and events worth learning about in their own environments (Harris and Katz, 2001). In the process of doing projects, students have opportunities to pose questions or generate theories. Project-based learning is formally defined as a systemic pedagogy engaging students to learn knowledge and skills through an inquiry process including complex, authentic questions, and the design of projects (Buck Institute for Education, 2008). The *Challenge 2000 Project-based Learning Guide* defines project-based learning as a model for classroom activity that shifts away from the classroom practices of short, isolated, teacher-centered lessons and emphasizes learning activities that are long-term, interdisciplinary, student-centered, and integrated with real-world issues and practices.
In project-based learning, the role of the teacher changes from lecturer to facilitator of information. However, teachers should, at any time, implement outside knowledge, interests, and experiences into their classroom lessons (Garran, 2008). The driving question provided to the students organizes and leads their activities. The investigation tries to answer their questions. The formation of models or evidence gathered represents the students’ ideas and understanding. The use of collaboration to share information and use of technology to research information are skills developed for a student’s future learning tasks (Alozie et al., 2010). Krajcik et al. (1994) identified five essential features of project-based learning projects, which include the following:

1. Students are to be engaged investigating an authentic question or problem through activities and organizing concepts and principles.
2. Students develop series of artifacts or products that explain the question or problem.
3. Students develop the investigations.
4. Teachers, members of community, and other students will be parts of a collaborative consulting group.
5. Teachers encourage students to use cognitive tools.

What is CBL?

Challenge Based Learning (CBL) is an active learning environment that engages students to plan their own learning. To reduce negative experiences and increase motivation in K-12 classrooms, Apple, Inc. (Cupertino, CA) developed the pedagogy of CBL (Educause, 2012). CBL is a structured model for course content with a foundation in earlier strategies, such as collaborative problem-based learning (Educause, 2012). CBL is different from project-based learning in that instead of presenting students with a problem to solve, CBL offers general concepts from which the students determine the challenges they will address (Johnson et al., 2009; Educause, 2012). CBL activities offer many of the benefits of project-based learning, as they engage students in real-world problems and make them responsible for developing solutions (Johnson et al., 2009). Using CBL, students have the satisfaction that comes from solving both the issue to be tackled and the solution they develop (Educause, 2012). As participants
determine where a problem lies, how a solution might be affected, and how technology can be leveraged to accomplish a workable result, they learn the value of critical thinking and reflection (Johnson et al., 2009). In Apple’s 2008 study of CBL conducted by Johnson et al. (2009), findings showed student engagement among participating ninth and tenth graders was rated at 97 percent or higher, and that student involvement peaked when they perceived the solutions they worked on to be of real value.

Motivation is defined as the process that initiates, guides, and maintains goal-oriented behaviors (Cherry, 2011). There are three major components to motivation: activation, persistence, and intensity (Cherry, 2011). Activation involves the decision to initiate a behavior. In CBL, activation of the decision to initiate learning is the introduction of the big idea. Persistence is the continued effort toward a goal even though obstacles may exist. In CBL, persistence involves the students defining the problem, asking the essential questions, and acquiring the knowledge needed to solve a problem. Finally, in CBL, intensity can be seen in the concentration and vigor that goes into pursuing a goal.

CBL builds on problem-based learning models where students engage in self-directed work scenarios or “problems” based in real life (Johnson et al., 2009). The teacher’s primary role shifts from dispensing information to guiding the construction of knowledge by his or her students around an initially ill-defined problem. Students refine the problem, develop essential questions, investigate the topic, identify the knowledge to be learned, and utilize the knowledge gained to work out a variety of possible solutions before identifying and defending the most reasonable one (Johnson et al., 2009; Rillero and Padgett, 2012). Documentation of the process and a high-quality production of findings further serve to give the process relevance to the world of actual work (Johnson et al., 2009). A unique feature of CBL is that problems are or can be tied to an idea of global importance (Johnson et al., 2009; Educause, 2012).
In the general CBL approach, as outlined by Apple (ali.apple.com), the big idea is an item of global significance; for classroom purposes, it is pragmatic to constrain (guide) the big idea to the topic / theme of the course. Once the big idea is introduced, students formulate questions that clarify the big idea and help establish the boundaries of the challenge. These questions are called “essential questions” (Apple, 2011). This sets the broader context and foundation for the work that will follow. The class then identifies a suitable challenge or is introduced to the challenge (Apple, 2011). This establishes the context for the unit/topic. The students begin the process of identifying the questions that will guide their analysis of the challenge topic (Apple 2011). These questions, called “guiding questions,” outline what the students think they need to know to formulate a viable solution. Students may need significant guidance from a teacher, depending on the particular course and student preparation (Apple 2011). This is where content knowledge and engineering-design process requirements are established. To further assist in the challenge, teachers organize guiding resources that include the content and processes students need to answer the guiding questions (Apple 2011). The guiding resources include guiding lessons and activities, in which the student teams seek to find answers to the guiding questions by participating in a variety of learning activities, conducting research, learning new material (independently, in groups, or as part of an instructor-led lesson), experimentation, simulations, games, interviewing, and exploring various avenues to assist in crafting the best solution (Apple 2011). The CEEMS program integrated the engineering design process into the CBL methodology. The engineering-design process guides and informs the solution of at least one guiding activity. Students must share their solution to the challenge often in multiple formats. Both oral and written communication skills should be developed as part of the process. An overview of CBL as used in the CEEMS program can be found in Figure 1, below.
Figure 3: CBL Process Overview (figure from the CEEMS Community of Practice meeting, 11-7-2012)

One observation within classroom scenarios according to the CBL is a change in both teacher and student roles. The student role takes on a stronger focus of being a more self-regulated learner. Due to the open-ended scientific nature of the examined research question, the teacher’s role focuses more on being a coach or co-experimenter.

Differences Between CBL and PBL

CBL is based in project/problem-based learning, but there are unique aspects, highlighted by Apple, Inc. (Johnson et al., 2009), including the following:

1. PBL is focused on a project solution, whereas CBL has a broader range of inquiry. Within the context of the learning environment, there are goals related to self-directed learning, content knowledge, and problem solving. To be successful, students must develop the self-directed learning skills needed in the engineering field. They must be able to develop strategies for identifying learning issues and locating, evaluating, and learning from resources relevant to that issue. The entire problem-solving process is designed to aid the students in following the engineering design process, which centers on hypothesis generation and evaluation. Finally, there are specific content learning objectives associated with each unit. Since the students have the responsibility for developing the problem and finding a solution, there is no guarantee that all of the content area objectives will be realized in a given unit. However, any given content objective occurs in several units and, hence, if it does not arise in one, it will almost certainly arise in one of the other units.
2. CBL connects students to real world problems they see in their communities. This focus helps with engagement and motivation. Students that are traditionally at risk of dropping out of math and sciences classes are encouraged through the connection of an authentic problem. Students and teachers work together to address a challenge, develop solutions and implement them in the community. Reports have shown CBL projects have been successfully utilized in communities (Educause, 2012). Testing the students’ solutions in real-life situations builds on learning. Both PBL and CBL require solutions to a problem with a final report on the findings, only CBL has a call to action that requires students to do something that makes a change in the community and/or world (Educause, 2012). With CBL, students develop and execute solutions that address a challenge in ways that have an impact on themselves and others. While each of these models often utilizes some technology, it is infused throughout CBL projects from beginning to end.

3. In CBL, students are encouraged to reflect on their learning and the impact of their actions (Johnson et al., 2009). Students and teachers publish their solutions to a worldwide audience for an even larger impact (Johnson et al., 2009). Teachers can assess students by viewing and evaluating their reflections and published work. This step is not emphasized in PBL.

**Importance of CBL**

Research has shown that student-centered learning approaches are efficacious in improving student learning (Hightower et al., 2011). Studies have shown keeping students not only engaged in engineering course content, but also in their educational community, can help strengthen a student’s perception of where they fit and can contribute in the engineering world, which results in higher retention rates (Carlone and Johnson, 2007; Fouad and Singh, 2011; Kittleson and Southerland, 2004).

**Research Questions**

The research questions for this study are:

1. Does using CBL in science, technology, engineering, and math (STEM) classrooms improve student experience?
2. Does using CBL in STEM classrooms improve student performance?

Gaining an initial understanding of these questions could provide a basis to develop strategies for better learning environments in STEM classrooms. The design of this environment was meant to simulate, and, hence, engage the learner in the problem-solving behavior of an engineer. Nothing was simplified or pre-specified for the learner. The facilitator assumed a major role in modeling the
metacognitive thinking associated with the problem-solving process. Hence, this was a cognitive apprenticeship environment with scaffolding designed to support the learner in developing metacognitive skills.

**Experimental Design**

The general purpose of the research was to investigate the use of CBL in a post-secondary environment at the University of Cincinnati in the College of Engineering and Applied Science. A research study on the teaching of a fundamental engineering course and the impact on the learning experience were carried out.

Research was conducted in the fall of 2013 and was approximately 15 weeks/4 months in duration. The undergraduate students auto-enrolled in sections of the Basic Electric Circuits (BEC) course. One section was taught in a lecture-style format and the other section was taught in a CBL format. Both sections were taught using the same curriculum based on expected learning outcomes developed by the curriculum committee.

The first four weeks of section 1 were taught using a traditional lecture-style format, the same as section 2. The first four weeks were used to give students the basic information needed throughout the course. Section 2 was taught throughout based on the already-existing lecture teaching methodology used in the College of Engineering and Applied Science.

**Justifications of the Methods**

A mixed method (qualitative and quantitative measures) was employed in this study. Triangulation of data was be used to interpret the data. This method provides a complete picture of the research problem. Mixed methods research provides strengths that offset the weaknesses of both quantitative and qualitative research (Jick, 1979).
The Qualitative Approach

Merriam (1998) characterizes qualitative research as an umbrella concept covering several forms of inquiry that help to explain the meaning of social phenomena with as little disruption of the natural setting as possible, and in which the focus of the study is on interpretation and meaning.

The current study focused on one course in the College of Engineering and Applied Science at the University of Cincinnati. The advantage of a qualitative research approach is that it provides detailed information on people, programs, or events in a natural context (Creswell, 1998; Yin, 1994). Qualitative research is also used to identify and describe the complex interactions and interrelationships among students and teachers in a section.

The Quantitative Approach

This study is classified as an exploration of consequences experimental study. In this study, researchers tested the influence of the CBL classroom experience on the student experience and performance compared to the traditional lecture-style classroom experience on student experience and performance. Two groups were involved in the study: an experimental group and a control group. Data was collected from scores on exams and quizzes to assess the relationship between CBL and student performance and experience.

Framework of Data Collection

School Setting

The University of Cincinnati is a public, urban university. It is primarily a commuter campus with over 42,000 matriculated students. The college offers 308 academic programs and has a student-to-teacher ratio of 15:1. The University of Cincinnati has 3,487 undergraduate students in the College of
Engineering and Applied Science (UC Fact Book, 2011). Of the 3,487 students, 516 are female, making up 14.7 percent of the college. Breaking down the number of underrepresented minorities enrolled in the College of Engineering and Applied Science, 4 (0.011 percent) students are American Indian or Alaska Native, of whom 1 (0.028 percent) is female; 121 (3.47 percent) are African American, of whom 31 (0.889 percent) are female; and 63 (1.81 percent) are Hispanic/Latino, of whom 7 (0.201 percent) are female.

**Students**

There were a total of 53 students enrolled in the BEC course. Students who enrolled in the BEC course were STEM students majoring in Chemical (CHE), Biomedical (BME) and Aerospace Engineering (AE), and one student majoring in Biology (BIOL-B). Academic experience ranged from 2nd to 5th year students, with a total of 13 female students and 40 male students. The demographic breakdown is given in Tables 6 and 7, below.

Students auto-enrolled in the BEC Course. This course is mandatory for engineering undergraduates.

<table>
<thead>
<tr>
<th>Table 6: BEC Course Gender Breakdown</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Female</strong></td>
</tr>
<tr>
<td>AE</td>
</tr>
<tr>
<td>BIOL-B</td>
</tr>
<tr>
<td>BME</td>
</tr>
<tr>
<td>CHE</td>
</tr>
<tr>
<td>Grand Total</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 7: BEC Course Class Breakdown</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Freshman</strong></td>
</tr>
<tr>
<td>AE</td>
</tr>
<tr>
<td>BIOL-B</td>
</tr>
<tr>
<td>BME</td>
</tr>
<tr>
<td>CHE</td>
</tr>
<tr>
<td>Grand Total</td>
</tr>
</tbody>
</table>
**Instructional Design**

One section of the class was taught in a lecture-style classroom format and the other section was taught with a mix of lecture-style and CBL-style format (see Appendix for BEC Course Syllabi). Teachers were split into blocks to cover content in units.

**Data Collection Procedure**

The analysis reported herein focused on two groups of students from the BEC course section 1 or section 2. Altogether, 53 students participated in this study. The content from four exams, five exit tickets, four lecture surveys, four CBL surveys, and a student satisfaction survey contributed by the students were analyzed and compared on a group basis.

**Data Sources**

**Exams**

All students took common pre-tests, common exams, and a common final. Each exam was scored and compared to assess the performance of a lecture-style format and a lecture-plus-CBL-style format.

**Lecture Survey**

Surveys were used to collect information to describe some aspects or characteristics of the graduate students teaching the course, as well as the students taking the class. Elements assessed for the students included topic, lecturer, presentation, content, and overall satisfaction. The survey also contained two open-ended questions that asked the two best things about the unit and the two worst things about the unit.
Student Satisfaction Survey

At the conclusion of the semester, each student completed the Student Satisfaction Survey (see Appendix for Student Satisfaction Survey). This survey was designed to assess the classroom experience. The survey was given at the conclusion of the semester after final exams. Each survey was anonymous and did not count toward the grade for the course.

Results

Analysis of Performance

Performance was analyzed based on exam scores. All exams administered contained a maximum of 34 points. Each section took a common exam. The descriptive statistics for student performance on these exams are given in Tables 8 and 9, below

| Table 8: Descriptive Statistics for Section 1, the CBL-Format Course |
|---------------------|---------|--------|--------|
|                     | Exam 1  | Exam 2 | Exam 3 |
| Mean                | 27.77   | 26.59  | 24.67  |
| Median              | 29      | 28     | 26     |
| Standard Deviation  | 4.09    | 4.10   | 6.78   |
| Maximum             | 33      | 30     | 32     |
| Minimum             | 16      | 16     | 0      |

| Table 9: Descriptive Statistics for Section 2, the Lecture-Format Course |
|---------------------|---------|--------|--------|
|                     | Exam 1  | Exam 2 | Exam 3 |
| Mean                | 27.28   | 25.08  | 24.68  |
| Median              | 27      | 26     | 30     |
| Standard Deviation  | 4.37    | 5.37   | 10.93  |
| Maximum             | 33      | 31     | 33     |
| Minimum             | 20      | 10     | 0      |

In the CBL-format course, the mean score for Exam #1 was higher than that for Exams #2 and #3. The standard deviations indicated that the exam scores were not widely dispersed amongst the mean
for all three exams. Section 1 of the BEC followed a normal distribution; approximately 68 percent of the students could be expected to fall in the range of scores between minus one standard deviation below the mean and plus one standard deviation above the mean, and approximately 95 percent of the students could be expected to fall in the range of scores between minus two standard deviations below the mean and plus two standard deviations above the mean.

In the lecture-format course, the mean for Exam #1 was higher than that for Exams #2 and #3. The standard deviations indicated that the exam scores were widely dispersed amongst the mean. The results from section 1 and section 2 were evaluated using a two-way Analysis of Variance. The p-value for section1/section 2 was greater than alpha (0.151 > 0.05), so researchers could not reject the null hypothesis that the means would be the same. The p-value for exams was greater than alpha (0.07 > 0.05), so the null hypothesis held as well (means were the same).

The results of a t-Test for overall experience scores in the BEC course are given in Table 10, below.

<table>
<thead>
<tr>
<th>Table 10: t-Test for Overall Experience Scores in BEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Section</td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td>4.38</td>
</tr>
<tr>
<td>Variance</td>
</tr>
<tr>
<td>t Stat</td>
</tr>
<tr>
<td>P (T&lt;=t) – one tail</td>
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<tr>
<td>t Critical one tail</td>
</tr>
<tr>
<td>P (T&lt;=t) – two tail</td>
</tr>
<tr>
<td>t Critical two tail</td>
</tr>
</tbody>
</table>

The mean student experience score for section 1 (the CBL format course) was 4.38, which was slightly higher for student overall experience than for section 2 (the lecture format course). The score in section 2 was 4.17. The difference between the means is not statistically significant.
Analysis of Experience

Students’ experiences were analyzed through the surveys. Students were asked two open-ended questions to rate their lecture experience. Question 1 asked students to write two of the best features of the classroom sessions. In the CBL section, six themes emerged from responses. These results are given in Table 11, below.

Table 11: Emerging Themes From “Two Best Things” Question on Lecture Evaluations for CBL Classroom

<table>
<thead>
<tr>
<th>Rank</th>
<th>Theme</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Communication</td>
</tr>
<tr>
<td>2</td>
<td>Example Problems</td>
</tr>
<tr>
<td>3</td>
<td>Enthusiasm</td>
</tr>
<tr>
<td>4</td>
<td>Care for Students</td>
</tr>
<tr>
<td>5</td>
<td>Interaction</td>
</tr>
<tr>
<td>6</td>
<td>Organization</td>
</tr>
</tbody>
</table>

Students assessed overall performance, saying instructors communicated well and made information easy to understand. Many students wrote comments such as "good teacher" and "able to teach.” The second emerging theme was an appreciation of example problems. Students said the teachers were excited about the material. The students also noted that they felt more engaged in the coursework. Students stated that the fellows cared for them and their learning. Some students gave examples stating the fellows would do practice problems and ask for questions while working on a problem.

Question 2 asked students to write two of the worst features of the classroom sessions. In the CBL section, three themes emerged from responses. These results are given in Table 12.
Table 12: Emerging Themes from “Two Worst Things” Question on Lecture Evaluation for CBL Classroom

<table>
<thead>
<tr>
<th>Rank</th>
<th>Theme</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Exam Preparation</td>
</tr>
<tr>
<td>2</td>
<td>Presentation</td>
</tr>
<tr>
<td>3</td>
<td>Pace</td>
</tr>
</tbody>
</table>

Students responded that they only wanted to review practice exams and work on what would be on the test. Over 92 percent of survey respondents said they only wanted lectures that went over exam material. Students also felt the presentation skills could be improved. Students said things like "don’t talk to the board" or "write larger.” The third theme was the pace of the class.

In the lecture-style section, three major themes emerged regarding what students liked the best. These results are given in Table 13, below. Students responded that the enjoyed how the lectures were organized because they came directly out of the book. The second theme that students indicated was the best, were the formative assessment techniques the graduate instructors employed. The students felt like it was good technique for the teachers to ensure the students understood course material. The third theme indicated by the students as the best part of the course was example problems. The students liked reviewing and practicing example problems because it helped them prepare for their exams.

Table 13: Emerging Themes from “Two Best Things” Question on Lecture Evaluations for Section 2

<table>
<thead>
<tr>
<th>Rank</th>
<th>Theme</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Organization</td>
</tr>
<tr>
<td>2</td>
<td>Formative Assessment</td>
</tr>
<tr>
<td>3</td>
<td>Exam Preparation</td>
</tr>
</tbody>
</table>

In the lecture section three major themes emerged regarding what students liked the least. These results are given in Table 14.
Table 14: Emerging Themes from "Two Worst Things" Question on Lecture Evaluations for Section 2

<table>
<thead>
<tr>
<th>Rank</th>
<th>Theme</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Presentation</td>
</tr>
<tr>
<td>2</td>
<td>Exam Preparation</td>
</tr>
<tr>
<td>3</td>
<td>Interaction</td>
</tr>
</tbody>
</table>

Three themes emerged for the lecture style section when discussing the two worst things about the course. The first theme to arise was presentation. Students gave critiques on how to present the lectures more effectively, i.e., do not talk to the board and use PowerPoint if handwriting is poor. The students’ second theme was exam preparation. Students responded they only wanted to review practice exams and work on what would be on the test. Over 89 percent of survey respondents said that they only wanted lectures that went over exam material. The third theme was interaction. Students’ felt they would have enjoyed the lectures more if they would be able to engage in deeper discussion about material being covered.

**Discussion**

To examine research question number #1 ("Does using CBL in STEM classrooms improve student performance?"), student performance was compared on Exams #1, #2 and #3 for both sections. Students enrolled in sections 1 and 2 of the BEC course were both taught using lecture-style pedagogy for the first four weeks, followed by Exam #1. The results of Exam #1 showed that students performed as expected and performed equally in both sections, with a mean of 27.77± 4.09 and 27.28± 4.37. For the following weeks, section 1 was taught using the CBL method and section 2 continued with the traditional lecture method. The results showed that the students in the CBL method section (section 1) had a slightly higher mean t than the students in the lecture method section (section 2); however, the difference was not statistically significant. Examining the standard deviation of each exam, scores were more widely dispersed about the mean in section 2, the lecture- method section, compared to that of
section 1, the CBL-method section. That means that in section 2, there were many students throughout the entire range of performance. The lecture pedagogy showed a separation of students in ability from students who excelled at understanding the content to students who struggled with understanding the content. This separation implied that the lecture-style format does not help students who are struggling to understand and improve in the course. However, in section 1, there was less of a separation in student performance. In section 2, all students scored around the average, and this could be attributed to the CBL teaching strategy being accessible to different types of learning.

To address research question #2 (“Does using CBL in STEM classrooms improve student experience?”), researchers looked at overall satisfaction scores submitted by students at the end of the semester. Although section 1 (CBL) had a slightly higher average score than section 2 (lecture) in student experiences, the differences were not statistically significant. This finding suggests that students’ experience was not heavily influenced by the pedagogy used in the classroom. One reason that the overall satisfaction score could be different is due to the course breakdown. Students may not have enjoyed the lecture style teaching that was used at the beginning of the course. After the lecture experience in the first four weeks, students may have developed negative feelings or determined that the course was typical to what they had seen throughout their time in the college. The lecture in the first four weeks may have set a negative tone that CBL could not reverse. Even though the overall satisfaction scores were not statistically different, when analyzing the qualitative responses, themes emerged that showed difference between the two sections.

The top two themes from the CBL section were “communication” and “an appreciation of example problems.” The theme of communication could be due to the role of the professor in the classroom. Teachers in a CBL environment provide information to students as they develop questions and need more information. This could show that CBL helps students feel comfortable asking questions
and engaging in dialogue with their professors. This finding is consistent with what has been seen in literature with PBL pedagogy (Barron and Darling-Hammond, 2008). Students also indicated they were happy to go through the material they just learned by walking through example problems in class as a group. In Chapter 1 of this document, the trend amongst secondary school students’ to learn mainly for the purposes of passing midterm examinations and standardized tests was discussed. Based upon the surveys, it appears that this trend largely continues with college students as well. On both the CBL and lecture-based course format surveys, respondents stated the most critical item that they wanted to receive from the course was test preparation. In the CBL survey, 92 percent of the students responded that the biggest need was in the area of test preparation and/or working through practice tests. Similarly, in the lecture-based survey, 89 percent of the students also responded that they wanted more test preparation and/or working through practice tests. This shows that students’ main concern is exams, their measure of success. This is further evidence that students have been conditioned from primary school to view exam grades as a primary measure of success in learning. In order to change that paradigm, students will have to have a new goal. This means the assessment techniques used in the classroom need to change from exams to something that tests learning.

Themes such as “interactive” and “caring” emerged for students in the CBL environment when asked what they liked the best. This suggests a student-centered classroom helps with student-teacher interaction. This also suggests that students value interaction with the teacher in the classroom. These findings are consistent with what has been seen in literature (Barron and Darling-Hammond, 2008). The lack of concern for students is a factor that has been identified in literature as a reason why students leave the colleges of engineering and applied sciences (Astin and Astin, 1992; Astin, 1993; Buyer and Connolly, 2006; McGourty et al., 1999). Students noted that CBL made them feel as if the teacher cared for them and their learning. This suggests that CBL has the potential to reduce negative experiences for students by creating a caring environment. Along with caring, students felt that the teachers were
enthusiastic about what they were teaching. Teacher excitement creates a positive learning environment. Studies have shown that a positive learning environment has a positive effect on student learning (Cohen, 2006). A positive learning environment is known to have a direct influence on motivational factors, such as student commitment to school, learning motivation, and student satisfaction, and perhaps a more indirect influence on student achievement (Cohen, 2006).

Students in the CBL section indicated that the items they liked the least were exam preparation, presentation skills, and pace. Students responded that they only wanted to review practice exams and work on what would be on the test. Over 92 percent of survey respondents said they only wanted lectures that went over exam material. Students also felt presentation skills could be improved. This theme could be attributed to the lack of teaching experience the fellows had before the fall semester. The third theme was the pace of the class. Students felt rushed and wanted more time with their projects. This theme has emerged in literature about the use of student-centered pedagogy, like PBL. Studies have indicated that PBL takes more time than a traditional lecture (Dahlgren, 2002). Considering the similarities between the two pedagogies, CBL is expected to follow the same trend.

In the lecture-style section, three major themes emerged regarding what students liked the most: organization, formative assessment, and exam preparation. Students stated they enjoyed how they could follow along in the lectures with the book. The lectures consisted of writing the information from the book on the white board. This theme is consistent with what has been found in literature. College students spend fewer than 3 hours reading textbook material, and they feel the instructor is responsible for reviewing material during class time as well as telling them what is important in the reading (Clump, Bauer and Bradley, 2004). This theme is also connected to the way students view success. Most students only care about information on exams because that is what they have learned is the measure of success. This pattern can be seen in research where reading percentages ranged from 21.21 percent
to only 42.96 percent before class and from 60.83 percent to 91.20 percent before exams (Clump, Bauer and Bradley, 2004). Another element that students noted was the lecturers asking if they all understood what was covered so far. The constant checking with students from the lecturer made the students feel as if they could ask questions and get clarity on information they did not previously understand. The third theme was exam preparation. Just as the CBL section expressed, students liked to review practice problems. They felt that going through the sample problems were helpful for exam preparation. This theme also ties into how students view success. The elements of the lectures they enjoyed the most were elements they felt would better prepare them to do well on exams as opposed to learning the material.

Students also noted elements of the lecture they like the least: presentation, interaction, and exam preparation. Presentation was approached in regards to how teachers presented the material. Students indicated things like “don’t talk to the board” and “write bigger.” These comments can be attributed to the lack of teaching experience the untrained graduate instructors had before teaching the fall semester. Students also indicated they would have liked a class that was more interactive. Students felt that deeper discussions about material would have been helpful. This correlates to the theme expressed by students in the CBL section, where CBL students noted that interaction was one of the best features of the class. This indicates that students value classroom interaction. Just as in the CBL section, students in the lecture section indicated they would have preferred to do more practice problems and practice exams. Over 89 percent of survey respondents said they only wanted lectures that went over exam material. This shows that students’ main concern is exams, their measure of success. This is further evidence that students have been conditioned from primary school to view exam grades as a measure of success.
Suggestions for Future Research and Limitations

Due to the dispersion about the mean in exam scores as well as the responses received from the undergraduate students discussed in this study, stakeholders should investigate using CBL in engineering courses. Although the differences in exam scores are not statistically significant, the dispersion around the mean suggest that students in a CBL course would benefit from the pedagogy (Brown 1988, p. 69) Due to the scarcity of literature on CBL in higher education it is important to develop a framework to address the pedagogy’s benefits on undergraduate students.

Limitations

This section of the paper is intended to describe those characteristics that define the parameters in the application or interpretation of the study’s results by elaborating on the generalizability and utility of the findings. In this study undergraduate students were studied for one semester. Studying students in a CBL environment over time would help to understand if CBL pedagogy changes the student thought and problem solving processes. Studying the students for one semester gave a snapshot view of how they think and how CBL can add to the learning process. However, a longitudinal study with students exposed to CBL on a more frequent basis would show how CBL changes learning and the thought process.

The atypical nature of the course could have contributed to student performance as well as student experience. Most college courses are taught by one professor and thus students have the opportunity to understand one professor’s teaching methodology and way of thinking. When the course has more than one professor, students may have a difficult time adjusting to each and both of the professors. It should be noted that the first four weeks of both sections were taught using the
lecture method. Research has shown that lectures are inefficient in promotion of thought (Bligh, 1998). The use of lectures in the beginning of the course may have negatively affected the students.

Another limitation of the study was the separation of the laboratory from the main course classroom period. Students conducted experiments in the laboratory that followed at separate syllabus. If the laboratory hour was connected to the course work, CBL could have had a stronger effect on students. The laboratory hour could have also skewed the results slightly, as students spent time working on experiments to help reinforce what they were learning in lecture; however, the lectures were not coordinated with the laboratory time even though the content was related.

The mode of assessment of student performance was solely based on exams in which students responded to questions with only one specific answer. This does not correlate to CBL pedagogical approaches in which students investigate problems with multiple solutions and develop the rationale to choose the optimal one and defend it (Johnson et al., 2009). The assessment measure used in classrooms must be changed in order for students to focus on learning and not exams (Savery and Duffy, 1995). It was clear from the responses received on the student satisfaction survey that when exams are introduced as part of the course the focus is shifted from course content and material to passing exams. Over 92 percent of survey respondents in the CBL classroom said they only wanted lectures that went over exam material and over 89 percent of survey respondents in the lecture style classroom said they only wanted lectures that went over exam material. This shows that students’ main concern is exams, their measure of success. Removing exams would allow for students to actively engage in the learning process (Savery and Duffy, 1995).

The BEC course selected for the research study included students who were 7.5 percent sophomores, 49 percent pre-juniors and 34 percent juniors. Thus, over 83 percent of the students
appear to have been set in their ways of learning and may not have been open to new approaches, such as CBL pedagogy. This could have skewed some of the responses.

**Threats to External Validity**

It was suggested that a sample could have been chosen from different types of schools with different demographics of students. Different universities may see different results based on the location, size, and type. In addition, universities that follow different curriculum structures may have varying results based on experiences the undergraduates have at that university.

**Role**

In this study, the researcher was an outsider and not a teacher carrying out challenge based learning in the school. It was impossible for the researcher to have access to all information. The whole picture may not have been seen such as opportunities for improvement in the implementation of CBL, the student’s engagement/interaction with the CBL process. These items were assessed using the viewpoint of the instructors/fellows and the students. Monitoring these items as a researcher may have added a third perspective to see the impact of CBL in the classroom. These items were outside the scope of this study but may be a significant in assessing how CBL works in classrooms. It is recommended that the researcher observe and assess each session to validate what the instructors and students report in surveys, focus groups, etc..

**Generalizations**

Every university has its unique features. However, the findings of this study provide a good suggestion for the implementation of CBL as well as an idea of what to expect from students. This study showed that students are more focused on exams than the learning process. This may be due to the format of the exams. The study was bound to keep similar exams as used for the control group section
which typically included single answer problems. If open ended, project based exam questions can be formulated for both sections, then results could have been different. Despite the lack of focus on the process, students enjoyed the learning environment’s interaction. CBL has also shown that students that would traditionally struggle in traditional lecture style teaching methodology may have more opportunities for success in the CBL classroom.

**Conclusions**

In conclusion, CBL is a pedagogical technique that situates learning in complex problem-solving contexts. It provides students with opportunities to consider how the facts they acquire relate to real world problems. CBL offers the potential to help students become reflective and flexible thinkers who can use knowledge acquired to take action. Still, careful research is needed to understand if and how these potentials might be realized. Since students are conditioned to judge their success based on exam performance the impact of CBL could be limited unless the process in which student performance for course grade is re-examined. Students must first understand the importance of what they are learning. The assessment used to measure success must match what is most important to the learning process.
Chapter 3 References


Seymour, E., and Hewitt, N. M. (1994). *Talking about leaving: factors contributing to high attrition rates among science, mathematics and engineering undergraduate majors: final report to the Alfred P. Sloan*
*Foundation on an ethnographic inquiry at seven institutions.* Ethnography and Assessment Research, Bureau of Sociological Research, University of Colorado.

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Chapter 4: Implications

Challenge Based Learning (CBL)

In this dissertation, students who enrolled in the Basic Electric Circuits (BEC) course offered in the fall semester were monitored for performance and experience. The course was comprised of two sections. One section of the class was taught in a lecture style classroom format and the other section was taught with lecture the first 4 weeks of the semester followed by CBL format the remaining 11 weeks. CBL shows promising results for student performance and experience. Students’ performance was compared on three exams for both sections. The results for Exam #1 showed that students performed as expected and performed equally in both sections, with a mean of 27.77± 4.09 and 27.28± 4.37. For the following weeks, section 1 was taught using the CBL method and Section 2 continued with the traditional lecture. The results showed that the students in the CBL method section (section 1) had a slightly higher mean t than the students in the lecture method (section 2). From this study, student performance was not significantly different when comparing the mean score but the variance was smaller in the classroom when compared to the lecture style classroom (see Chapter 3, Table 8 and 9). This implies that students who may traditionally struggle with the course material will benefit from CBL.

CBL also shows no harm to students. There are two main concerns about student centered pedagogy. One is that it takes too long to implement and the format sometimes does not allow for students to cover all the necessary information outlined in the curriculum. This study has shown that students perform equally as well as students in lecture based classroom learning, the same amount of material in the same amount of time.
This dissertation has also shown that the assessment measure used in classrooms must be changed in order for students to focus on learning and not exams. It was clear from the responses received on the student satisfaction survey that when exams are introduced as part of the course the focus is shifted from course content and material to passing exams. Over 92 percent of survey respondents in the CBL classroom said they only wanted lectures that went over exam material and over 89 percent of survey respondents in the lecture style classroom said they only wanted lectures that went over exam material. This shows that students’ main concern is exams, their measure of success. Removing exams would allow for students to actively engage in the learning process.

Currently CBL is primarily used in the K-12 classrooms. CBL is pedagogy that can be used not only in a K-12 environment but also in a post-secondary classroom environment. In CBL students work on challenges that are addressing real world problems (Johnson et al., 2009). Students should be assessed on their process to answer the challenges as opposed to using an exam to assess what they have learned. Assessing their process would emphasize the importance for critical thinking. CBL is particularly important to engineers because it ties content to real world problems that students will see in the field, it places an emphasis on critical thinking, and it exposes them to collaborative learning (Johnson et al., 2009). Many students cannot see the importance of what they are learning and how it is related to engineering which causes them to leave the college (Milem and Astin 1994; Seymour and Hewitt, 1994). CBL connects content to context. Using CBL, students develop the skills to address real world problems and design solutions (Johnson et al., 2009). In a real world setting students are required to work in groups and often times on multidisciplinary teams. CBL places students in groups and requires them to solve and defend the real world solutions as a team (Johnson et al., 2009).

Currently the test structure is the only priority of students, not allowing them to fully engage in the CBL process. In the study conducted in this dissertation, the academic performance of students in
both the lecture and CBL class sections were assessed with exams. Students responded that they only wanted to review practice exams and work on what would be on the test. Assessment should be based on the process students use to solve the challenge and the best solution selected to be presented in the class. A future study should be conducted to gauge learning if the CBL section is conducted with an assessment that is more in line with the CBL pedagogy. This approach is currently being piloted in BME 3020C Sensing and Measurements, for which BME 3071C Basic Electric Circuits, is a prerequisite. In BME 3020C, exams are not used for assessment. Instead, three rubrics have been created that students use to assess their own performance and the performance of their classmates on team-based written project reports, oral presentations, and labs.

**Preparing Future Faculty**

The preparing future faculty program that was developed for this study led to positive improvement on teaching self-efficacy. Two groups of graduate students were compared: trained CEEMS fellows and untrained graduate instructors.

The summer experience included the trained CEEMS fellows teaching for one week in an undergraduate classroom. The results from this experience impacted the CEEMS fellows’ Teaching Engineering Self-Efficacy Survey (TESS) scores. Three CEEMS fellows had a TESS mean score increase and one had a TESS mean score decrease. After the fall semester, three of the fellows’ TESS means scores increased whereas one CEEMS fellow’s TESS score decreased. The increase in self-efficacy shows the impact of educational training and teaching experience. Since the majority of the CEEMS fellows’ TESS score increased, it is concluded that the program can serve as a good foundation for what is needed in preparing future faculty programs.
Each untrained graduate instructor had a teaching experience of three weeks with no educational training and 100 percent of the graduate instructors had a mean TESS score decrease. The difference in the self-efficacy scores shows the longer the teaching experience, the more negative the influence on the graduate student self-efficacy, if not reinforced with educational training and/or shadowing experience. The decrease also shows that graduate instructors have an inflated sense of teaching self-efficacy. That means they are overly confident in their teaching skills until they have a teaching experience. The realization of true ability from new faculty members is a factor in success. If a new faculty member thinks they can teach, but realize they have opportunities for improvement they originally did not realize, the faculty member may get frustrated. Frustration has been linked to poor performance (Waterhouse and Child, 1953). A poor teaching performance leads to negative classroom experience for undergraduates (Seymour and Hewitt, 1994). This cycle may be part of the high attrition rates in the college of engineering.

CEEMS fellows also noted the importance of the fall shadowing experience in K-12 classrooms. This experience allowed them to develop skills they could not otherwise acquire. During the fall semester, fellows spent 10 - 20 hours a week in K-12 classrooms, as well as participated in the fall teaching of the BEC course. Throughout the reflections, two themes emerged from the group: Understanding students and teaching style. Understanding students is a unique theme for participants of the CEEMS program. This theme has not been identified as a learning outcome in other PFF programs. Research has shown that understanding students in schools requires strong, continuous relationships between teachers and students so they learn to “read” each other over time (Hargreaves, 2000). Teachers’ understanding of the student impacts student experience (Hargreaves, 2000). The second theme of teaching style is supported by literature on faculty development programs. An enhanced teaching skill was a theme that fellows from the GK-12 program had also developed (Gamse et al., 2010).
This was an expected theme, due to CEEMS fellows spending time in K-12 environments similar to those of the GK-12 fellowship program.

The results of this study show that educational training is important to improving the learning environment for undergraduate students. After the conclusion of the study, three of the CEEMS fellows’ TESS means scores increased whereas one CEEMS fellow’s TESS score decreased. The increase in self-efficacy shows the impact of educational training and teaching experience. Since the majority of the CEEMS fellows’ TESS score increases, it is concluded that the program can serve as a good foundation for what is needed in preparing future faculty programs. Guskey and Passaro (1994) found that teachers with a high self-efficacy can motivate students in learning even when a student is disinterested (Guskey and Passaro, 1994). Research has found positive correlations between teacher’s self-efficacy and student performance and achievement (Anderson, Greene, and Loewen, 1988; Ashton and Webb, 1986; Moore and Esselman, 1994; Midgley, Feldlaufer, and Eccles, 1989; Ross, Hogaboam-Gray, and Hannay, 2001).

Training future faculty using techniques that have been developed through this research has the potential to change the culture in the colleges of engineering and applied sciences. This study also shows the potential to collaborate with the colleges of education and psychology to understand the teaching preparation programs that have already developed to improve upon the training that was used in the study. This research highlights the importance of educational training for graduate students in STEM fields. With over 60 percent of STEM graduate students pursuing careers in academia, it is important they are prepared for the roles and responsibilities of a faculty member. Traditionally, STEM graduate students have little to no teaching experience so an education training program should be mandatory to help develop future faculty that will have a direct impact on the success of future undergraduate students. It is the responsibility of the University, college, degree program and research
advisor to ensure that each graduate student is adequately prepared for core job responsibilities after graduation. This research gave a foundation of what should be included in that training to emphasize the importance of teaching. A future study should be conducted to determine which element of the training is the most beneficial to the future faculty training program. At a minimum all graduate students should participate in the summer educational training, shadow trained teachers, and teach an undergraduate course.

**Impact of this Research**

Engineering education is a field that works with educational institutions and industry to improve education, promote faculty development, and to develop ways to increase the participation and success of underrepresented groups in the engineering profession. While intervention programs help to narrow educational gaps, improvements have been incremental. Research has found that engineering programs have a higher attrition rate than any other program, with attrition rates exceeding 60 percent (Besterfield-Sacre, Atman and Shuman, 1997) and underrepresented (i.e., all women and ethnic men) students underperforming and dropping out of STEM programs at much higher rates (White, Altschud and Lee, 2008). With these trends, it is important for the college to use engineering education scholarly works and research to improve the environment and help with the increased demand of technical professionals.
Chapter 4 References:


Appendix
### Engineering Pedagogical Content Knowledge Self-efficacy

1. I can explain the different aspects of the engineering design process.  
2. I can discuss how given criteria affect the outcome of an engineering design project.  
3. I can explain engineering concepts well enough to be effective in teaching engineering.  
4. I can assess my students' engineering design products.  
5. I know how to teach engineering concepts effectively.  
6. I can teach engineering as well as I do most subjects.  
7. I can craft good questions about engineering for my students.  
8. I can employ engineering activities in my classroom effectively.  
9. I can discuss how engineering is connected to my daily life.  
10. I can spend the time necessary to plan engineering lessons for my class.  
11. I can explain the ways that engineering is used in the world.  
12. I can describe the process of engineering design.  
13. I can select appropriate materials for engineering activities.  
14. I can create engineering activities at the appropriate level for my students.  
15. I can stay current in my knowledge of engineering.  
16. I can recognize and appreciate the engineering concepts in all subject areas.  
17. I can guide my students' solution development with the engineering design process.

### Motivational Self-efficacy

18. I can motivate students who show low interest in learning engineering.  
19. I can increase students' interest in learning engineering.  
20. Through engineering activities, I can make students enjoy the class more.

### Instructional Self-efficacy

21. I can use a variety of assessment strategies for teaching engineering.  
22. I can adequately assign my students to work at group activities like engineering design.  
23. I can plan engineering lessons based on each student's learning level.  
24. I can gauge student comprehension of the engineering materials that I have taught.  
25. I can help my students apply their engineering knowledge to real world situations.

### Engagement Self-efficacy

26. I can promote a positive attitude toward engineering learning in my students.  
27. I can encourage my students to think creatively during engineering activities and lessons.  
28. I can encourage my students to think critically when practicing engineering.  
29. I can encourage my students to interact with each other when participating in engineering activities.

### Disciplinary Self-efficacy

30. I can control disruptive behavior in my classroom during engineering activities.  
31. I can keep a few problem students from ruining an entire engineering lesson.  
32. I can redirect defiant students during engineering lessons.  
33. I can calm a student who is disruptive or noisy during engineering activities.  
34. I can get through to students with behavior problems while teaching engineering.  
35. I can establish a classroom management system for engineering activities.

### Outcome Expectancy

36. I am generally responsible for my students' achievements in engineering.  
37. When my students do better than usual in engineering, it is often because I exerted a little extra effort.  
38. My effectiveness in engineering teaching can influence the achievement of students with low motivation.  
39. When a student gets a better grade in engineering than he/she usually gets, it is often because I found better ways of teaching that student.  
40. If I increase my effort in engineering teaching, I see significant change in students' engineering achievement.  
41. I am responsible for my students' competence in engineering.
**Cincinnati Engineering Enhanced Math and Science Fellows**

Fall Semester. Credit Hours: 3; Meeting time: Tuesday and Thursday 10:00 – 11:30; Meeting Place: 840 Old Chemistry Building; Grading:

Last updated: 05/08/13

**Description.** The Cincinnati Engineering Enhanced Mathematics and Science Program (CEEMS) is led by the University of Cincinnati in partnership with 14 school districts. CEEMS fellows will learn about the CEEMS programs and how they will assist with the mission of the CEEMS program. Students discuss effective teaching methods, with a focus on teaching K-12 math and science. Topics include instructional approaches and best teaching practices in teaching middle and high school students, creating course content, defining learning outcomes, conducting effective assessments, polishing presentation skills, encouraging active learning, managing student projects and teams, understanding the standards used in school systems, and conducting research in engineering education. CEEMS fellows will learn how to incorporate all topics to create a challenge based learning classroom the incorporates engineering to in turn help K-12 math and science educators better implement and teach engineering design. Each student creates a syllabus and related materials for an undergraduate course they will teach in the fall that can be included in a Teaching Portfolio. Information on the CEEMS program is available at [http://ceas.uc.edu/special_programs/ceems/CEEMS_Home.html](http://ceas.uc.edu/special_programs/ceems/CEEMS_Home.html)

**Learning Outcomes.** By the end of the course, each student will:

1. Prepare a paper on scientifically documented best teaching practices in teaching math and science middle and high school students and how challenge-based learning and engineering pedagogical approaches are similar and different than the other.


4. Develop a Unit with K-12 educators that incorporate challenge based learning, engineering design process, and assessment.

5. Develop a syllabus, with learning outcomes that follow challenge based learning for an undergraduate course in engineering.

6. Prepare, present, and receive feedback on one lecture

7. Develop sample materials for course assessment.

8. Document plans for related activities such as interacting with students, encouraging active learning, and managing student projects and teams.

9. Understand the principles of engineering education research and how results in the field can be applied to improve teaching and learning.

**Instructor:** This will be a team-taught course by a variety of instructors that will present on topics listed above.


**Supplemental Texts:**


Additional references:

1—CEEMS fellows guidelines: provided by Julie Steimle

Work to Be Completed:

1. Weekly readings and other assignments.
2. Family Science Academy Competition (held in July)
3. Development of a Unit as expected from CEEMS teachers.
4. Development of syllabus on course to be taught in the fall.
5. Development of a Teaching Portfolio.
6. Journal with short summaries of the most valuable ideas, in your opinion, from each week's discussion.
7. Completing all project related tracking and assessment activities planned for the fellows in a timely manner.

Grading:

70% - Homework
20% - Journal/Reflections
10% - Course Essay

ADD GRADING SCALE

Schedule (subject to change):

NOTES:

1. Reading the assigned sections in the text BEFORE coming to class is a requirement.
2. Additional assignments will be added; check each week for updates,
3. Students are expected to attend all class sessions listed, to actively participate, and to complete assignments in a timely manner. If it is necessary for you to miss any class due to extenuating (extreme) circumstances, you must contact the instructor(s) prior to your absence to make alternative arrangements for completion of class activities and assignments. Failure to do so will negatively affect your grade for the course
4. Remember to keep a journal containing your notes on each week's discussion and your own comments on what was discussed. We will discuss these journal entries throughout the semester.

WEEK 1:

Pre-Reading:
1. US K-12 Education System – source TBA
2. NGSS Reference Document- source TBA

05/28:

1. Seminar requirements
2. Teaching Survey
3. State Standards Overview
4. NGSS Overview
Reading: Common Core Reference Document, NAE - Executive Summary.

Assignment:
1. Write a two-page paper (single line spaced, Arial 10 font size, 1 inch margins, 6 pt spacing between paragraphs) on how NGSS are connected to engineering and the engineering design process.
2. Journal/Reflection of information learned in the week.

05/30:
1. Common Core Overview

Reading: K-12 pedagogy – TBA, Chapter NAE – Chapter 1
Assignment:
1. Write a two-page paper (single line spaced, Arial 10 font size, 1 inch margins, 6 pt spacing between paragraphs) on how Common Core Standards are connected to engineering and the engineering design process.
2. Journal/Reflection of information learned in the week.

WEEK 2:

06/04:
1. K-12 educations system overview
2. K-12 education pedagogy
3. Chapter 1 Discussion

Reading: Chapter NAE – Chapter 2
Assignment:
1. Find 2 papers about K-12 pedagogy and prepare 20-minute presentation, followed by 5-10 minute question and answer session.

6/06:
1. K-12 education pedagogy continued
2. K – 12 education pedagogy Paper Review (led by fellows)
3. Misconception/ Perceptions
4. Chapter 2 Discussion

Reading: CBL Reference Document, Start NAE- Chapter 3
Assignment:
1. Write a two page paper: Can perceptions become stereotyped and what impact can that change have on learning in the classroom?
2. Journal/Reflection of information learned in the week.

WEEK 3:

06/11:
1. Introduction to CEEMS
2. Overall Unit Template Walk Through
3. Implementation of CBL Approach and Assessment Instruments Overview
4. CBL Approach Mini Activity
Reading: Chapter NAE – continue Chapter 3,
Assignment:
1. Work in groups of two to prepare CBL Approach Implementation for a Unit

6/13:
1. CBL Continued
2. Groups implementation of CBL exercise

Reading: EDP Reference Document, Finish NAE- Chapter 3
Assignment: TBD
1. Write a two- page paper on how CBL can be incorporated in (a) a high school math or science class and (b) an undergraduate engineering freshmen class; basic electric circuits compare and contrast the two implementations.
2. 
3. Journal/Reflection of information learned in the week

WEEK 4:

06/18:
1. Implementation of EDP and Assessment Instruments Overview
2. EDP Approach Mini Activity
3. Chapter 3 Discussion – led by the Fellows

Reading: Assessment Document- TBA
Assignment:
1. Write a two-page paper on “comparing and contrasting scientific enquiry process and engineering design process implementation in a classroom (illustrate with examples).

6/20:
1. EDP continued

Reading: Assign review of 2 math and 2 science (one each for middle and high school) units created by last year SIT participants
Assignment:
1. Journal/Reflection of information learned in the week.

WEEK 5:

06/25:
1. Basic Electric Circuits Course Overview
2. Unit Template link to Undergraduate Course

Assignment:
1. Finish creating a unit

6/27:
1. Basic Electric Circuits Unit Creation

Reading: Assign review of 2 science (one each for middle and high school) units created by last year SIT participants.

Assignment:
1. Finish creating a science unit (select either for middle or high school class – if math unit is selected for middle school than the science lesson should be for high school and vice versa).
2. Journal/Reflection of information learned in the week.

WEEK 6:
7/2

1. Family Science Academy Overview
2. How the competitions works (provide examples)

Reading: TBA
Assignment:
1. Develop Assessment to ensure students and parents understand the big idea
2. Journal/Reflection of information learned in the week.

WEEK 7:
7/9

1. Syllabus development

Reading: TBA
Assignment: TBA

7/11 – This Class will meet after coaching session from 2:30 to 3:30 in 609 Old Chem (Whitney Gaskins)

2. Family Science Academy Preparation

Reading: 
Assignment: 

WEEK 8: (Note: This week involves working on two Saturdays)

7/13 (Saturday): Introduction of the Competition at the Family Science Academy

7/20 (Saturday): Hold the Family Science Academy Competition

Assignment:
1. Journal/Reflection of information learned in the week

The following weeks will be dedicated to course revamp for the fall basic electric circuits course:

WEEK 9:
7/23 – Lecture Draft
7/25 – Lecture practice

**WEEK 10:**

7/30 – CBL draft

8/1 – CBL Refinement

**WEEK 11:**

8/6 – Exam Prep/ Exit Tickets

8/8 – Course Overview

**WEEK 12:**

Focus Group – Date TBD

Each week fellows should write a journal/reflection about weekly activities
CEEMS RESOURCE TEAM
JOB DESCRIPTION, RESPONSIBILITIES, AND APPLICATION

Part-time/Independent Contractor: $14,000/year

Overview
Three Resource Teams, each containing three members, will be hired to support the teacher participants attending the Summer Institute for Teachers (SIT). Each Resource Team will be assigned to 6-8 classroom teachers in Year 1 (2012-2013) and 12-16 teachers in Years 2 to 5 (2013-2014 to 2016-2017). The three Resource Teams will directly report to the CEEMS District Coordinator and one UC faculty member from the CEEMS core team. Each team will consist of individuals with the following qualifications: 1) an experienced 7-12 science or math teacher; 2) an engineer or scientist; 3) an educator with expertise in curriculum and/or assessment.

Time Expectations:
- Appointment will be from May 1, 2012 to April, 2013 for Year 1. Renewal of contract for each subsequent year will be considered based on performance.
- Approximately 4-6 hours per week in May and June 2012, prior to the start of the 2012 SIT Program. Collectively the whole Resource Team (9 individuals) will create the video and web resources (details presented later) for the 2012 SIT participants, and make them available through the interactive project website, MSPnet.
- Attendance at the CEEMS Summer Institute, June 18-August 3, 2012 from 10:30 am to noon daily (in addition to some preparation time), where Resource Team members will meet assigned SIT teachers and begin guiding them, as detailed below.
- Approximately 4-6 hours per week during the school year. Resource team members must have enough flexibility in their schedules to be able to observe secondary teachers in their classrooms and meet with teachers at times convenient to them.

Purpose of Resource Team and Responsibilities:
- We borrow the tested Clinical Model from teaching hospitals, where practitioners, clinical professors, and researchers work together to improve services to patients and prepare future practitioners. In our project an experienced Resource Team will take on this role.

- Each secondary teacher (SIT participant) will develop and implement three instructional units as a result of their participation in the CEEMS Summer Institute under the guidance of the assigned Resource Team. During each summer participants will fully develop one classroom unit and develop an implementation plan for that unit and two additional units for the academic year. The assigned Resource Team will review and recommend them for approval to the CEEMS District Coordinator. The classroom units prepared will satisfy the following criteria:
  - The teachers will identify the units aligned to common core standards based on student data that shows an area of need.
  - Each unit will have a pre/post assessment.
  - Video tutorials, one to three minutes in length, will be created for each unit that highlight the lesson’s approach to learning. These will serve as a preview and valuable reference for future users. Resources are available to help teachers develop these tutorials.
  - Videotaped classroom implementations: When the unit is implemented in the teacher’s
classroom, portions of the unit will be videotaped. This serves in the lesson refinement process.

- The Resource Team will work closely with their assigned teachers as they create, teach, review, revise, and share the three units. The teachers, with guidance and training provided by the assigned Resource Team, will integrate the electronic versions of the units into a teacher’s portfolio. This will be used by the Resource Team for review and feedback.

- The Resource Team and each assigned teacher share the responsibility for developing and testing curriculum design (i.e., units), teaching techniques, and student learning modalities. They will follow the process detailed in the flow chart below.

As eluded above, the Resource Team and the assigned teacher team will also focus on unit refinement after implementation using student assessment data to identify why some materials were educationally unsuccessful for some students. Participants will then customize the instructional materials to address these problems for later use in classrooms.

- All teachers’ units will be made available on a dedicated project website using a standard format. Each Resource Team will ensure this format is followed and will approve the each unit documentation produced by the teachers for dissemination and forward it to the District Coordinator for approval.

- Prior to the start of the SIT, during May and June of 2012, the three Resource Teams will collectively work to produce the video and web resources for SIT participants working to obtain the Certificate in Engineering Education or the Masters in Curriculum and Instruction (CI) degree with Engineering Education (MCIEE) specialization. The two Grant Coordinators (will be available to assist in this endeavor on request. The video and web resources will include professionally recorded and short features demonstrating how to set up activities, how to design and implement effective and interdependent cooperative group work, how to use probing questions to elicit student thoughts and encourage critical thinking, and how to assess students based on the inquiry techniques employed. Additional features may include short lectures and published literature on relevant content, and discussions of participants with their Resource Team. These video and web resources will be created by Resource Team members collectively prior to the 2012 SIT Program and expanded during the first academic year (2012-2013) as the project progresses and additional implementation needs get identified, and provided to SIT participants through the interactive project website, MSPnet.
QUALIFICATIONS FOR RESOURCE TEAM MEMBERS

Each team will include three members representing each of the skill sets outlined below.

Secondary Math or Science Teachers

- At least ten years’ experience teaching math or science in grades 7-12
- Experience coaching and collaborating with fellow teachers
- Good written and oral communication skills
- Preferred: Familiarity and experience working with Web 2.0 Tools
- Ideal candidate will have used challenge based or design based learning in his/her classroom or be familiar with problem-based learning or inquiry

Engineers or Scientists

- At least five years’ experience in his/her field
- Familiar with engineering design process; ability to adapt process to math and science teaching
- Good written and oral communication skills
- Proven ability to work as a team and to communicate technical concepts in layperson’s terms
- Preferred: Familiarity and experience working with Web 2.0 Tools

Educator with Specialization in Curriculum and/or Assessment

- Masters’ degree or higher in curriculum and instruction, assessment and evaluation, or similar field
- Experience evaluating, coaching, or providing professional development to teachers
- Experience working in a variety of school districts (urban, suburban, rural)
- Team player with a proven track record of implementing innovative classroom instruction
- Good written and oral communication skills
- Preferred: Familiarity and experience working with Web 2.0 Tools
- Preferred: original teaching licensure/certificate in 7-12 math or science
The Cincinnati Engineering Enhanced Mathematics and Science Program (CEEMS)

Application for Resource Team

Due Date: Friday, March 23

If applying as an independent contractor, please complete the attached UC personal services contract, which can be emailed to julie.steimle@uc.edu or mailed to:

Julie Steimle  
University of Cincinnati  
PO Box 210012  
Cincinnati, OH 45221

Please email professional resume, cover letter, and application to julie.steimle@uc.edu. Please make sure your name, email, and phone number appear on every document and in the body of the email.

Please review the job description and answer the following questions with 150 (+-50) words:

- Describe characteristics of an effective academic coach. How would you exemplify those characteristics in your work with secondary teachers?
- Summarize your understanding and experience of challenge based learning and design based learning.
- To help teachers develop short videos highlighting each instructional unit, what web resources would you suggest? Each resource team will consist of three members.
- Please describe your ability, using examples, to work collaboratively within a team.
**BEC CBL Feedback Form**

I. Please fill in the information in the box below

<table>
<thead>
<tr>
<th>Date:</th>
<th>Grade:</th>
</tr>
</thead>
</table>

II. Please rate the following statements:

<table>
<thead>
<tr>
<th></th>
<th>Excellent</th>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Thinking about the competition you just completed:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>1. Overall, I would rate this unit as…</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td></td>
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<tr>
<td>2. We received guidance from our teacher when we asked for it.</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
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<tr>
<td>3. I learned a lot.</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
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<tr>
<td>4. I helped to solve part of a big problem.</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
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<tr>
<td>5. I worked harder on this unit than I usually do on school work.</td>
<td>O</td>
<td>O</td>
<td>O</td>
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<tr>
<td>6. I felt like I was doing something important.</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
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<td>7. I contributed to the group’s solution.</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
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<tr>
<td>8. Listening to other student’s ideas was an important part of this competition</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
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<tr>
<td>9. I like problems best when they really make me think.</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
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<tr>
<td>10. I feel using challenges is a more effective way to learn than the way we are usually taught.</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
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<tr>
<td>11. How this competition was taught (challenge-based learning approach) enhanced my interest and desire to learn.</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td></td>
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<tr>
<td><strong>Thinking about your future:</strong></td>
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<td>12. This competition made me interested in learning more about Engineering.</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
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<tr>
<td>13. This competition helped me feel more confident about studying math or science.</td>
<td>O</td>
<td>O</td>
<td>O</td>
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<tr>
<td>14. The competition was different from other lessons I’ve had in this program</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
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<tr>
<td>15. I was able to learn how the competition’s content relates to what I see in the real world.</td>
<td>O</td>
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<tr>
<td>16. I learned about the jobs people have that use the knowledge taught in this competition</td>
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</tbody>
</table>

17. In your own words, how was the challenge answered?

18. How did you act like an engineer during this unit? What type of engineer did you act like? (Answer both questions)

19. If you were the teacher, how would you make this unit better so that students learn more?

(Please use the back of this page if you need more space to write.)

Rev. 7/18/13
Lecture Evaluation Form

Please rate the session on the scale indicated. Your comments are most appreciated.

Presenter:  
Date:  
Title:  

<table>
<thead>
<tr>
<th></th>
<th>Unacceptable</th>
<th>Needs work</th>
<th>Good</th>
<th>Excellent</th>
<th>Outstanding</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

The Topic
The choice of topic was relevant to me

The Presenter
Enthusiasm
Interaction with the audience

The Presentation
Information was presented in an organized manner
Used case-based methods; related information to practical problems
Quality of audiovisual aids

The Content
Volume and complexity of the information was appropriate
Related content to current evidence in the literature

What were the two best things about the session?

What two things about the session would you like to see improved?

Other comments:

Overall, how would you rate this event?
BME 3071C Basic Electrical Circuits
& Laboratory
Fall 2013

Course Description: BME 3071 introduces you to simple electric circuits composed of resistors, capacitors, inductors, and operational amplifiers.

The laboratory component of the course introduces students to the tools and techniques for building electric circuits and measuring current and voltages of those circuits.


Instructor: Brian Ervin
PhD grad, Electrical Engg
Office: Office: 487 Rhodes Hall
Email: bervin61@gmail.com
Office hours: TBA

Samuel Miller
PhD grad, Materials Sc. Engg
Office: Office: 487 Rhodes Hall
Email: millers19@gmail.com
Office hours: TBA

Patricia Okafur
PhD grad, Materials Sc. Engg
Office: Office: 607 Rhodes Hall
Email: okaforpa@mail.uc.edu
Office hours: TBA

Ankurman Shrestha
PhD grad, Chemical Engg
Office: Office: 607 Rhodes Hall
Email: shrestan@mail.uc.edu
Office hours: TBA

Class Schedule: Attached below.

Lab Schedule: Attached below.
Teaching style: Lecture and Challenge Based Learning approach.

Challenge Based Learning (CBL): An engaging multidisciplinary approach to teaching and learning that encourages students to leverage the technology they use in their daily lives to solve real world problems.

Students are asked to work in groups and also individually to develop deeper knowledge of the topics being covered, accept and solve challenges. They are also expected to go explore other topics outside of Electrical circuits in order to come up with a viable solution for their challenge in hand.

Learning Objective: Upon completion of this course, you will be able to:
- identify and explain basic electric circuit component
- define electric circuit properties of current, voltage, and power
- mathematically model simple electric circuits
- solve for a circuit’s current, voltage, and power
- implement simple electric circuits to measure current and voltage
- relate the application of electrical circuits in your field of engineering

Attendance Policy: No grades for attendance but is highly recommended.

Grading Policy:

Labs – 12%
CBL Activities - 8%
Exit Tickets and Pre - Test - 10%
3 Exams - 12% each
Part I Final Exam - 17%
Part II Final Exam - 17%

Missed Exam Policy: Students will not be allowed to make up a missed exam unless they have provided an excusable absence, if possible, prior to the exam.
<table>
<thead>
<tr>
<th>Date</th>
<th>Reading Assignment</th>
<th>Topics</th>
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<tbody>
<tr>
<td>August 26th</td>
<td>Common Pre-Test</td>
<td>Course Outline, Introductions</td>
</tr>
<tr>
<td>28</td>
<td>Chapter 1</td>
<td>Chapter 1</td>
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<tr>
<td>30</td>
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<td>Chapter 1 Review</td>
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<tr>
<td>September 4th</td>
<td>Chapter 2</td>
<td>2.1-2.3</td>
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<tr>
<td>6</td>
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<td>2.3-2.6</td>
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<td>9</td>
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<td>2.7-2.8</td>
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<td>11</td>
<td>Chapter 3</td>
<td>3.1-3.3</td>
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<td>13</td>
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<td>3.3-3.5</td>
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<td>16</td>
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<td>3.7-3.7</td>
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<tr>
<td>18</td>
<td>Exam #1</td>
<td>4.1-4.3</td>
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<td>20</td>
<td>Chapter 4</td>
<td>4.4-4.6</td>
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<td>27</td>
<td>Chapter 5</td>
<td>CBL</td>
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<td>October 2nd</td>
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<td>11</td>
<td>Exam #2</td>
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<td>14</td>
<td>Chapter 6, 7 &amp; 8</td>
<td>CBL</td>
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<td>28</td>
<td>Exam #3</td>
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<td>November 1st</td>
<td>Chapter 9 &amp; 10</td>
<td>CBL</td>
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<td>18</td>
<td>Common Final Part #1</td>
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<td>Chapter 11 &amp; 12</td>
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<td>December 2nd</td>
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<tr>
<td>See Finals Week Schedule</td>
<td>Common Final Part #2</td>
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