Changing the Learning Environment in the College of Engineering and Applied Science Using Challenge Based Learning

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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 colleges 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. 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.**

***Index Terms*—challenge based learning, engineering education, learning outcomes, and pedagogy**

I. 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 [32]. It is believed that these changes have negatively affected student learning and motivation, which leads to high dropout rates [24].

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 [43]. 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 [39] resulting from changes in cognition and emotion, a loss of motivation, and a reduction in behavioral agency [22][39]. 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 [37]. Seymour and Hewitt [44] 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 [6][41]. Research has shown the more positive and dynamic the first year experience for engineering freshman the more positive students' attitudes, expectations, and skill level [6].

A. *Theoretical Framework*

1) *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 [23] 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 [7]. 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 [11] 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.

2) 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 [42]. Creating authentic learning environments has the potential to increase student engagement and learning [38]. 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 [34]. 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 [8].

Constructivism contains eight main instructional principles according to Savery and McDuffy [42]:

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.

3) 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 [19]. CBL is a structured model for course content with a foundation in earlier strategies, such as collaborative problem-based learning [19]. 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 [19][29]. 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 [29].

Using CBL, students have the satisfaction that comes from solving both the issue to be tackled and the solution they develop [19]. 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 [29]. In Apple's 2008 study of CBL conducted by Johnson et al. [29], 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 [14]. There are three major components to motivation: activation, persistence, and intensity [14]. 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 [29]. 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 [29][40]. Documentation of the process and a high-quality production of findings further serve to give the process relevance to the world of actual work [29]. A unique feature of CBL is that problems are or can be tied to an idea of global importance [19][29].

In the general CBL approach, as outlined by Apple [2], 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" [2]. 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 [2]. 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 [2]. 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 [2]. 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 [2]. 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 [2]. The CEEMS program integrated the engineering design process into the CBL methodology and have used the flow chart shown in fig. 1 for constructing middle and high school math and science curriculum units. 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.

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.

4) Differences Between CBL and PBL

CBL is based in project/problem-based learning, but there are unique aspects, highlighted by Apple, Inc. [29], 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 [19]. 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 [19]. 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 [29]. Students and teachers publish their solutions to a worldwide audience for an even larger impact [29]. Teachers can assess students by viewing and evaluating their reflections and published work. This step is not emphasized in PBL.

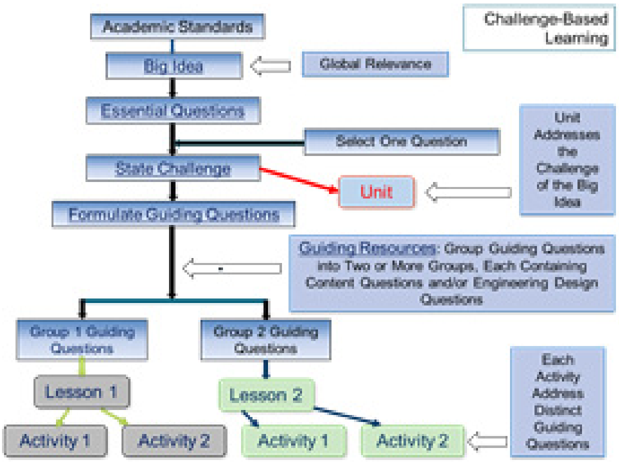

Figure 1. CBL Process Overview (figure from the CEEMS Community of Practice meeting, 11-7-2012)

5) Importance of CBL

Research has shown that student-centered learning approaches are efficacious in improving student learning [27]. 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 [13] [20][31].

II. 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.

CEEMS fellows and graduate instructors taught the different sections of the Basic Electric Circuits (BEC) course. The 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 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

During the summer, the CEEMS fellows enrolled in a 3-credit-hour course in which they learned about the CEEMS program and how they could become effective teachers. During the course 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. 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.

Thus, the Fellows learnt about actual practice of classroom teaching and classroom dynamics (it was like a co-op experience), the theory for which they learnt in the summer course taken prior going to their teacher's classroom. Fellows taught the BEC course as part of their teaching practicum, since they were being prepared to become future engineering faculty as per the design of the program.

A. Framework of Data Collection

1) 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. In the fall of 2013, the University of Cincinnati had 3,487 undergraduate students in the College of Engineering and Applied Science [45]. 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.

2) 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. The demographic breakdown is given in Tables 1 and 2, below.

TABLE I.
BASIC ELECTRIC CIRCUITS COURSE BREAKDOWN

Major	*Female*	*Male*	*Grand Total*
AE		1	1
BIOL		1	1
BME	5	17	22
CHE	8	21	29
Grand Total	13	40	53

TABLE II.
BASIC ELECTRIC CIRCUITS COURSE BREAKDOWN

Major	*Freshman*	*Sophomore*	*Pre Junior*	*Junior*	*Senior*	*Grand Total*
AE				1		1
BIOL	1					1
BME		2	11	8	1	22
CHE		2	15	9	3	29
Grand Total	1	4	26	18	4	53

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

3) 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. Teachers were split into blocks to cover content in units.

B. 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.

C. Data Sources

1) 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.

2) 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.

3) Student Satisfaction Survey

At the conclusion of the semester, each student completed the 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.

III. 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 3 and 4, below.

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 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.

IV. 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 6, below.

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.

TABLE III.
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 IV.
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

TABLE V.
T-TEST FOR OVERALL EXPERIENCE SCORES IN BEC

	Section 1	*Section 2*
Mean	4.38	4.18
Variance	1.55	3.89
t Stat	.759	
P (T<=t) – one tail	.225	
t Critical one tail	1.66	
P (T<=t) – two tail	.449	
t Critical two tail	1.98	

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 7.

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 8, 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.

In the lecture section three major themes emerged regarding what students liked the least. These results are given in Table 9.

TABLE VI.
EMERGING THEMES FROM "TWO BEST THINGS" QUESTION ON LECTURE EVALUATIONS FOR CBL CLASSROOM

Rank	*Theme*
1	Communication
2	Example Problems
3	Enthusiasm
4	Care for Students
5	Interaction
6	Organization

TABLE VII.
EMERGING THEMES FROM "TWO WORST THINGS" QUESTION ON LECTURE EVALUATIONS FOR CBL CLASSROOM

Rank	*Theme*
1	Exam Preparation
2	Presentation
3	Pace

TABLE VIII.
EMERGING THEMES FROM "TWO BEST THINGS" QUESTION ON LECTURE EVALUATIONS FOR LECTURE CLASSROOM

Rank	*Theme*
1	Organization
2	Formative Assessment
3	Exam Preparation

TABLE IX.
EMERGING THEMES FROM "TWO WORST THINGS" QUESTION ON LECTURE EVALUATIONS FOR LECTURE CLASSROOM

Rank	*Theme*
1	Presentation
2	Exam Preparation
3	Interaction

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.

V. 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 [5]. 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 [5]. 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 [3][4][12][35]. 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 [16]. 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 [16].

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 [18]. 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 [15]. 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 [15]. 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.

VI. 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 [9]. 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.

A. 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 [7]. 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 [29]. The assessment measure used in classrooms must be changed in order for students to focus on learning and not exams [42]. 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 [42].

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

VII. 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.

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REFERENCES

[1] Alozie, N., Eklund, J., Rogat, A., and Krajcik, J. (2010). Genetics in the 21st century: the benefits and challenges of incorporating a project-based genetics unit in biology classrooms. The American Biology Teacher, 72(4), 225-230. http://dx.doi.org/10.1525/abt.2010.72.4.5

[2] Apple (2011). Challenge Based Learning Take action and make a difference. Retrieved from: https://www.challengebasedlearning.org/public/admin/docs/CBL_Paper_October_2011.pdf

[3] Astin, A. W. (1993). Forging the Ties That Bind: The Dilemma of the Modern University. College Board Review.

[4] Astin, A. W., and Astin, H. S. (1992). Undergraduate Science Education: The Impact of Different College Environments on the Educational Pipeline in the Sciences. Final Report.

[5] Barron, B., and Darling-Hammond, L. (2008). Teaching for meaningful learning: A review of research on inquiry-based and cooperative learning. Powerful learning: What we know about teaching for understanding, 11-70.

[6] Besterfireld-Sacre, M., Atman, C., and Shuman, L. (1998). Engineering student attitudes assessment. Journal of Engineering Education, April, 133-141. http://dx.doi.org/10.1002/j.2168-9830.1998.tb00333.x

[7] Bligh, D. A. (1998). What's the Use of Lectures?. Intellect books.

[8] Bransford, J. D., and Vye, N. J. (1989). A perspective on cognitive research and its implications for instruction. Toward the thinking curriculum: Current cognitive research, 1.

[9] Brown, J. D. (1988). Understanding research in second language learning: A teacher's guide to statistics and research design. London: Cambridge University Press.

[10] Buck Institute for Education (BIE). (2008). Project-based learning. Retrieved from http://www.bie.org/index.php/site/PBL/pbl_handbook_introduction/#history.

[11] Bui, N. H., and Alearo, M. A. (2011). Statistics anxiety and science attitudes: Age, Gender, and Ethnicity Factors. College Student Journal, 45(3).

[12] Buyer, L. S., and Connolly, C. H. (2006). Identifying the most important factors affecting retention. In Proceedings of the Noel-Levitz National Conference on Student Recruitment, Marketing and Retention.

[13] Carlone, H. B., and Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. Journal of Research in Science Teaching, 44(8), 1187-1218. http://dx.doi.org/10.1002/tea.20237

[14] Cherry, K. (2011). Social Learning Theory an Overview of Bandura's Social learning Theory. The New York Times Company.(online article).

[15] Clump, M. A., Bauer, H., and Bradley, C. (2004). The Extent to which Psychology Students Read Textbooks: A Multiple Class Analysis of Reading across the Psychology Curriculum. Journal of Instructional Psychology, 31(3).

[16] Cohen, J. (2006). Social, emotional, ethical, and academic education: Creating a climate for learning, participation in democracy, and well-being. Harvard Educational Review, 76(2), 201-237.

[17] Creswell, J. (1998). Qualitative inquiry and research design: Choosing among five traditions. Thousand Oaks, CA: Sage.

[18] Dahlgren, M. A., and Dahlgren, L. O. (2002). Portraits of PBL: Students' experiences of the characteristics of problem-based learning in physiotherapy, computer engineering and psychology. Instructional Science, 30(2), 111-127. http://dx.doi.org/10.1023/A:1014819418051

[19] Educause: Seven Things You Should Know About Challenge Based Learning (2012) Retrieved from: http://educause.edu/eli

[20] Fouad, N. A., and Singh, R. (2011). Stemming the tide: Why women leave engineering. Center for the Study of the Workplace report, University of Wisconsin–Milwaukee.

[21] Garran, D. K. (2008). 'Implementing project-based learning to create "authentic" sources: the egyptological evacuation and imperial scrapbook project at the Cape Cod lighthouse charter school.' The History Teacher, 41(3), 379-389.

[22] Gentile, J. R., and Monaco, N. M. (1988). A Learned Helplessness Analysis of Perceived Failure in Mathematics. Focus on Learning Problems in Mathematics, 10(1), 15-28.

[23] Good, T. L. (1979). "Teacher effectiveness in the elementary school." Journal of teacher education, 30(2), 52-64http://dx.doi.org/10.1177/002248717903000220

[24] Harackiewicz, J. M., Barron, K. E., Pintrich, P. R., Elliot, A. J., and Thrash, T. M. (2002). Revision of achievement goal theory: Necessary and illuminating.

[25] Harris, J.H., and Katz, L.G. (2001). Young investigators: The project approach in the early years. In Harel, I. and Papert, S. (Eds.). (1991). Constructionism. Norwood, NJ: Ablex

[26] Hernández-Ramos, P., and De La Paz, S. (2009). Learning History in Middle School by Designing Multimedia in a Project-Based Learning Experience. Journal of Research on Technology in Education, 42(2). http://dx.doi.org/10.1080/15391523.2009.10782545

[27] Hightower, A. M., Delgado, R. C., Lloyd, S. C., Wittenstein, R., Sellers, K., and Swanson, C. B. (2011). Improving Student Learning By Supporting Quality Teaching.

[28] Jick, T. D. (1979). "Mixing qualitative and quantitative methods: Triangulation in action." Administrative Science Quarterly, 602-611. http://dx.doi.org/10.2307/2392366

[29] Johnson, L. F., Smith, R. S ., Smythe, J . T.,and Varon, R. K . (2009). Challenge-Based Learning: An Approach for Our Time. Austin, Texas: The New Media Consortium

[30] Jonassen, D.H., and Grabowski, B.L. (2003). Handbook of individual differences, learning and instruction. Hillsdale, NJ: Lawrence Erlbaum.

[31] Kittleson, J. M., and Southerland, S. A. (2004). The role of discourse in group knowledge construction: A case study of engineering students. Journal of Research in Science Teaching, 41(3), 267-293. http://dx.doi.org/10.1002/tea.20003

[32] Kohn, A. (2000). The case against standardized testing: Raising the scores, ruining the schools. Portsmouth, NH: Heinemann.

[33] Krajcik, J. S., Blumenfeld, P. C., Marx, R. W., and Soloway, E. (1994). "A collaborative model for helping middle grade science teachers learn project-based instruction." The Elementary School Journal, 94(5), 483-497. http://dx.doi.org/10.1086/461779

[34] Marton, F., and Booth, S. A. (1997). Learning and awareness. Psychology Press.

[35] McGourty, J., Besterfield-Sacre, M., Shuman, L. J., and Wolfe, H. (1999, November). Improving academic programs by capitalizing on alumni's perceptions and experiences. In Frontiers in Education Conference, 1999. FIE'99. 29th Annual (Vol. 3, pp. 13A5-9). IEEE.

[36] Merriam, S.B. (1998). Case Study Research in Education: a qualitative approach. London: Jossey-Bass Publisher.

[37] Milem, J. F., and Astin, H. S. (1994). April. Scientists as teachers: A look at their culture, their roles, and their pedagogy. In Annual Meeting of the American Educational Research Association, New Orleans, LA.

[38] Patrick, H., and Yoon, C. (2004). Early adolescents' motivation during science investigation. The Journal of Educational Research, 97(6), 319-328.

[39] Peterson, C. (1993). Learned helplessness. John Wiley and Sons, Inc..

[40] Rillero, P.,and Padget, H. (2012). Supporting Deep Conceptual Learning. T.H.E Journal. Retrieved from: http://online.qmags.com/TJL1112/default.aspx?pg=37andmode=1#pg37andmode1

[41] Rugarcia, A., Felder, R. M., Woods, D. R., and Stice, J. E. (2000). The future of engineering education I. A vision for a new century. Chemical Engineering Education, 34(1), 16-25.

[42] Savery, J. R., and Duffy, T. M. (1995). Problem based learning: An instructional model and its constructivist framework. Educational technology, 35(5), 31-38.

[43] Seligman, M. E. (1975). Helplessness: On depression, development, and death. WH Freeman/Times Books/Henry Holt and Co.

[44] 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.

[45] The University of Cincinnati Fact Book (2012) retrieved from: http://www.uc.edu/provost/offices/institutional_research/student_reports.html

[46] Thomas, J. W. (2000). A review of research on project-based learning.

[47] Yin, R. (1994). Case study research: Design and methods (2nd ed.). Thousand Oaks, CA: Sage

[48] J. Clerk Maxwell, *A Treatise on Electricity and Magnetism*, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.

[49] I. S. Jacobs and C. P. Bean, "Fine particles, thin films and exchange anisotropy," in *Magnetism*, vol. III, G. T. Rado and H. Suhl, Eds. New York: Academic, 1963, pp. 271–350.

[50] K. Elissa, "Title of paper if known," unpublished.

[51] R. Nicole, "Title of paper with only first word capitalized", *J. Name Stand. Abbrev.*, in press.

[52] Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, "Electron spectroscopy studies on magneto-optical media and plastic substrate interface," *IEEE Transl. J. Magn. Japan*, vol. 2, pp. 740–741, August 1987 [Digests 9th Annual Conf. Magnetics Japan, p. 301, 1982]. http://dx.doi.org/10.1109/TJMJ.1987.4549593

[53] M. Young, *The Technical Writer's Handbook*. Mill Valley, CA: University Science, 1989.

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