Integrating the Challenge Based Learning Approach in a Freshman Engineering Foundations Course: Instructor's Perspective

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Introduction

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[1, 4]. Research has shown the more positive and dynamic the first year experience for engineering freshman the more positive students' attitudes, expectations, and skill level[1].

To address the above issue, the Department of Biomedical, Chemical and Environmental Engineering (**BCEE**) in the College of Engineering and Applied Science (**CEAS**) at the University of Cincinnati (**UC**) provided a unique and challenging engineering research and entrepreneurship experience as part of a required first-year *Engineering Foundations (ENED1020)* course in the 2014 Fall Semester at UC. This integrated engineering research-entrepreneurship experience was provided to students enrolled in four sections of ENED 1020. This project was provided as part of a NSF S-STEM grant, entitled, *"Scholarships in Science, Technology, Engineering, and Mathematics (**S-STEM**): Bridging Our Students to Their Future,"* which focuses on engaging and preparing students for research or entrepreneurship careers through four degree tracks offered to BCEE undergraduate students from sophomore to senior year.

This paper provides: (1) a brief overview of the ENED 1020; (2) teaching methodologies and execution of the Grand Challenge Project (**GCP**) in ENED 1020; (3) Instructors perspective of the GCP project (4) concluding remarks summarizing instructors' recommendations

ENED 1020: Engineering Fundamentals

The full details of the ENED 1020 course are outlined by the Project Team in a separate paper, *"Integrating the Challenge Based Learning Approach in a Freshman Engineering Foundations Course: Project Team Perspective,"* at this conference. The information outlined below provides a brief summary of the teaching components used throughout the semester.

The *ENED 1020: Engineering Foundations* course serves as an introduction to all fields of engineering to incoming freshman. It is a common course taken by all incoming freshman in the first semester, in sections with 40-60 students in each. The course includes lectures as well as "hands-on" experimental modules that enable students to explore mechanical, chemical, and electrical systems, and conduct four required laboratory investigation projects in teams of 3-4

students each, including bridges, fuel cells, thermodynamics and electronic communications and signal processing applications. Special laboratory equipment and kits are provided to conduct these experiments and the students are guided to perform these experiments by teaching assistants (**TAs**: trained upperclass undergraduates), with one TA support for every two teams. Each student team completes a report for each lab using a prescribed format. In addition, students complete a fifth project, called the "Choice Project," in which the students are asked to design their own experimental investigation, different from the ones completed, using the knowledge and equipment from the four required projects. Usually, teams extend one of the required projects for the Choice Project, for example, doubling the energy production from a fuel cell. As for the required projects, each team submits a written report for the Choice Project also. Students also receive training in engineering ethics and in professional skills such as communication, teamwork, problem-solving, and synthesis. Representatives from degree-programs in CEAS and from industrial organizations are invited to provide additional information concerning career opportunities in engineering to students.

The student learning objectives (**SLOs**) for ENED 1020 are given below: At the completion of this course, students will be able to:

1. Describe their program's curriculum and co-op requirements and its experiential learning and career opportunities.
2. Describe the other CEAS disciplines and the career opportunities those disciplines provide.
3. Demonstrate the ability to design and conduct experiments, as well as to analyze and interpret data.
4. Demonstrate the ability to identify, formulate, and solve engineering problems.
5. Demonstrate the ability to communicate effectively and work in teams.
6. Demonstrate an understanding of professional and ethical responsibility.

For the purposes of this study, 4 sections of the ENED 1020 course participated in the GCP that included Challenge Based Learning (**CBL**), Engineering Research Process (**ERP**) and Entrepreneurship Process Model (**EPM**). These sections are called treatment sections in this paper. The comparison sections are sections of ENED 1020 that followed the standard curriculum and were taught by two of the instructors also teaching the treatment sections.

Teaching Methodologies and Execution

The full details of the execution of the teaching methodologies used in ENED 1020 by the Project Team are presented in a separate paper, *"Integrating the Challenge Based Learning Approach in a Freshman Engineering Foundations Course: Project Team Perspective,"* at this conference. The information outlined below provides a brief summary of the teaching components used throughout the semester.

Challenge Based Learning

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[2]. CBL is a structured model for course content with a foundation in earlier strategies, such as collaborative problem-based learning[2]. 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 [2,3].

Engineering Research Process (ERP)

The ERP guides and informs the solution of the challenge. The objective is to guide the learner to a series of "observations" about potential problems associated with a Grand Challenge and to formalize a "hypothesis" that can be researched and answered.

Entrepreneurship Process Model (EPM)

The Entrepreneurship Process Model (EPM), explores the viability of the product resulting from ERP, as a solution to the challenge, to take it to the real world (market-fit)). The EPM includes following five key components: The value proposition, the focus, the entrepreneur, the environment, and engagement.

Execution of the GCP

For treatment sections, the CEEMS graduate fellow introduced the GCP to students early in the semester, on September 4th. The full details of the execution of the GCP in ENED 1020 by the engineering graduate Fellows are presented in a separate paper, *"Integrating the Challenge Based Learning Approach in a Freshman Engineering Foundations Course: Teaching by Intern Engineering Doctoral Students Perspective,"* at this conference. In this sub section the execution of the GCP is outline from the course instructors' perspective.

1. One lecture section in the first week of the course was designated specifically tor the fellows to introduce themselves to the class as well as the project. In this lecture, students were informed about CBL, S-STEM and the flipped classroom. The graduate fellow addressed the class to explain the grand challenge by presenting the "Big Idea" and how the grand challenge project would be incorporated throughout the semester.
2. After each lab students were to fill out post-lab surveys to explain how the lab would relate to their grand challenge project. The short surveys were used to help reinforce what was learned in the lab as well and how concepts can be interdisciplinary.
3. During the last three weeks of the semester students worked on their grand challenge projects.

Training for Instructors

Instructors that participated in the GCP were not trained to conduct the project. A meeting was held to explain the project and how it would be executed throughout the semester. Each instructor was assigned a graduate fellow who was trained to conduct the GCP. Instructors

were told that graduate fellows would provide all the information needed for students to conduct their final projects. As one faculty stated, "this was a retrofit" of the GCP into an established course.

Evaluation and Results

To evaluate the ENED 1020 Course from a teachers perspective, a mixed methodology was used that provided data for formative continuous improvement of the project. Qualitative data was collected from each faculty member via interviews. Interview data was collected from the instructors, via email and or, phone interviews. Observations made from faculty members were supported with quantitative and qualitative data that was collected from student surveys and course evaluations.

Instructor Interviews

Instructors were asked, "Were you prepared to have the CEEMS fellow incorporate the GCP into your course". Two instructors were notified the week classes started that they would be participating in the GCP and two had been preparing for the inclusion of the GCP during the summer. The time instructors had to prepare for GCP inclusion changed how the GCP was executed in each section classroom. For example, one faculty took a hands off approach and treated the class as an educational research project and did not interfere with what the Fellow was doing.

> *Other professors were able to plan in advance. Due to schedule changes, I did not have a lot of time to prepare for the GCP. I do not think my lack of preparation for GCP would have mattered if I'd had more interaction with my fellow. From my understanding, the fellow was completely in charge of the project and I was just to allow time for the implementation throughout the semester. There was little interaction and communication with the graduate fellow. The communication came via third party, or not at all. I was completely in the dark about what was supposed to happen with the grand challenge presentation. The fellow attended my class sporadically. Students would ask questions that the fellow should have been able to answer but did not. It negatively impacted the student experience with CBL.* – Faculty quote

In another instance, the course was taught by a faculty member who had experience teaching the class and was working with a Fellow who was also one of her graduate students. This allowed this instructional team to work together more closely and use this as a training experience for the Fellow.

> *I worked well with my CEEMS Fellow, who was also one of my PhD students. However, I had another advantage because I was already prepared to give my students a discipline-specific Final Project. As a member of the Curriculum*

Committee, I was responsible for the inclusion of the Final Project into the 2014 Syllabus and had taught the class previously. So, I had already designed the project that became the Grand Challenge. … I treated this section as an opportunity to train my PhD student … I would discuss difficulties separately with the Fellow and allowed him to make adjustments. – Faculty quote

Regarding the connection between GCP and other course projects, instructors had varying experience. Instructors noted that it may be beneficial if an entirely new project was selected for students to conduct for GCP to see if there was a true connection of concepts, not execution, made between early course projects and the GCP.

I think the idea of the GCP was great. However, students had conducted a similar experiment during the labs conducted earlier in the semester. I do not think students could see the difference in the labs because they did not understand what was required of them. A different project would be better so they would have to see the connection of concepts. – Faculty quote

I worked closely with my Fellow to revise my original Final Project to include aspects of the earlier project (specifically, electric circuits). Specifically, my project was a computational model of an irregular heartbeat. We first used the electric circuit lab to simulate a therapy for the irregular heartbeat. – Faculty quote

The GCP conducted in my section was the same project that students had completed earlier in the semester. I do not think the students learned anything from repeating the project. Maybe a different project should be selected in the future. – Faculty quote

Instructors noted the importance of Fellow training. The experience may have been improved if all Fellows were equally knowledgeable, organized and had excellent communication skills. It was also mentioned that fellows conducing the GCP should have teaching experience prior to implementing GCP in a course. It is necessary for the fellows to have practical experience so they better understand the students and classroom management. During the interviews, instructors were asked, "What training or support would have been helpful from your prospective? Were the Fellows adequately prepared for the GCP execution?" There comments included:

The fellows that carry out the project should be trained by going through the summer program and part of that training should require them to be in front of the classroom. It is important for the fellows to learn how to mange the classroom. Managing a classroom is difficult. Professors also need to be fully trained on the new pedagogy that will be used. Extensive training it necessary especially if the fellow needs support. If I is not possible for the instructors to be

fully trained there needs to be more than one fellow managing the class so support is provided. – Faculty quote

I think the instructors need to understand GCP and the fellows were not capable of education the faculty. So the Project Team should have taken on this task. – Faculty quote

It didn't seem like my fellow was prepared. I do not think he knew was happening for the GCP. It was evident that he was not used to teaching. I tried to help when I could but because I did not have the details of the project it was difficult to fully support him. It may have helped if the fellow came to the class more often so students could have developed a better relationship with him. – Faculty quote

When asked "How do you perceive the students' experience in the GCP?" instructors had varying viewpoints with one common theme; engagement. Student engagement was noted as an improvement. Instructors heard mixed reviews of the project from students, but students provided their thoughts in surveys and the course evaluations (see Results from Student Course Evaluations).

I noticed that my students were really engaged in the process trying to find solutions to their GCP. They wanted to solve the problem and see something exciting happen. Many students like the business side of the process, they seemed to enjoy that the product development was interdisciplinary and it opened their eyes to a different aspect of engineering. However, the students claimed to hate the project. –Faculty quote

The students gained kills that are beneficial in their third year. It would be interesting to assess the same students in throughout their career. The questions they asked let me know that were thinking deeper we need to be able to foster those skills. – Faculty quote

While, as one faculty stated, "the students were grappling with concepts they usually do not discuss in this course, such as filtration versus absorption", overall the instructors indicated there is need for improvement in the execution of the GCP. When instructors were asked, "How do you feel the course went with the Grand Challenge Project (GCP) project as part of it? Consider CBL, ERP, and EPM teaching aspects; Flipped Classroom; Tracking Surveys and Homework given during the semester for PGC; and final deliverables produced and presented - Project Presentation and Project Report.", representative quotes included:

I was completely in the dark on the ERP and EPM aspects of the project. I wasn't able to see how those elements tied into CBL. I did hear students talk about cost and marketing. As far as flipped classroom, information was not posted for it to be considered a flip classroom. Most of the information was given during the

lectures and/or the labs and the students were asked to comment and work on their projects at that time. The homework and tracking surveys that were given during the course were not assigned according to plan. Students were given short windows to fill them out and a lot of the time they were not given at all. – Faculty quote

Because of a faculty-scheduling quirk, the project investigators did not teach the course. Therefore, the actual instructors were pretty much in the dark about everything that was going on. I do not believe the Fellows were any better informed as I was never able to get a clear picture of how everything fit together. ENED 1020 has some inherent problems. It is conducted at an academic level too low to warrant being a college of engineering freshmen course. Many of the students had done exactly the same work in high school. – Faculty quote

The GCP had quite a few problems. The project itself was just a repeat of the project that was conducted earlier in the semester. Students had a hard time buying into CBL, ERP and EPM because it was drastically different from the rest of the course. Homework and surveys were an issue because they were often times posted late with unreasonable timeframes for completion. They also were graded incorrectly. I had to spend a lot of time making sure students understood that I would assign final grades and not to worry so much about the missed deadlines and confusing grading. – Faculty quote

The project went well. Students were engaged and asked a lot of thoughtful questions. … They may not realize the benefits of [GCP experience] until they are juniors or seniors. – Faculty quote

Instructors provided suggestions that could help improve a GCP execution in the future when asked "What improvements would you suggest when ENED 1020 is taught again? Consider: planning; course structure; training for yourself, TAs and CEEMS Fellows; interactions with CEEMS Fellows; interactions with TA; and interactions with students." The major themes were increased organization and communication at all levels. Some of the specific suggestions included additional training, regular project meetings, and different projects.

I would love to do the project again, but it would need a few improvements. Overall the project engages students. If GCP were conducted properly it would help tie content to prospective careers, which is necessary for students to understand. I would have the project planed ahead of time. The more unorganized it is the lower the student experience will be. I would utilize more advanced technology. Students were hindered in their creative thinking process by the lack of diverse materials. We should try to have a bigger budget to obtain the materials they may need or introduce the students to simulation. Simulations

would probably be the most beneficial because that is the method used in industry. – Faculty quote

There needs to be a complete redesign of ENED 1020. The course, as presently designed, has weak learning outcomes, poor assessment methods, and does nothing to prepare students for the rigors of their discipline or even introduce students to their discipline. TAs and instructors must be trained together so there is a uniform understanding of the elements of the project and their significance. Finally, regular meetings between the project team and the staff. As an instructor, I was very uncomfortable turning over my class to a graduate student. If I understood, and agreed with, the principles being employed, then my concern would have been lessened significantly. – Faculty quote

I think its great that a department decided to come to the class and try something different. The project was designed to I think the project would work if they trained the fellows on teaching and picked a project that students haven't already conducted during the semester. –Faculty quote

Student Surveys

As described in the companion paper, *"Integrating the Challenge Based Learning Approach in a Freshman Engineering Foundations Course: Project Team Perspective,"* written by the project team and presented at this conference, student surveys completed treatment and comparison sections at the end of the course. Due to the major differences in the implementation of the Fellow's GCP and that of the comparison section's Final Student Choice Project, the results from these two student groups are not directly comparable for all sections. But, qualitative comparisons can be made for the treatment and comparison sections taught by the same two faculty. When these results are compared, the students in the comparison sections rated the Choice Project higher on than the GCP.

These results are consistent with instructor observations and are further supported by voluntary student comments made on the course evaluations. These course evaluations are distributed by the College for all courses at the end of the semester. Student comments for the comparison sections were general in nature and did not specifically address the Choice Project; general positive comments related to the course and professor. For the treatment courses, the students' comments were more specific and identified the areas of improvement for the course and GCP when it is taught again.

Most student comments include ones that highlighted the need for better organization and communication which is consistent with the instructors' observations. Representative comments include:

Thumbs up for [professor], but probably a thumbs down for the organization of the course. I don't know who's responsibility that is, but I missed many assignments simply because I was not aware they were due. – Student on Treatment Section Quote

There was a lack of communication between [the professor] and [the fellow]. This caused an enormous amount of confusion as to the purpose of the class and what we were supposed to do. – Student on Treatment Section Quote

I thought the class was good along with professor. However, I thought the grand challenge was terrible and was not well planned at all. – Student on Treatment Section Quote

The class was generally a disorganized mess and nobody was ever sure of what was supposed to be done. It would be nice to have been explained what was going on in recitation a lot more clearly beforehand. – Student on Treatment Section Quote

In addition these communication and organization related comments, some students identified that the GCP was more challenging than the required laboratories. While student's perceived it as a negative aspect of the course, an objective of the GCP to have the student's think more critically and incorporate ERP and EPM into their solution and their mentioning these aspects of the project is actually a positive outcome for the S-STEM project. Student comments included:

… the GCP seems to focus a great deal on more advanced aspects of engineering which the majority of the students taking this class will not be able to grasp or understand. – Student on Treatment Section Quote

This course material is intended for high school students that are potentially interested in engineering. It is not intended for engineering majors. The Grand Challenge is a process intended for professionals backed by resources, not first year students with virtually no backing. Little to no instruction was given about the Grand Challenge and students were left to flounder. – Student on Treatment Section Quote

"Grand Challenge" sounds a bit pompous and pretentious for a project that's being conducted by freshman in college with absolutely no knowledge on the subject, so I would appreciate that name being changed if the project is kept in the course. – Student on Treatment Section Quote

Conclusions and Recommendations

Fellow, faculty and student evaluation data are consistent and indicate that there were positive and negative aspects of the ENED 1020 GCP implementation. The faculty, project team and fellows need to work together to maintain student engagement and promote steady planning progress so that the GCP is more fully integrated into the ENED 1020 course. Four main recommendations came from instructors to improve GCP.

Interaction

As indicated from the evaluation and results section there was little interaction between some of the faculty members, project team and fellows. With improved interaction the project may have improved results because all parties will be well informed and able to understand the process.

Organization

Noted by both the instructors and the students, GCP projects should be well organized so students can benefit from the process. The process and requirements outlined in the beginning of the semester were not executed during the semester. Increased organization will lead to better results

Training

Instructors did not participate in training on CBL, ERP or EPM. Some instructors were familiar with CBL prior to the project but not with the additional elements. It was mentioned by instructors that if they had trained just as the fellows were trained they would be able to support the project and the fellows in a better capacity.

Project Selection

Instructors and students both indicated the importance of having a project that was different from the projects conducted throughout the semester. Improved project selection could help students understand the connection of concepts taught throughout the semester and give them an opportunity to work on something they haven't already seen in the semester.

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