Work-in-Progress – Creating a Collaborative Community in a First-Year Engineering Design Project

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***Abstract* – In many First-Year Engineering courses, students are often organized into groups when tasked with completing design projects. This type of team-based learning offers numerous benefits such as improving communication skills and problem solving abilities. Additionally, students are capable of completing tasks that exceed the skills of an individual student when working in a team. While team-based learning has been proven to be beneficial, structuring classes where the teams are encouraged to compete against one another may have detrimental impacts on students, especially females. Instead, by restructuring design projects so that classroom-wide collaboration is encouraged, student performance, as well as retention, may improve. A pilot study was conducted in spring 2016 to evaluate the effects of such a restructuring.**

Index Terms – Collaboration, Design Project, First-Year Engineering, Team-based Learning

INTRODUCTION

Team-based, cooperative learning is a tool often utilized in engineering courses due to the numerous benefits it awards. Students gain a deeper conceptual understanding of topics in addition to enhancing professional skills such as teamwork, written and oral communication, and problem solving. Team-based learning is often presented in the form of group projects. Students working in teams are capable of academic achievements that are typically beyond the ability of an individual student.

In the honors first-year engineering (FYE) course at the host institution, students are organized into groups of four to work on a semester long design project culminating in the creation of an autonomous robot capable of completing specified tasks. The current scenario depicts each group as a competing company and the best robot prototype at the end of the semester will be chosen for full-scale design. Each section of the course has typically nine teams competing against each other as well as all the teams from other sections. In 2016, nearly 80 teams competed against each other at the final competition.

Due to the competitive nature of the course, teams are often secretive with their designs and unwilling to provide help or feedback to other teams. Not only does this contribute to an unfriendly environment, but it also limits opportunities to gather new ideas and creative solutions. In an effort to change this, the author proposes a restructuring of the scenario to one that encourages collaboration. By framing the entire class as a "company" in which each team acts as a project task group within that company, teams will be more open to sharing ideas and solutions with other teams.

The focus of this research is to explore whether creating a class-wide collaborative community in a FYE design project impacts student performance. Teams will have the opportunity to be exposed to a far greater number of ideas in this classroom format and during the brainstorming process, exposure to a large quantity of ideas is critical for success. By starting the project with a better design, teams are more likely to do well over the course of the semester. Additionally, removing some of the competitive nature from the project will help create a more inclusive climate conducive for sharing and collaboration. Approximately half of the sections of the course will be randomly selected to partake in the restructuring of the scenario. Student performance will then be evaluated at the end of the semester and compared to the comparison group, which consists of the sections still using the current scenario.

BACKGROUND

Team-based learning is a popular practice in FYE classes as a method to introduce students to many of the professional skills required by industry [1]. When working as a practicing engineer, collaborative partnerships are essential [2]. Collaboration is particularly valuable in engineering where innovation is critical. The Nobel Prize winner, James Watson, who co-discovered the double-helix DNA molecule acknowledged this when he stated, "Nothing new that is really interesting comes without collaboration." Collaborating in the classroom is a powerful tool when implemented appropriately [3]. Reference [2] states "collaboration is generally described as an approach involving joint intellectual efforts between students, or between students and the instructor." The literature indicates that collaborative learning is, in fact, beneficial to student performance [2].

A meta-analysis of 378 studies found that student success was higher when working in a cooperative environment as opposed to working individually or in a

competitive arrangement [4]-[5]. A study by Deutsch in 1949 found evidence that suggests college students perform better when working in a cooperative environment as opposed to a competitive one [6]-[7]. Another study by Prince in 2004 found that student retention also improved as a result of collaborative learning in addition to academic achievement [8]. Collaborative learning, when incorporated into the curriculum, not only better prepares students to work in industry, but also has more immediate benefits such as a positive influence on student persistence, academic achievement, and attitude regarding learning [2] [9].

Additionally, the competitive nature of many engineering courses may be detrimental to female retention, which generally prefer a more supportive environment [2] [10]. Studies have observed positive results when women work in collaborative teams and the classroom environment encourages cooperative behavior [11]. Research shows that cooperative learning and collaboration promotes more positive attitudes toward the subject area and learning than competitive environments and the more positive a student's attitude is toward college, the more likely the student will stay in college [3]. The same can be said with regards to the student's selected major [12]; thus increasing the amount of collaboration in the classroom and minimizing the competitive aspects may result in the increased retention of women.

Competition may have a place in the classroom, albeit a smaller place than it currently has. Adding an aspect of competition helps to create a business-like environment that can aid in the professional development of the students [7]. Additionally, engineering students are likely to enter careers where working under pressure is a necessity and "learning by losing" is a valuable process to prepare students for their future profession [7] [13]. Structuring the classroom so that the focus in on collaboration, while still adding an element of competition observed by competing across entire course sections may create the proper balance of the two approaches.

PILOT STUDY

During the spring semester of 2016, Corrigan structured her class in a new way: the entire class was structured as a "company" with Corrigan as the "manager", teaching assistants (TAs) as "senior engineers", and teams of 4 were the "project task groups". This class structure was modeled after a typical engineering consulting company based on Corrigan's experience working in industry. In the typical scenario, instructors met with teams individually throughout the semester to discuss progress and help with the team's design; however in Corrigan's class, teams sent one individual to represent their team at "board meetings" which were held every two weeks. Meetings were then conducted as a class with Corrigan and a few TAs leading the meetings and the team representatives providing input. The team representative would then report back to their individual team with information obtained during the meeting.

The collaborative community that was created as a result of this approach was particularly beneficial during the initial design process. Groups shared their designs with the entire class and were able to develop new ideas and/or expand on current ideas due to the variety of designs and approaches that were shared. Additionally, the inclusive atmosphere encouraged groups to help other groups over the course of the semester. Teams were observed providing other teams that were struggling during robot testing with useful feedback. An end-of-semester survey prompted students to answer questions, which were created using the MUSIC model of academic motivation. The MUSIC model helps to inform instructors regarding why a particular instructional strategy will motivate students to engage in learning [14]. Furthermore, anecdotal evidence from open-ended journal responses gathered from the section that utilized this approach suggest it to be an effective organizational structure that encouraged collaboration and aided in the design process.

FUTURE WORK

The pilot activities will continue during the 2017 spring semester. Multiple sections of the Fundamentals of Engineering Honors (FEH) sections will participate in the research study. The scenario will be restructured for these sections so that the entire class is organized as a company comprised of project task groups.

Instructors will conduct "board meetings" throughout the project. In these meetings, each team will send a representative to participate in the meeting. The representative will then report back to the group after the meeting. Each meeting will have a specific agenda that is provided to all instructors at the start of the semester; thus allowing for consistency during meetings. A total of four board meetings will be conducted during the design project, which each team member attending one meeting. The board meetings allow for the class to engage in group processing, which is critical to cooperative learning. A study by Johnson, Johnson, and Smith in 1998 stated that group processing maximizes learning for both the individual and the other members of the group by "a) streamlining the learning process to make it simpler (reducing complexity), b) eliminating unskilled and inappropriate actions (error-proofing the process), c) continuously improving students' skills in working as part of a team, and d) giving group members an opportunity to celebrate their hard work and successes" [3].

As another method to encourage collaboration, one representative from a team will shift to another group from a short period and work with that group to provide feedback and insight on their design at least 2 times during the design project. The representative will listen to the team describe their robot and some of the difficulties they have encountered lately. The representative will then share their thoughts and ideas with the team. Not only will the team gain a fresh perspective on their problems, but the representative will also gain information that may prove beneficial to their own team's design.

RESEARCH QUESTIONS

The full-scale implementation of the project will seek to answer three primary research questions:

- Does classroom-wide collaboration improve student performance?
- Does the classroom climate change when groups within a class are not competing against one another?
- Does classroom-wide collaboration impact various stages of the design project (brainstorming, design, construction, programming, and documentation) differently?

FUTURE EVALUATION AND ASSESSMENT

In order to answer the first research question presented, individual student grades will be collected at the end of the semester. The grades analyzed will be the student's overall design project grade as well as the student's competition grade. These grades will be compared to those from the comparison group. In addition to grades, the self-efficacy of individual students will be evaluated at the end of the project using a validated instrument implemented through an end-of-semester survey, such as the instrument created and validated by Carberry, Lee, and Ohland in 2010, which measures engineering design self-efficacy [15].

To access the second research question, students will participate in the end-of-semester survey, which will also contain questions regarding classroom climate. The survey will contain questions that have already been validated. In order to gain further perspective on the classroom climate, students will also participate in focus groups and one-on-one interview sessions, both from the comparison group and those with the intervention to provide a more detailed narrative regarding the class environment and personal experiences throughout the design project. Over the course of the design project, an observer will sit in on classes to gather information concerning group dynamics and classroom climate in order to provide additional insight on the classroom environment.

The third research question will also be assessed using the end-of-semester survey and focus groups to evaluate student perception of the impact of collaboration on the different phases of the design project. While student perspective is important, it will also be valuable to obtain feedback from the instructors regarding the impact of collaboration; therefore, interviews will also be conducted with faculty to access their opinions regarding the impact of collaboration.

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