The Impact of Project-Based Group Work on Engineering College Students' Content Knowledge and Affect

Anne Marie Aramati Casper[1]
Rebecca Atadero[2], Ph.D.
Meena Balgopal[1], Ph.D.
Karen Rambo-Hernandez[1], Ph.D.

[1] School of Education
[2] Department of Civil & Environmental Engineering
Colorado State University
Fort Collins, CO 80523
Corresponding author Email: Aramaticasper@gmail.com

Paper presented at the annual conference of the National Association of Researchers in Science Teaching, Puerto Rico, April 2013

Abstract

Throughout the United States, low enrollment and low retention rates in engineering programs are indicative of the need for curriculum change that will produce well prepared future engineers who can create innovation in response to 21st century challenges. Using social cognitive theory, we performed a pilot study to analyze the impact of problem based learning (PBL) and project based learning (PjBL) instruction on an undergraduate engineering class. We used a structural equation model based on social cognitive theory to analyze student self-efficacy, outcome expectations, intention to stay in engineering, and concept inventory scores Compared to the traditionally taught control class (n=40), the students in the treatment class (n=67) performed equally well on the statics concept inventory, and had higher levels of engineering related self-efficacy, controlling for pre-test scores (p<.05). Higher levels of self-efficacy, along with outcome expectations, were associated with a higher likelihood of staying in engineering (p<.05). We used a coding heuristic to analyze the types of conversation students participated in during group work in the treatment class. Analysis of student discourse revealed that students participated in more group knowledge building conversations (Concept Negotiation, or CN) in their initial group meeting for the well-defined PBL assignment, compared to the ill-defined PjBL assignment (p<.05). Our results indicate that a PBL and PjBL based curriculum was effective in improving factors that impact student retention in engineering, and that the way assignments are defined in PBL and PjBL impacts student discourse while working on the projects.

Background

It is critical for the United States to have a technically competent workforce to ensure the continued competitiveness of the United States (National Research Council, 2007, 2010). The future of engineering, the importance of engineering to society, and the means of educating future engineers have all been given recent attention by the National Academies. According to the National Academy of Engineering (2004) future engineers need to have strong skills in analysis; practical ingenuity; creativity; communication; business and management; leadership; ethics and professionalism; dynamism, agility, resilience and flexibility; and be lifelong learners. Therefore, future engineers cannot simply be taught in traditional lecture-based classrooms without opportunities to develop problem-solving and communication abilities. In response, the National Academy of Engineering (2005) has made 14 recommendations, including: the integration of 1) design projects early in engineering programs; 2) the importance of lifelong learning for professional engineers; 3) discussions of the interdisciplinary nature of engineering as undergraduates; and 4) case studies in curricula.

In spite of the National Academy of Engineering recommendations (2005), there is still a disconnect between professional goals for educating future engineers and collegiate engineering education. It is important for engineering educators to find ways to both engage their students and provide them with the knowledge and skills needed for their professional careers (Heywood, 2005). However, it is still common for engineering educators to rely on direct instruction (“teacher talking” methods), which rarely promotes development of the higher-order cognitive skills that are necessary for both student and professional success (Bransford, Brown, & Cocking, 2000). Moreover, low retention rates and concern for educating globally competitive graduates (King, 2012) also necessitate changes in current engineering instructional strategies.

Problems in retention indicate problems in instruction, which need to be directly addressed to increase retention rates. When engineering programs and educators address the problems identified by research, such as curriculum that needs updating, the quality of student experiences in classes, and the attitudes that students have toward engineering, educators and programs get at the root issues that impact engineering enrollment and attrition (Besterfield-Sacre, Atman, & Shuman, 1998; Litzler & Young, 2012).Low levels of women and minorities in engineering may also contribute to the low enrollment and retention of engineering students. The low number of physics bachelor’s degrees awarded to women and minorities has been identified as a reason why only 2% of STEM bachelor’s degrees are in physics (Mulvey & Nicholson, 2007). Since the percentages of women earning bachelor’s degrees are similar for both physics (21%) (Mulvey & Nicholson, 2007) and engineering (18.4%) (National Science Foundation, 2010), the lack of women in engineering is also a part of the overall low numbers of degrees awarded.

Test scores and preparedness do not explain the low enrollment and retention of minorities and women in engineering (Sawtelle, Brewe, & Kramer, 2012). Research on students enrolled in undergraduate engineering degree programs has identified three groupings of undergraduate engineering students, the committed, ambivalent, and at-risk groups (Litzler & Young, 2012). Retention of the at-risk and ambivalent groups was found to revolve around quality experiences in the classroom, particularly with quality experiences with faculty (Litzler & Young, 2012). Additionally, attitude upon entering an engineering program is important, as Besterfield-Sacre et al. (1998) identified differences in attitudes upon entry to the program between students who remained in their engineering program and those that left in good standing. Oddly, in Litzler and Young (2012), quality experiences with Graduate Teaching Assistants (GTAs) were correlated with poor retention, indicating that an unmeasured variable is probably involved, and that quality GTAs are not replacements for quality student contact with professors.

Existing education practices that are aligned with the National Academy of Engineering's (2005) recommendations of incorporating design early in the curriculum will support the transition of engineering education that is necessary to meet calls for reform and will subsequently support student enrollment and retention in engineering (Besterfield-Sacre et al., 1998; Litzler & Young, 2012). These shifts update curricula by requiring the use of pedagogical best practices and have the ability improve the quality of student experiences.

Problem-based learning (PBL)

Problem-based learning activities that are embedded in class time fulfill the above needs and are consistent with the goals of the New Engineering Education Paradigm (Splitt, 2003). Therefore, teaching styles such as Problem-Based Learning (PBL) or, the related but distinct, Project-Based Learning (PjBL), are appealing inquiry-based teaching options that may allow us to increase student learning and motivation to learn (Evenson & Hmelo-Silver, 2000), while also addressing low enrollment and retention. Both PBL and PjBL provide students with opportunities for taking ownership of their learning by applying knowledge to solve problems. Consequently, PBL and PjBL strategies may increase student self-efficacy and outcome expectations, which may lead to improved retention rates within engineering degree programs.

PBL is characterized by students working collaboratively in small groups to solve a problem (Hmelo-Silver, 2004) and has been associated with increased student motivation to learn (Gallagher, Sher, Stepien, & Workman, 1995). In PBL, the problem is central to the learning experience and is presented first; knowledge is then acquired through self-directed learning to solve the problem (Gijbels, Dochy, Van den Bossche, & Segers, 2005). The best problems for

PBL have been described as “complex, ill-structured, and open-ended; to support intrinsic motivation, they must also be realistic and resonate with the students’ experiences” (Hmelo-Silver, 2004, p. 244).

While there can be concerns about the breadth of knowledge obtained by students in a more-focused PBL or PjBL setting, meta-analyses of studies looking at group-work and PBL based classes do not provide a simple answer to the question of how classes that step away from the traditional broad, lecture format impact the breadth of student knowledge. A meta-analysis of small group work in undergraduate STEM (science, technology, engineering, and mathematics) classes studied between1980 and the late 1990s found that small group work increased student achievement, persistence and attitudes (Springer, Stanne, & Donovan, 1999). In contrast, a more recent meta-analysis of tertiary classes without identified subject areas found that students taught using PBL may have a smaller knowledge base, despite their stronger ability to apply knowledge (Dochy, Segers, Van den Bossche, & Gijbels, 2003).

Despite the age of the Springer et al. (1999) study, which explains why it does not differentiate types of group work, its results may be more pertinent to our research than the more recent meta-analysis. Engineering PjBL requires students to design a solution to a problem through experiential learning opportunities, promoting both knowledge acquisition and application skills (Helle, Tynjala, & Olkinuora, 2006). PBL and PjBL in other subject areas may not require the same depth of knowledge acquisition, making it important to focus on studies in similar content areas. Additionally, Dochy et al. (2003) states that the lower knowledge base effect is primarily driven by two studies they refer to as outliers; when the two outlier studies are removed from analysis the difference between PBL and traditionally taught classes approaches zero. Because of the lack of clarity in the literature, and caveats in Dochy et al. (2003), it is possible that the outcome of student knowledge may vary based on factors that vary within different types of PBL and traditional lecture classes.

Changing Student Attitudes and Beliefs about Engineering

The gender divide has closed in many occupations, but not in engineering. The National Science Foundation's most recent graduation statistics show that only 18.4% of engineering bachelor's degrees go to women, with 57.2% of all bachelor's degrees received by women (2010). Only the category of computer sciences, at 18.2%, has less than 40% of its degree's earned by women (National Science Foundation, 2010). In physics, a related discipline, it has been reported that that only 21% of bachelor's degrees go to women, whereas the gender split is approximately even in chemistry, math, and other natural sciences (Mulvey & Nicholson, 2007). It is these types of data that prompt researchers to examine what variables or conditions may explain the gender disparity in engineering.

People often pursue goals and efforts that they believe they can achieve; this is often referred to as self-efficacy (Bandura, 1977). It has been suggested that a high sense of professional self-efficacy is necessary when choosing careers and areas of study (Lent, Brown, & Hackett, 1994). A study of self efficacy in 10 traditional (at least 70% women) and 10 non-traditional (30% or fewer women) occupations, engineering was identified as the most difficult, by a sample of women in a core-requirement introductory college class (Betz & Hackett, 1981). Only 30% of the women sampled believed they could complete the education requirements, 51% indicated they could perform the job duties, and of those who said they felt they could perform the job duties, women had lower confidence in their ability to complete the job well compared to male students (Betz & Hackett, 1981). Hence, women exhibited lower self-efficacy than their male counterparts, in spite of similar academic abilities, which were indicated by no significant differences in their respective ACT scores. Additionally, while ACT scores were predictors of men's self efficacy in engineering, they were not predictors of women's self efficacy in engineering. Because interest and self-efficacy were strong career option predictors for both genders, this construct is worthy of further examination in engineering education studies.

Theoretical Framework

This research is framed using Bandura's social cognitive theory (1986), his preceding theories about self-efficacy (1977, 1982), as well as the career-specific social cognitive framework developed by Lent et al. (1994), which is rooted in Bandura's (1986) social cognitive theory.

Social cognitive theory states that an individual's behavior is driven by three interacting factors: behavior, cognitive and other personal factors, and environmental events (Bandura, 1986). While many factors influence the three interacting factors, self-regulation and self-reflection are the two components that relate most strongly to our work (Bandura, 1986). In self-regulation, a behavior is regulated by a process where an individual compares their actions to a set of internal standards (Bandura, 1986). Decisions about future behaviors depend on one's perception of how their past behaviors stood up to the internal standards (Bandura, 1986). Self-reflection is used to create knowledge about an individual's self and the world, as well as to evaluate and change one's thinking (Bandura, 1986). Self-reflection allows an individual to monitor his/her own ideas, and then act on or make predictions about these ideas (Bandura, 1986). While self-reflection usually leads to true conclusions, erroneous conclusions that are made can be falsely confirmed through acting upon an erroneous conclusions, leading to discrepancies in an individual's perception of his/her self and the world (Bandura, 1986)

Attitudes about one's ability to perform a task or complete a goal are measured by self-efficacy, a term first defined by Bandura (1977). Self-efficacy expectations refers to an individual's beliefs about his/ her ability to successfully complete a specific task or behavior (Bandura, 1977). These efficacy expectations are rooted in four factors: performance accomplishments; vicarious experiences; verbal persuasion; and physiological states used to judge capabilities, strength, and vulnerability (Bandura, 1977). When an individual experiences success it positively reinforces their self-efficacy expectations, whereas failure negatively reinforces self-efficacy expectations, particularly when an individual is a novice in a situation and failure is not linked to lack of effort (Bandura, 1977).

In a manipulative study, Bandura (1982) found that ability to perform a task is correlated with perceived self-efficacy. However, ability and perceived self-efficacy do not change at the same rates; either perceived self-efficacy or behavior may increase or decrease faster than the other factor. Additionally, perceived self-efficacy is a better predictor of future performance than past performance (Bandura, 1982).

The view that one is unable to perform a task or a goal has two sources: doubt in ability or confidence in ability with expectations of an unresponsive environment (Bandura, 1982). The expectations of individual that a given behavior will lead to a particular outcome is referred to as outcome expectations (Bandura, 1977). Because perceptions of both ability and environmental responsiveness impact behavior, an individual's actions are best predicted by the combination of self-efficacy and outcome expectations (Bandura, 1982).

When an individual's performance is based on perceived low self-efficacy, he/she must change their self-efficacy to achieve mastery of challenging tasks (Bandura, 1977). For this change to occur, an individual must experience perceived progress in their ability to accomplish a task at increasing levels of difficulty (Bandura, 1977; 1982; 1986). While performance is the strongest self-efficacy enforcer, the three other sources of perceived self-efficacy can also cause improvement. Therefore, even observing someone else who one identifies with complete a task improves self-efficacy (Bandura, 1982). To develop strong, lasting self efficacy, an individual must perform self-directed mastery, which strengthens and generalizes their expectations of self-efficacy (1977). From an academic standpoint, career-specific social cognitive theory states that self-efficacy and outcome expectations are influenced by experiential learning opportunities, personal factors, and learning context (Lent et al., 1994).

For example, an engineering student with lower perceived self-efficacy will have more difficulty solving problems and mastering course content than student with higher perceived self-efficacy. To be more successful, the first student needs to change his/her self-efficacy by experiencing success through one of the four sources that build self-efficacy. Once a student has success, sees another similar individual succeed, is persuaded by others that they can succeed, or can mentally see themselves as succeeding, that student will be more likely to believe they can succeed at future similar activities, and therefore be more likely to actually succeed in the future (Bandura, 1986). Curriculum that scaffolds student learning, supporting each student to progress from whatever level they are starting at, provides students with the ability to experience repeated successes and improve their self-efficacy. Conversely, if a student does not believe that they have sufficient tools to complete a task, and does not receive external support, their self-efficacy will continually decrease as their perception of inability is continually reinforced.

To better understand how the use of PBL and PjBL learning in an undergraduate engineering course impacts self-efficacy and, in turn, influences learning outcomes and performance, we analyzed student response to a traditional and a PBL/PjBL learning environment. A PBL/PjBL based curriculum that is measured by changes in student self-efficacy, outcome expectations, learning outcomes, and performance, addresses the earlier discussed problems in engineering education by providing students with an environment that helps them develop problem-solving abilities, uses updated pedagogical techniques, and changes the classroom experience, in turn, possibly changing student attitudes toward engineering (Besterfield-Sacre et al., 1998; Litzler & Young, 2012).

The current paper describes the results from our pilot study that incorporated PjBL experiential learning in a spring 2012 statics course. Statics is a required course for civil and mechanical engineering degrees and is primarily an application of Newtonian mechanics. Because there are two Statics sections offered each semester, we were able to designate one section as our "treatment" site and the other as our "control." To answer our research questions, we conducted two inter-related analyses: one hypothesis-driven and one exploratory. Our findings will inform the larger-scale study that begins in fall 2012.

Research Hypotheses:

1. Students who participate in Statics classes with a PjBL curriculum (compared to those in a traditionally taught lecture-based course) will demonstrate

- Higher learning gains on the Concept Assessment Tool for Statics (CATS)
- Higher posttest scores in constructs of interest in social cognitive theory after controlling for pretest scores on the Engineering Affect Assessment (EAA)

Exploratory Research Questions:

2. Did the nature of talk vary by type of task? And was the proportion of time spent in concept negotiation related to project grades?

Methods

Our collaborative research team consisted of two civil engineers, a science education researcher, an education assessment researcher, and a science education graduate student. Two engineering instructors each taught a section of Statics, one using the traditional lecture-based approach (40 of 43 students chose to participate in pre/post testing), the other using a PjBL curriculum (67 of 73 students chose to participate in pre/post testing). Students in the treatment class were all expected to work in pre-assigned groups of 3-5 students three times during the semester to demonstrate their knowledge of a) equilibrium; b) structures (bridges); and c) friction. In the treatment class, 35 students volunteered to have their group work video recorded. At the beginning and end of the course, all students in both classes completed the CATS (Steif & Dantzler, 2005) and the EAA (developed by the authors based on Lent et al., 2008). Student consent was obtained before any data were gathered. Most of the students in both classes were White (72%). The traditionally taught class had nine females (25%), while the PjBL course had seven females (13%). Students did not know about the differences in curriculum or instruction when selecting courses.

Students in the treatment class (seven groups) who volunteered to be video recorded used flip cameras during their initial in-class group meeting when presented their PjBL assignment. We developed three types of assignments (tasks) along a continuum: a moderately structured assignment, with opportunities for deviation (Task 1); a well-structured assignment (Task 2); and an ill-defined assignment that required student innovation (Task 3). Tasks 2 (designing and building a bridge that met specific parameters) and 3 (selecting a real-life situation for which friction is beneficial and creatively presenting a demonstration of the concept, along with an explanation of what would occur in a frictionless or near-frictionless environment) included a written component involving calculations that demonstrated depth of concept knowledge and self-reflections written by each student.

Data Analysis

The CATS and EAA results were analyzed to compare the scores of treatment and control classes. A structural equation model based on the social cognitive theory was analyzed using AMOS v. 20 (Arbuckle, 2012). The variables of interest were the posttest scores of self-efficacy, outcome expectations, intention to stay in engineering, and the CATS. The model presented in this paper reflects only those variables that pertain explicitly to social cognitive theory. We also collected data on other constructs (e.g., attitude toward engineering and engineering identity), but discussion of these results is beyond the scope of this paper. We analyzed the videos using a coding heuristic informed by Kittleson and Southerland (2004); the "nature of talk" was classified into one of five categories: *administrative*, *procedural*, *conceptual negotiation (CN)*, *conceptual explanation (CE)*, or *off topic (OT).* We calculated the total percentage of time each group engaged in each of these categories. We did not collect data on the amount of time students spent working outside of class, nor on the subsequent in-class discussions students held. As students were assigned to different groups for Tasks 2 and 3, group number could not be used to compare individual groups or students between the two projects.

To establish trustworthiness of our findings, a guideline for inter-rater coding was concurrently developed. One of us coded 21% of the video recordings to establish inter-rater coding reliability. Before discussion over one-half of the codes overlapped between the two coders. We then discussed the discrepant results, and after clarification of coding criteria, completed the coding process with a 95% coding overlap. The video results were analyzed to compare the project and problem based assignments. The mean amount of time each group spent in each type of conversation was calculated for the bridge and friction assignments. The mean percent of time groups spent in each conversation type were compared using Pearson's Chi-squared tests using SPSS (Table 1). Pearson's r correlations were performed to obtain the strength of the relationship between the percent of time a group spent in CN and their final grade for the assignment.

Findings

Specific Hypothesis Tests

After controlling for pretest CATS scores, there was no statistically significant difference between treatment and control posttest CATS scores (β= -.007, p=.95). Further, model fit indices indicated that the structural equation model provided a good fit to the data (Figure 1). After controlling for all other variables in the model, treatment had a positive statistically significant effect ($p<.05$) on self-efficacy. For every one standard deviation change in student self-efficacy, student intention to stay in engineering was expected to increase by 0.48 standard deviations ($p<.001$). For every one standard deviation change in self-efficacy, outcome expectations increased by 0.18 standard deviation units (non-statistically significant effect). For every one standard deviation change in outcome expectations, student intention to stay in engineering increased by 0.29 standard deviations ($p<.001$). There was a non-statistically significant positive effect of student intention to stay in engineering on CATS posttest scores. Further, as might be expected, student pretest CATS scores were predictive of posttest CATS scores over and above all other variables in the model ($p<.001$). However, pretest scores on the CATS were not predictive of post self-efficacy scores or outcome expectations. Further the correlation between treatment and pretest CATS was non-significant, which indicated that students in the treatment and control group did not differ on the CATS pretest scores.

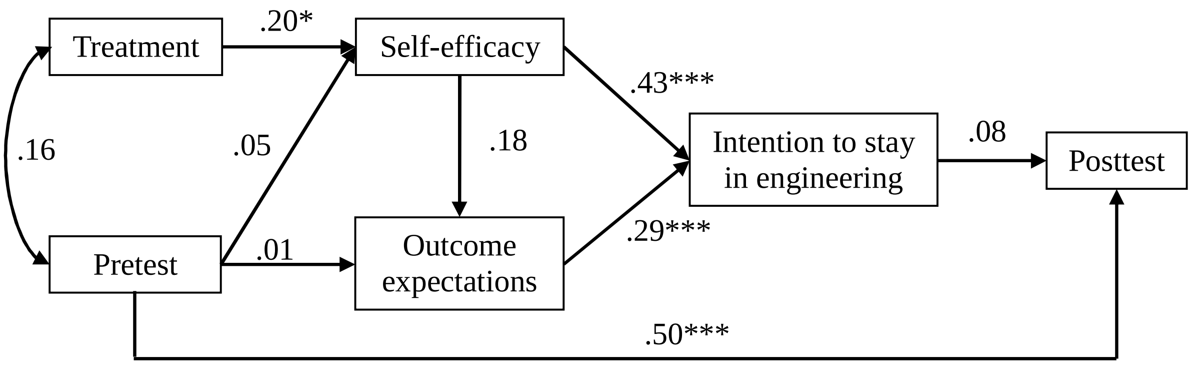

Figure 1: Standardized estimates of the effect of treatment on role of self-efficacy on outcome expectations, intentions to stay in engineering, and post-test scores. Self-efficacy, outcome expectations, and intentions to stay in engineering are all posttest scores. χ^2 (*df*=15)=25.96, p=.04; Comparative fit index= .946; root-mean-square-error-average (90% CI)= .080 (.019, 0.131). Squared multiple correlation of self-efficacy= .43, outcome expectations=. 36, intention=.56, and posttest= .26. Pre-test scores for self-efficacy, outcome expectations, and intentions to stay in engineering were included but not illustrated in the above model as controls for the respective outcome of interest.
* p<.05, **p<.01, ***p<.001.

Exploratory Research Question Results

The video analysis revealed statistically significant differences between the nature of talk students had during their initial group discussions and type of task (Table 1). Students spent a higher percentage of their time in concept negotiation (CN) while working on the bridge task (p<.001), compared to a higher percent of time spent on administrative and procedural discussion while working on the friction task (p<.001). Concept negotiation has been identified as an important type of discussion and may be an indicator of students' motivation to apply foundational concepts in required class activities. CN involved rich exchanges between most or all group members, whereas concept explanation involved a single individual explaining concepts to group members. The discursive activity of concept negotiation is consistent with constructivist learning opportunities that STEM education researchers support (National Research Council, 2012).

Table 1. *Chi-squared tests comparing the percent of time spent in each conversation type for the project-based bridge assignment and the problem-based friction assignment.*

Variables	*df*	Chi-squared	p-value
Administrative Bridge (8.1%) vs Friction (18.8%)	1	14.30	<.001
Procedural Bridge (24.3%) vs Friction (46.4%)	1	20.05	<.001
Conceptual Explanation Bridge (8.7%) vs Friction (10.6%)	1	0.43	0.513
Conceptual Negotiation Bridge (51.9%) vs Friction (17.2%)	1	23.17	<.001
Off Topic Bridge (6.9%) vs Friction (6.9%)	1	0.00	0.99

We further explored CN and student project grades on the two tasks. During the initial group discussion of the bridge task, the proportion of the time spent in concept negotiation was positively correlated with project grades (r=.79, p=0.035). However, in the friction project, there was a statistically non-significant negative relationship between the percent of time spent in CN and the friction grade (r= -.72, p=0.068).

Discussion and Implications

One of the major hurdles of using non-traditional teaching techniques in engineering classes is to ensure that students will gain sufficient knowledge comprehension in order engage in higher order skills. Meta-analyses of PBL and group-work based undergraduate classes have had conflicting results regarding the impact of PBL/group-work on student content knowledge

(Dochy et al., 2003; Helle et al., 2006; Springer et al., 1999). To have time to complete the projects in the Statics class, some of the typical content was trimmed from the treatment class, thus providing the students with a narrower breadth of content. While the students in the treatment section did not outperform students in the control class on the CATS posttest, the results show that the students in the treatment performed as well as students in the control. The fact that treatment student posttest scores did not decrease, and the self-efficacy of treatment students increased, suggests that PjBL curriculum positively impacted engineering students' affect while still enabling them to perform as well as the control on the statics concept inventory.

Another challenge for engineering programs is maintaining student retention (King, 2012). Students in the treatment group had a higher increase in their self-efficacy scores, and in turn, students with higher self-efficacy scores had a greater intention to stay in engineering. These findings add support for the restructuring of engineering classes when retention is a concern. Future analysis of data collected on other constructs (e.g., engineering identity, attitudes toward engineering) in both the pilot and full study may reveal additional treatment effects.

The exploratory video analysis indicated that the different types of group assignments students participated in the treatment class promoted student learning differently (Table1). The clearly defined, project-based bridge assignment promoted much more CN (51.9%) than the more abstract, problem-based friction assignment (17.2%, χ^2=23.17, p<.001). Getting students to participate in CN during group work is one of the goals of group work, since it involves students constructing knowledge together. In student group work, CN is often rare and difficult to encourage (Kittleson & Southerland, 2004). While we did not record student discourse during all of their group work sessions, the high percentages of CN we found in our bridge project indicates that specific assignment details and type (PBL vs PjBL) may have a huge impact on the type of discourse students engage in while working on an assignment. The difference in correlations between time spent in CN and final project grade between the bridge (r=.79, p=0.035) and friction (r= -.72, p=0.068) assignments also indicates that effectiveness of group work in relation to final outcomes may similarly be impacted by assignment details and type. If future work can identify specific assignment characteristics that support increased CN in group work, those findings would be able to help guide curriculum reform by helping to structure group work in a more beneficial manner.

While our pilot study results provide insight into the impact of PBL/PjBL curriculum on engineering student self-efficacy, outcome expectations, and content knowledge, preconceptions about each professor may have impacted student course selection, as well as motivation to participate in course activities, even thought the two sections were taught at the same time. In the full study, both lab sections will be taught by the same professor, removing any instructor effects.

Our future studies will involve the continued testing of PjBL assignments along the inquiry continuum. The relationships between PjBL and self-efficacy, and self-efficacy and intention to stay in engineering identified in this pilot study suggest that gender might be an important variable for future exploration. Felder, Felder, Mauney, Harmin Jr., and Dietz (1995) found that women entered their engineering program better prepared then their male counterparts, but showed a decline in confidence and expectations as they proceed through the engineering curriculum (Felder et al., 1995). Additionally, retention rates for men and women were similar, despite women student's better preparation (Felder et al., 1995).

Extrapolating Felder et al.'s (1995) findings, women had lower retention rates then their equally prepared male counterparts, which may be a major contributing factor to why women are still a minority in engineering (National Science Foundation, 2010). Therefore, programs that help support the success of women in engineering bolster an underrepresented population, as well as supporting overall numbers of enrollment and retention.. While our sample sizes were too small to perform analyses including the effect of gender, if the larger enrollment of Fall classes in our full study provides for a large enough sample, we will include statistical analyses of gender in our assessment of the program.

Sawtelle et al. (2012) synthesized from the literature that women in physics, a closely related discipline to engineering, need a more collaborative and less competitive environment, want a deeper conceptual understanding, need a better connection of science to real life, and have different out of school experiences and prior knowledge than their male counterparts. In Sawtelle et al.'s (2012) study, which compared traditional and inquiry instruction, they found that the success (passing the class) of male students was predicted by mastery experiences, whereas the success of women students was predicted by vicarious learning experiences. Sawtelle et al. (2012) also found a clear positive effect of vicarious learning and retention of the students in the inquiry class, whereas the effect of vicarious learning on retention for the students in the lecture class was small and ambiguous. If we are able to include gender into our future research, our results will help to further knowledge about the persisting gender gap in engineering, and may help define curriculum that helps remove the barriers that still exist for women in engineering.

The National Research National Research Council (2012) implores science and engineering educators to adopt research-based instructional practices to improve undergraduate learning outcomes. In this vein, our study examines how engineering students learn how to apply foundational physics concepts during design tasks. Because our research focuses on the impact that curricular design and instructional strategies can have on content knowledge and self-efficacy, our findings will be of interest to undergraduate educators in many STEM disciplines. Moreover, our interdisciplinary research team illustrates the importance of endeavors that bring together experts in engineering, science education, and educational assessment in our effort to improve undergraduate STEM education.

References

Arbuckle, J. (2012). AMOS (Version 20.0). Chicago, IL: Amos Development Corporation.

Bandura, A. (1977). Self-efficacy: Toward a Unifying Theory of Behavioral Change. *Psychological Review, 84*(2), 191-215.

Bandura, A. (1982). Self-Effcacy Mechansm in Human Agency. *American Psychologist*, *37*(2), 122-147.

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Englewood Cliffs, NJ: Prentice Hall.

Besterfield-Sacre, M., Atman, C. J., & Shuman, L. J. (1998). Engineering Student Attitudes Assessment. *Journal of Engineering Education, 97*(April), 133-141.

Betz, N. E., & Hackett, G. (1981). The Relationship of Career-Related Self-Efficacy Expectations to Perceived Career Options in College Women and Men. *Journal of Counseling Psychology, 28*(5), 399-410.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (2000). *How People Learn: Brain, Mind, Experinece and School.* Washington, D.C.: National Academy Press.

Dochy, F., Segers, M., Van den Bossche, P., & Gijbels, D. (2003). Effects of problem-based learning: a meta-analysis. *Learning and Instruction, 13,* 533-568.

Evenson, D. H., & Hmelo-Silver, C. E. (2000). *Problem-based learning: A research perspective of learning interactions*. Mahwah, N.J.: Lawrence Erlbaum Associates.

Felder, R. M., Felder, G. N., Mauney, M., Harmin Jr., C. E., & Dietz, E. J. (1995). A longitudinal study of engineering student performance and retention III. Gender differences in student performance and attitudes. *Engineering Education, 84*(2), 151-163.

Gallagher, S. A., Sher, B. T., Stepien, W. J., & Workman, D. (1995). Implementing Problem-Based Learning in Science Classrooms. *School Science and Mathematics, 95*, 136-146.

Gijbels, D., Dochy, F., Van den Bossche, P., & Segers, M. (2005). Effects of problem-based learning: A meta-analysis from the angle of assessment. *Review of Educational Research, 75*(1), 27-61.

Helle, L., Tynjala, P., & Olkinuora, E. (2006). Project-based learning in post-secondary education: theory, practice and rubber slingshots. *Higher Education, 51*, 287-314.

Heywood, J. (2005). *Engineering education: Research and development in curriculum and intruction*. Hoboken, NJ: John Wiley & Sons, Inc.

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? *Educational Psychology Review, 16*(3), 235-266.

King, C. J. (2012). Restructuring Engineering Education: Why, How And When? *Journal of Engineering Education, 101*(1), 1-5.

Kittleson, J. M., & 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. doi: 10.1002/tea.20003

Lent, R. W., Brown, S. D., & Hackett, G. (1994). Toward a Unifying Social Cognitive Theory of Career and Academic Interest, Choice, and Performance. *Journal of Vocational Behavior, 45*(79-122), 79.

Lent, R. W., Sheu, H., Singley, D., Schmidt, J. A., Schmidt, L. D., & Gloster, C. S. (2008). Longitudinal relations of self-efficacy to outcome expectations, interests, and major choice goals in engineering students. *Journal of Vocational Behavior, 73*, 328-335.

Litzler, E., & Young, J. (2012). Understanding the Risk of Attrition in Undergraduate Engineering: REsults from the Project to Assess Climate in Engineering. *Journal of Engineering Education, 101*(2), 319-345.

Mulvey, P. J., & Nicholson, S. (2007). Physics undergraduate enrollments and degrees. http://www.aip.org/statistics/trends/reports/EDphysund07.pdf: American Institute of Physics Statistical Research Center.

National Academy of Engineering. (2004). *The Engineer of 2020: Visions of engineering in the new century*. Washington, D.C.: National Academies Press.

National Academy of Engineering. (2005). *Educating the Engineer of 2020: Adapting engineering education to the new century*. Washington, D.C.: National Academies Press.

National Research Council. (2007). *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*. Washington, D.C.: National Academies Press.

National Research Council. (2010). *Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5*. Washington, D.C.: National Academies Press Retrieved from http://www.nap.edu/catalog.php?record_id=12999.

National Research Council. (2012). *Discipline-Based Education Research: Understanding and Improving Learning in Undergraduate Science and Engineering*. Washington, D.C.: National Academy Press.

National Science Foundation. (2010). *Special tabulations of U.S. Department of Education, Integrated Postsecondary Education Data System, Completions Survey, 2001-10.* http://www.nsf.gov/statistics/wmpd/pdf/tab5-1.pdf.

Sawtelle, V., Brewe, E., & Kramer, L. H. (2012). Exploring the Relationship Between Self Efficacy and Retention in Introductory Physics. *Journal of Research in Science Teaching, 49*(9), 1096-1121.

Splitt, F. G. (2003). The challenge to change: On realizing the new paradigm for engineering education. *Journal of Engineering Education, 92*(2), 181-188.

Springer, L., Stanne, M. E., & Donovan, S. S. (1999). Effects of Small-Group Learning on Undergraduates in Science, Mathematics, Engineering, and Technology: A Meta-Analysis. *Review of Educational Research, 69*(1), 21-51.

Steif, P. S., & Dantzler, J. A. (2005). A statics concept inventory: Development and psychometric analysis. *Journal of Engineering Education*, *94*(4), 363-371.