Project-Based Learning in Statics: Curriculum, Student Outcomes, and Ongoing Questions

Introduction

Project-based learning is a term that can be used to describe many different student experiences, and it is closely related to other types of student centered or inductive learning practices such as problem based learning, case-based teaching and discovery learning[1]. While there is a great deal of variety in what constitutes a project, two key features can be used to define project-based learning: the assignment is driven by a motivating problem to be addressed and requires some kind of end product, be it a report, presentation or physical artifact[2]. Other common characteristics of projects are students working in teams[3] and the greater emphasis on the application, rather than acquisition, of knowledge[4].

Projects are a natural fit for engineering education because they reflect professional practice and provide an opportunity for students to develop the teamwork and communication skills they will need[5]. Furthermore, the broader use of projects in engineering curricula is compatible with recommendations for improving engineering education, such as including design early in the curriculum[6]. Projects are also reported to improve student motivation to learn[1, 2, 7].

While project-based learning has been widely adopted for senior design capstone courses and is becoming more common in freshman level courses[8], the use of projects in intermediate courses in engineering science is still rare. The National Science Board[9] has identified three key challenges facing engineering education including the need to retain more engineering majors and the need to teach these students the professional skills needed to practice in the 21st century. Projects can be an important instructional strategy that engineering educators can implement to address these challenges; however, in-depth evaluations of the effect that project-based learning has on a variety of student outcomes are difficult to find[3]. Without formal evaluations of the effect of projects, it can be hard to justify the time spent by faculty to develop and implement project-based learning in their courses. This is particularly true in an academic culture where incentives, such as tenure and promotion, are strongly aligned with faculty research productivity rather than teaching outcomes[10].

Purpose

The intent of this study was to measure the effect of project-based learning on a variety of student outcomes related to both content knowledge and affect. Three group design project assignments were developed and implemented in an intervention course. Several different assessment tools were used to compare student outcomes for the intervention section against a control section. This paper provides a summary of the complete effort including a description of the project assignments and primary findings from all of the assessment tools. Further details and more complete analyses for individual assessments will be published in forthcoming journal articles.

Study Overview

Statics was chosen for this study because it is typically taught in a large lecture format and is an important gateway course for several engineering majors. It is generally taken early in the second year – an important time when students may be considering whether to stay in the major or not. The study was conducted over the course of two semesters. The spring of 2012 semester was used as a pilot semester to test out both the project assignments and the assessment tools. During this semester two sections of statics were taught by two different instructors. The section with the project-based interventions had a final enrollment of 72 students while the control section had a final enrollment of 42. Data from this semester were collected and analyzed[11], but the true experimental semester occurred in the subsequent fall. This paper focuses on findings from the fall.

In the fall of 2012, two sections of statics were taught back-to-back, three days a week by the same instructor. The intervention section had 101 of 112 students consent to participate, while the control section had 108 of 115. The study design was quasi-experimental as students were not randomly assigned to the sections; rather both sections were opened for enrollment, and students were allowed to register for the sections without knowledge of the planned intervention. Furthermore, students were prevented from switching sections after they learned of the research activities because both sections were full, and the department did not provide overrides for students looking to switch sections. The control and intervention sections were 86% and 77% male, respectively, and 5% and 7% ethnic minority students. The classes were primarily composed of mechanical (52% control and 46% intervention), civil (32% and 30%), and environmental (11% and 16%) engineering majors. Chi-square tests revealed no statistically significant differences in the classes on ethnicity (χ^2 [df = 7] = 4.81, p = .68), sex (χ^2 [df = 1] = 2.57, p = .11), or major (χ^2 [df = 7] = 3.87, p = .80).

Curriculum and Instruction

This study was designed to examine the effect of adding group design projects to a traditional statics course. The projects were used as a supplement to, rather than replacement for, traditional instruction. Other aspects of the courses were kept as similar as possible. The control and intervention sections were taught with the same lecture content. An audience response system (i.e., clickers) was used most days in both sections in an effort to engage students and offer some feedback on understanding (formative assessment). In the intervention section students were allowed roughly 20-30 minutes of class time to meet with their groups for each of the three design projects. At the beginning of the semester the intervention section also had a one day lecture on the engineering design process that the control section did not have. In order to keep lecture schedules in the two sections roughly aligned, the control section had extra in-class examples on the days the intervention section was working in groups.

Student grades were based on homework assignments from the textbook (15% control, 13% intervention), class participation including audience response system use and participation in research activities or completion of alternative assignments (10% control, 7% intervention), midterm exams (45% control, 30% intervention), group design projects (0% control, 30% intervention), and a final exam (30% control, 20% intervention). The three midterm exams were administered during class. The exam content was identical for both classes – three versions of each exam were made and these three versions were distributed in both sections. During the experimental semester, the intervention section presented their projects during an evening time usually reserved for exams, because in-class presentations had taken up a lot of time in the pilot semester.

In the intervention section the course content was grouped into three rough units with one of the group design projects relating to the content of each unit. The midterm exams also were administered roughly at the end of each unit. To encourage students to link the projects to their future as engineers, at the beginning of the semester a lecture period was spent talking about the engineering design process. For each project, teams of students were required to design and construct an artifact, demonstrate its operation to the class, and prepare a report including a description of their design and the analysis (based on their statics knowledge) they conducted. Reports also included a self-reflection requirement for which students had to explain what they learned from the project and how they would approach the project differently, if given the same assignment again. The project teams were assigned by the instructor and changed for each project. The grouping of students did not follow any set of guidelines, but groups were created to ensure that students who consented to be video-recorded were placed with one another.

The first unit covered equilibrium. Lecture topics during this period included equilibrium of particles and rigid bodies, vector summations of forces and moments, and computing reactions. For this unit students were asked to work in teams of mostly five students to build a Rube Goldberg machine that would raise a team flag. The machine was required to have at least one component per group member, and each group member was to serve as the "design engineer" for that component having responsibility for its analysis. Each component was required to operate on principles that could be described with statics. Components generally operated by having some external effect disturbing an existing equilibrium condition. Ramps, teeter-totters, pulleys, and weights were common features of the machines. Thirty percent of their grade was based on the actual machine with the remaining seventy percent from the report and analysis. The same project was used in both the pilot and experimental semesters, however in the fall, perhaps because the demonstrations were made outside of class time, groups made much larger and more elaborate machines that, in some cases, required a long setup time. If this project is used again in the future, grading criteria will include limits on setup time and, perhaps, on size.

The second unit focused on applications of equilibrium with topics such as trusses, frames, machines and beams. Student teams built a bridge using only materials provided by the instructor (basswood sticks and string). The bridge was required to span a distance of 0.61 meters (2 feet), and was loaded via point load at the midspan of the bridge. This project included three phases. Teams first had to submit a design drawing of the bridge they planned to construct. This drawing was graded primarily on neatness and clarity (15% of total grade). In the second phase teams had to construct the bridge (15% of total grade) and write a portion of the report describing how they arrived at their design concept, analyzing the components of the bridge, and predicting a failure location (40% of total grade). After testing teams had to write about the failure of their bridge and explain and analyze why it failed the way it did (30% including self-reflections). The same assignment was used in the spring and fall sections. Future improvements to this project should include a quicker technique for applying load (ball bearings in a bucket were used) and students should be required to formally analyze the failures of the other bridges in the class. Student conversations during the loading presentations clearly indicated that they were thinking about the pros and cons of different configurations. Formalizing this discussion would be valuable.

The third unit was not as well defined; it included friction and other topics such as moment of inertia and virtual work that need to be covered in a statics course. The project for this unit covered friction. In the spring, pilot groups were asked to identify a real world engineering design situation where friction is an important variable in either a positive or negative sense. Groups had to demonstrate this situation in class and explain how friction was working to help or hinder the situation. They also had to prepare calculations showing the effect of friction and how the situation would be different if friction was not present. One goal of the project was to encourage teams to learn more about different types of friction independently. While there were some interesting and unique demonstrations (fire starting, friction in climbing knots, the operation of clutches) there was also much duplication with three presentations on bike brakes and three presentations on bike wheel bearings. This assignment was very open ended without a real design objective. In the fall, the project was reconsidered and was rewritten to require students to produce an actual design. Teams were given dimensions of a ramp and asked to help the school mascot climb the “mountain” using friction to their advantage. This project again resulted in quite a bit of duplication with the mascot sitting on some type of sled or cart that was pulled up the ramp being a very common approach. The mascot was held on the cart with a high friction surface, such as sandpaper. With this modification to the assignment the intent for teams to independently learn about friction to create an innovative approach was not well communicated, and very few teams did any research beyond looking up typical friction coefficients. Some combination of these two assignments would be attractive for future efforts.

Assessment Tools

At the beginning and end of the semester consenting students in each section were asked to complete the Concept Assessment Tool for Statics (CATS)[12], and the Engineering Affective

Assessment (EAA) online outside of class time. The EAA was compiled by the authors and included questions related to two different theoretical frameworks. Social Cognitive Career Theory (SCCT) was used to investigate student career development, including their intention to remain in engineering. The SCCT questions used on the EAA were adapted from Lent et al.[13]. The Patterns of Adaptive Leaning Scale (PALS)[14] was used to measure constructs related to achievement goal theory as a way to investigate possible changes or differences in motivation and their relationship to academic outcomes of interest between the control and intervention sections. Further background and results for these two frameworks are provided in subsequent sections.

In addition to these quantitative tools, video recordings of teams were made for video analysis of group work dynamics. For each of the three design projects teams were given 20-30 minutes of class time to meet with their groups. Teams were composed so only students consenting to be videorecorded were placed with one another. For each project 12 of 22 teams were videotaped although upon review not all videos were suitable for analysis. During times reserved for group work each team was given a small video camera (flip cam), tripod, and directions to record their group meeting.

Content Knowledge Outcomes

The CATS and the final exam were the only assessment tools used to measure and compare content knowledge outcomes. However, the final exams were not identical for the two classes and cannot be directly compared. Students in the control and intervention sections showed no statistically significant difference in their post CATS scores ($t=-.17$, $p= 0.86$) based on an independent samples t-test. This finding is interesting because of differences in the ways the students in the two sections spent their course related time. On one hand the control section had the equivalent of roughly two to three additional fifty minute lectures on statics content compared to the intervention section because of the class time the intervention section spent working in groups and talking about engineering design. On the other hand, students in the intervention section likely spent more time outside of class working on course related activities because they were assigned the same textbook homework problems as the control section, plus the three group project assignments. The lack of difference in the post CATS score seemed to indicate that students in the intervention section were not harmed by re-directing some class time from lectures to the project activities. Furthermore, the finding that the additional time spent outside of class on statics topics did not result in higher post CATS scores for the intervention section is consistent with a number of studies that have found that the link between time spent outside of class and course grades is weak at best[15, 16, 17, 18].

It is also important to acknowledge limitations of the CATS assessment as the only measure of differences in student content knowledge in this study. The CATS is a concept inventory designed to measure grasp of basic statics concepts. It is appropriate for this study because it measures concepts that students should learn from any statics class, no matter how it is taught.

At the same time, the strength of this assessment is also a weakness. Students who completed the projects had different experiences with the course materials, and items that were more focused on the specific content covered by the projects may have shown differences in content knowledge. For example, in the intervention section the second project covered bridges and most groups constructed and tested a design involving trusses. These groups may have had a different level of understanding of trusses than students in the control section, but the CATS did not include any questions specific to trusses. Future assessment efforts would benefit from using additional tools to measure content knowledge.

Social Cognitive Career Theory (SCCT)

Social Cognitive Career Theory[19] has been adapted from the more general Social Cognitive Theory[20] to specifically consider the way that the social cognitive variables (self-efficacy, outcome expectations, and goals) interact with other variables in the environment to describe career development. SCCT is composed of three overlapping models that describe how people 1) develop interests in specific careers, 2) make choices about and take actions in pursuit of particular careers, and 3) perform within their chosen domain. This study made use of the performance model (Figure 1).

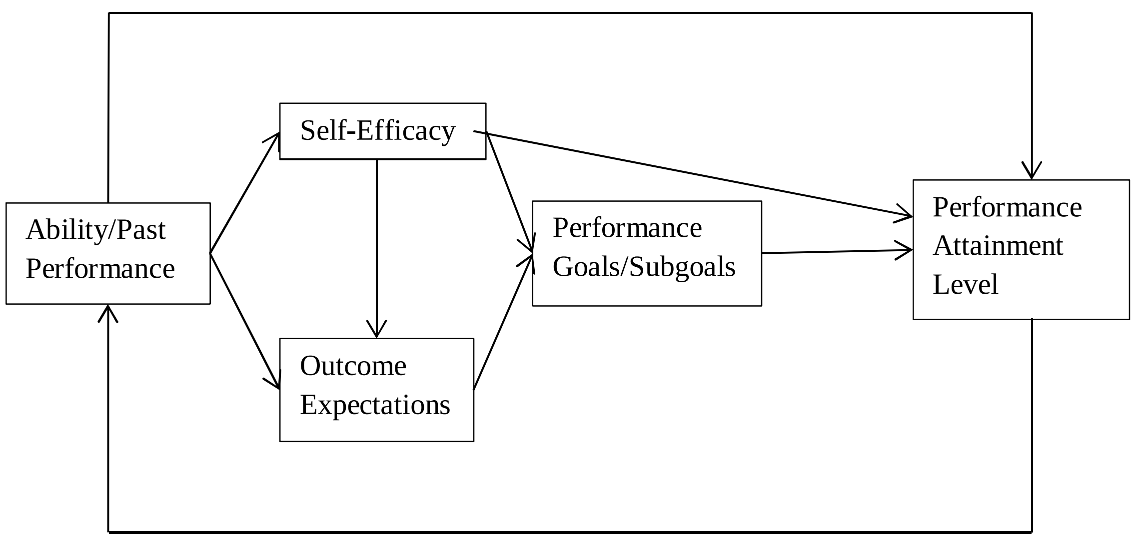

Figure 1. Social Cognitive Career Theory Performance Model [19]

The EAA collected data about variables, including self-efficacy and outcome expectations (Fig. 1). The intention to persist in engineering was modeled as part of the performance goals, and student CATS scores were used to indicate performance attainment. We hypothesized that students in both sections would demonstrate career development consistent with the SCCT model including the mediated relationships, and that students in the intervention section who participated in the project assignments would experience a positive change in their intention to persist and their CATS score that could be measured with the SCCT model.

A series of t-tests revealed no statistically significant differences between the control and intervention sections at pre-or post-test, indicating no main effects of the project assignments on the social cognitive variables. The groups also showed similar relationships among the variables at pre and post-test, with the exception that the moderately positive relationship (r=0.27) between post self-efficacy and post outcome expectations was statistically significant (p <.05) for the intervention section but was not significant for the control section A multi-group structural equation analysis of the SCCT model was conducted for the intervention and control groups. This analysis revealed that the magnitude of the effect of self-efficacy and outcome expectations on goals was similar for both sections, as was the effect of self-efficacy on CATS. However, self-efficacy only influenced outcome expectations for the intervention group, and goals were only statistically significantly predictive of the CATS for the intervention group. Thus, students taught in the control class did not demonstrate the career development pattern predicted by SCCT.

Analyses were also conducted to explore the mediations proposed by the SCCT model. A bootstrapping procedure with 10,000 repetitions to create a 95% bias corrected confidence interval for the indirect effect was used[21, 22]. For the intervention class, the effect of self-efficacy on goals was partially mediated through outcome expectations, this mediation did not hold for the control section. Subseqently, we tested for the mediated effect of self-efficacy through outcome expectations and goals on the post CATS score. In this case the mediated path was again found to be statistcialy significant for the intervention section, but not the control section.

SCCT was found to be a good fit for the data we collected, and this model was able to show the impact of curriculum on student development and intention to persist in engineering. Our findings indicate that the projects seemed to affect student career goals by aligning student appraisals of their efficacy as an engineering student with their expectations of success in the statics course and as a future engineer. Students in the intervention class made the connection between their own abilities and the outcomes they could expect from remaining in an engineering major, which had a positive effect on their goals and academic performance. Students in the control section did not draw the connection between their ability and expected outcomes.

Achievement Goal Theory

To capture how the incorporation of projects influenced student motivation, we examined student motivation through the lens of achievement goal theory. In short, achievement goal theory posits that students want to display competence (performance orientation) and/or be competent (mastery orientation[23]). Because project based learning was expected to make the application of knowledge more salient for the intervention class, we first hypothesized that these students would display higher levels of mastery orientation and lower levels of performance orientation when compared to the control class. We also hypothesized that students' mastery orientation in both classes would be positively associated with final exam scores and scores on statics concept inventory (Concept Assessment Tool for Statics [CATS][12]). Further, we expected that students' performance orientation (defined as wanting to avoid looking bad or trying to look good in front of peers) would be negatively associated with student scores on the same assessments.

Normally, performance goal orientation is further subdivided into performance approach (wanting to look good) and performance avoidance (wanting not to look bad [23]). However, in some samples, these two may not be distinguishable[25]. For this sample of students the correlations between these two constructs were quite high ($r_{pretest}$=.75, $r_{posttest}$=.81), and exploratory factor analysis indicated only one factor. Thus, we collapsed these two constructs into one.

Independent sample t-tests indicated that students in the intervention class had higher mastery orientation and lower performance orientation at the beginning of the semester immediately after the syllabus was introduced ($t_{mastery}$=2.11, p=.04, d=.32; $t_{performance}$=-2.22, d=-.34, p=.03). The difference in mastery orientation was still present between the two classes at the end of the semester ($t_{mastery}$=2.45, p=.02, d=.42) but not performance orientation ($t_{performance}$ = -1.59, d=-.37, p=.11). This partially supported the first hypothesis.

Because the two classes differed on their goal orientations at the beginning of the semester, we ran separate multiple regression analyses to examine the relationship between goal orientations and the CATS controlling for the pretest CATS scores as well as the final exam score. In the intervention class, mastery orientation was positively associated with scores on the CATS (β=0.09, b=7.44, p=.01), and performance orientation was negatively associated with final exam scores (β=-0.24, b=-0.31, p=.03). In the control class, only the pre-assessment was uniquely predictive of the scores on the CATS and the final exam over and above the mastery and performance orientations. Thus, the final two hypotheses only held for the intervention class and then only partially.

These findings, that the intervention class exhibited greater mastery orientation and lower performance orientation, hint at the ability of project-based learning to change student motivation in engineering courses. The deeper approach to learning taken by students with a mastery orientation is important in a foundational course such as statics an important prerequisite for higher-level engineering courses. It would be interesting to know if the mastery orientation adopted by students in the intervention section carries over to future courses.

Video Analysis

In the intervention section students were asked to videotape one in-class group meeting for each of the three projects. Videos were analyzed to study student interactions, which may help explicate student performance outcomes, while participating in design tasks. During the pilot and experimental semesters we examined student interactions during group work to answer several research questions: (1) Did the nature of talk vary by type of task? (2) Was the proportion of time spent in concept negotiation related to project grades? (3) How did the nature of talk vary in groups with different gender ratios?

Research questions 1 and 2 were explored using a coding heuristic informed by Kittleson and Southerland[26]. Students' "nature of talk" was classified into one of five categories: *administrative*, *procedural*, *conceptual negotiation (CN)*, *conceptual explanation (CE)*, or *off topic (OT)*. Results for the pilot are presented in [13], and analysis for the experimental semester is ongoing.

Videos from the pilot and experimental semesters were combined for research question 3 in order to increase the pool of data. In addition to the "nature of talk" heuristic, we used inductive coding to examine how women and men interacted with one another when there was only one woman or there were two women per group. After several rounds of coding by two coders, utterances and supporting gestures (e.g., taking notes, turning to a group member) were recorded in four categories: (i) Initiate/Respond (new concept introduced/comment made about a concept or idea previously introduced), (ii) Novel/Reiterate (new idea or information added/reiteration of statement previously made), (iii) Statement/Question (declarative statement/ query about concept), and (iv) Hesitant/Not Hesitant. Hesitancy was defined as displaying at least two of the following characteristics: use of filler words, breaks in speech, rising inflection as if asking a question, or preface discrediting the claims being made. Data were organized as: 1) the types of participation and nature of talk; 2) who led the discussion; 3) occurrence of conceptual talk or not; and 4) who was engaged in conceptual talk, if it occurred. 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.

We found that women in the 1-woman groups initiated discussions less, initiated and participated in conceptual discussions less, and their contributions were acknowledged less by their male peers. In the 1-woman groups, only half (5 of 10) had a topic initiated by a woman, compared to all 2-woman groups (6 of 6 groups, 11 of 12 women in the groups). A higher percentage of the 1-woman groups (8 of 10) participated in conceptual discussion than 2-woman groups (3 of 6). However, there were more 2-women groups in the first project, where many groups had already worked on their project prior to class discussion. Overall, women, regardless of group type, rarely initiated conversation regarding statics and Newtonian physics (CN or CE). For groups with conceptual discussion, women in 2-women groups initiated conceptual discussion more (all 3 groups, 3 of 6 women) than in 1-woman groups (1 group). All of the women in 2-woman groups participated in conceptual discussions. In 1-woman groups, while 6 of 8 women participated in conceptual discussions, only 1 woman made influencing contributions. In two of the 1-woman groups, after a woman introduced a conceptual idea, her male group-mates ignored her comment, and about 1-2 minutes later, when a man re-introduced the idea as novel, it was quickly acknowledged by the group. Three women students were members of both 1-woman and 2-women groups. None of these women appeared to be hesitant in either type of group, but all three women were engaged in more discussion when they were in 2-women groups. The most important finding of this exploratory study is that the number of times and amount of time that women engaged in either CN or CE discussions was much less frequent than that of men. Because the number of women was so much lower than that of men, we did not conduct any statistical analyses.

Our findings support findings of others who study women in engineering and we posit that our study begs further research on the impact of project based tasks on mixed gender groups. Calls for reform of engineering education[6] are very supportive of problem-based authentic tasks, as well as of opportunities for students to develop their collaborative and communication skills, since these are necessary skills for professional engineers. If engineering educators respond to these calls and begin modifying their curricula to incorporate such activities, it is essential that we identify how groups can be assigned or project based learning prompts developed to not discourage women from persisting in engineering degree programs.

Summary and Conclusions

In this project we used a variety of methods to assess the impact of project-based learning in a statics course by comparing student outcomes in control and treatment sections. Content knowledge as measured by the CATS for the two sections was the same. Using SCCT we found that students in the intervention section drew a connection between their self-efficacy in the course and their outcome expectations for the course and their engineering major. This connection in turn impacted student goals and CATS scores. The connection between self-efficacy and outcome expectations was not present for students in the control section. Student motivation was investigated using achievement goal theory. Students in the intervention section demonstrated a higher mastery orientation and lower performance orientation than students in the control section at the beginning of the semester following the presentation of the different course syllabi. By the end of the semester, intervention section students still had a higher mastery orientation, but their performance orientation now matched the control section. We suspected that this was due to the approaching final exam and assignment of final course grades. In-class group work in the intervention section was recorded and analyzed, indicating that male and female students did not necessarily interact within their group members in the same ways.

The differences in student outcomes between the two sections were modest but measureable. Positive impacts were measured for the project-based learning sections using several assessment tools. While the changes in student outcomes were modest, they were in proportion to the changes made in the course. The project experience was not immersive; the projects were used as a supplement to traditional instruction. Instructor time was spent developing the new assignments and grading the projects, but in subsequent semesters only additional grading will be necessary. Thus, the means of implementing group design projects investigated in this study is accessible to most engineering educators who want to improve student learning and affect outcomes. We have shown that even this fairly straightforward modification benefits students. We hope that faculty members recognize that they can gradually improve their courses by starting with a simple improvement, such as that described above, and progressively enhance their assignments.

Areas for Future Research

The findings of this study have illuminated several promising areas for further research. An especially important area for further investigation is asking what aspects of the project-based learning experience produced the observed changes in student outcomes? Group work alone has been associated with many of the benefits we witnessed [27]. It would be valuable to know what role, if any, the hands-on construction, introduction to design, or practical application of lecture topics had on student learning. Video analysis results from the pilot[13] indicated that the type of project prompt could be important to how groups interacted (and we would hypothesize what they learned). A follow up experiment in a different course to further investigate the type of prompt was conducted in Fall 2013 for which the data need to be analyzed.

Another area for study is the long term effects of this project-based course on students' learning and affective outcomes. Do the impacts described in this paper persist, or are they dimmed by subsequent courses taught without projects? Also, how would the results presented here change for a more immersive project experience? We made modest curriculum changes and produced some benefit for students. Would more dramatic changes lead to much larger benefits for students? And finally, we would like to specifically highlight the need for additional research to ensure that all students are benefitting comparably from project-based curricula. We found that female students may interact with peers differently than male students do in groups with different gender composition. If projects are more often adopted in the name of engineering education reform, it is important to make sure these reforms benefit all students.

Acknowledgement

This material is based upon work supported by the National Science Foundation Research Initiation Grants in Engineering Education Program under Grant No. 1137023. We would also like to acknowledge the assistance of Nathan Miller and Alexandra Dukeman who assisted with the course as GTAs.

Bibliography

1. Prince, M.J. and Felder, R.M. (2006). Inductive Teaching and Learing Methods:Definitions, Comparisons and Research Bases. *Journal of Engineering Education,* 95(2), 123-138.
2. Blumenfeld,P.C., Soloway, E., Marx, R.W., Krajcik, J.S., Guzdial, M., & Palincsar, A. (1991). "Sustaining Project-Based Learning: Sustaining the Doing, Supporting the Learning. *Educational Psychologist:* 26(3&4), 369-398.
3. Helle, L., Tynjälä, P., and Olkinuora, E. (2006). "Project-Based Learning in Post-Secondary Education – Theory, Practice and Rubber Sling Shots," *Higher Education*, 51: 287-314.
4. Mills, J.E. and Treagust, D.F. (2003). "Engineering education – is problem-based or project-based learning the answer?" *Australasian Journal of Engineering Education*, http://www.aaee.com.au/journal/2003/mills_treagust03.pdf
5. Schachterle, L. and Vinther, O. (1996). Introduction: The Role of Projects in Engineering Education. *European Journal of Engineering Education*, 21(2), 115-120.
6. National Academy of Engineering. (2005). *Educating the Engineer of 2020: Adapting engineering education to the new century*. Washington, D.C.: National Academies Press.
7. Thomas, J.W., *A Review of Research on Project-Based Learning,* San Rafael, CA: Autodesk Foundation, 2000.
8. Dym, C.L., Agogino, A.M., Eris, O. Frey, D.D. and Leifer, L.J. (2005). Engineering Design Thinking, Teaching and Learning. *Journal of Engineering Education,* 94(1), 103-120.
9. National Science Board. (2007). *Moving forward to improve engineering education.* Arlington, VA.: National Science Foundations. Retreived from http://www.nsf.gov/pubs/2007/nsb07122/nsb07122.pdf.
10. National Research Council. (1995). *Engineering Education: Designing an Adaptive System.* Washington, D.C.: National Academy Press.
11. Casper, A.M., Balgopal, M.M., Rambo, K., Atadero, R., & Fontane, D. "The impact of project-based group work on engineering college students' content knowledge and affect." Annual Conference of the National Association of Researchers in Science Teaching, Puerto Rico (refereed, April 2013).
12. Steif, P. (2010). Concept Assessment Tool for Statics (CATS). https://cihub.org/resources/3.
13. Lent, R. W., Sheu, H. B., Singley, D., Schmidt, J. A., Schmidt, L. C., & 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*(2), 328-335. doi: 10.1016/j.jvb.2008.07.005
14. Midley, C., Maehr, M.L., Hruda, L.Z., Anderman, E., Anderman, L., Freeman, K.E., Gheen, M., Kaplan, A., Kuman, R., Middleton, M.J., Nelson, J., Roeser, R., & Urdan, T. (2000). *Manual for the Patterns of Adaptive Learning Scales.* Ann Arbor: University of Michigan Press.
15. Guillaume, D. W., & Khachikian, C. S. (2011). The effect of time-on-task on student grades and grade expectations. *Assessment & Evaluation in Higher Education, 36*(3), 251-261.

16. Nonis, S. A., & Hudson, G. I. (2006). Academic performance of college students: Influence of time spent studying and working. *Journal of Education for Business*, *81*(3), 151-159.
17. Plant, E.A., Ericsson, K.A., Hill, L., and Asberg, K. (2005). Why study time does not predict grade point average across college students: Implications of deliberate practice for academic performance. *Contemporary Educational Psychology*, 30, 96-106.
18. Schuman, H., Walsh, E., Olson, C., & Etheridge, B. (1985). Effort and reward: The assumption that college grades are affected by quantity of study. *Social Forces*, *63*(4), 945-966.
19. Lent, R.W., Brown, S.D., and Hackett, G. (1994). Toward a unifying social cognitive theory of career and academic interest, choice, and performance. *Journal of Vocational Behavior*, 45, 79-122.
20. Bandura, A. (1986), *Social Foundations of Thought and Action: A Social Cognitive Theory*. Englewood Cliffs, NJ: Prentice Hall.
21. MacKinnon, D. P., Fairchild, A. J., & Fritz, M. S. (2007). Mediation Analysis. *Annual Review of Psychology, 58*, 593-614. doi: 10.1146/annurev.psych.58.110405.085542
22. Shrout, P. E., & Bolger, N. (2002). Mediation in experimental and nonexperimental studies: New procedures and recommendations. *Psychological Methods, 7*(4), 422-445. doi: 10.1037/1082-989X.7.4.422
23. Anderman, E. M., & Wolters, C. A. (2006). Goals, Values, and Affect: Influences on Student Motivation. In P. A. Alexander & P. H. Winne (Eds.), *Handbook of educational psychology*. (pp. 369-389). Mahwah, NJ US: Lawrence Erlbaum Associates Publishers.
24. Nicholls, J. G. (1984). Achievement motivation: Conceptions of ability, subjective experience, task choice, and performance. *Psychological Review, 91*(3), 328-346.
25. Linnenbrink-Garcia, L., Middleton, M. J., Ciani, K. D., Easter, M. A., O'Keefe, P. A., & Zusho, A. (2012). The strength of the relation between performance-approach and performance-avoidance goal orientations: Theoretical, methodological, and instructional implications. *Educational Psychologist*, *47*(4), 281-301.
26. 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.
27. Springer, L., Stanne, M.E., and Donovan, S.S. (1999). Effects of Small-Group Learning on Undergraduates in Science, Mathematics, Engineering, and Technology. *Review of Educational Research*, 69(1), 21-51.