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

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Introduction: Potential Contributions of Student Design Projects to Challenges Facing Engineering Education

Challenges	Potential Contributions of Project-Based Learning
Teaching required disciplinary content in a 4 year degree program	Projects offer the opportunity for students to be at least introduced to many topics and encourage self-directed learning.
Promoting creativity and innovation in students	Projects can be more open ended without "correct" answers. They offer students the chance to bring their own ideas into the situation.
Promoting life-long learning	Projects help students see the range of information beyond what is learned in school, introduce them to resources they can use in the future, and teach them how to find new resources.
Encouraging knowledge flexibility	Projects can force students to apply their knowledge to different contexts.
Helping students relate to the profession especially in early years	Projects can introduce realistic situations to students and help them see the relevance of the fundamental (e.g., mathematical, scientific) principles to engineering design and analysis.
Practical ingenuity	Construction of a final product can give students hands-on experience.
Motivating students	Providing relevance, promoting creativity, and presenting challenging situations can all be used to motivate student learning.
Providing personal interaction with students	Personal interaction with faculty has been shown to be an important motivator, particularly for underrepresented students, but with growing class sizes this can be difficult. The context of a project can allow for small group meetings or encourage students to participate in office hours.
Teaching non-technical skills	Projects offer a perfect opportunity to combine communication, group work and leadership skills with technical content, ethics and management concepts can also be introduced.

Problem Statement and Objective

While projects appear to have much to offer engineering education, rigorous evaluations of the impact of projects on student outcomes are rare. [1,2]

The objective of the project is to study the incorporation of three group design projects into a sophomore level statics course and to measure the effect of the changes on student outcomes including content knowledge and various affective outcomes.

Research Overview

In a quasi-experimental design, two sections of Statics were taught by the same instructor during the Fall of 2102

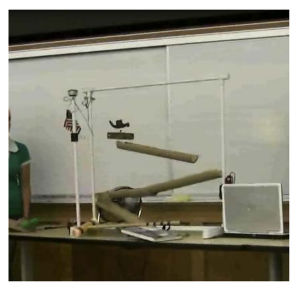
	# of Students Consenting to Data Collection	Class Makeup	Instructional Style
Comparison Section	108 of 115	Male: 86% Ethnic Minority: 5%	Lecture, clickers, textbook homework
Intervention Section	101 of 112	Male: 77% Ethnic Minority: 7%	Lecture, clickers, textbook homework, 3 group design projects

Project Descriptions

For each project, teams of 5 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 they conducted based on their statics knowledge.

Unit 1: Equilibrium - Rube Goldberg Machines

- Each team member is "design engineer" for at least one component
- Must be able to describe operation using principles of statics
- Objective is to raise a team flag




Unit 2: Applications of Statics - Basswood and String Bridges

- Design and construct bridges to span 2 feet using only materials provided by instructor
- Bridges point loaded at the center during class presentations
- 3 stages of reporting: 1) preliminary design drawing, 2) analysis and predictions, 3) failure analysis


Unit 3: Misc. Statics Topics - Using Friction to Your Advantage

- Design a system to help Cam the Ram get to the top of the mountain, using friction to your advantage

Evaluation Tools and Findings

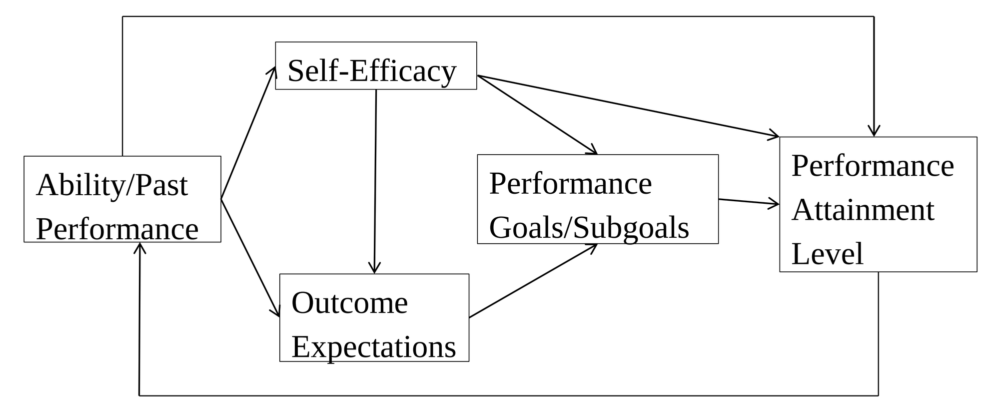
Content Knowledge – Concept Assessment Tool for Statics (CATS)[3]

No statistically significant difference between the two sections

- CATS is available through *cihub.org*
- 27 multiple choice questions
- Students in intervention section had less lecture time with the material due to project activities
- Students in comparison section likely spent less time on statics outside of class
- This assessment tool was limited to basic concepts, and for example did not have any questions about trusses (topic of project 2)

Intention to Persist – Social Cognitive Career Theory (SCCT) [4]

SCCT Performance Model Lent, Brown and Hackett (1994)



Performance Goal: Intention to Persist
Performance Attainment : CATS score

The two sections 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 the control.

A multi-group structural equation model revealed that self- efficacy indirectly influenced goals though outcome expectations as well as performance levels though outcome expectations and goals- but *only* for the intervention section.

Motivation – Achievement Goal Theory [5]

In short, achievement goal theory posits that students want to display competence (performance orientation) and/or be competent (mastery orientation).

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, d=.32 p=.04 ; $t_{performance}$=-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, d=.42, p=.02) but not performance orientation ($t_{performance}$ = -1.59, d=-.37, p=.11).

Group Interaction – Video Analysis

In the intervention section, one in-class group meeting for each project was video-recorded.
Three research questions are being considered as analysis proceeds:

(1) Did the nature of talk vary by type of task?
Some indication that a guided assignment led to more conceptual discussion than a more open assignment, follow-up study conducted in fall 2013.

(2) Was the proportion of time spent in concept negotiation[6] related to project grades?
Unclear

(3) How did the nature of talk vary in groups with different gender ratios?
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.

Conclusions and Continuing Research

Our primary conclusions:

1. Differences in student outcomes between the two sections were modest, but measurable, and students in the intervention section showed benefits in affective outcomes in particular.
2. Although the course changes required initial instructor effort to prepare, they could be readily sustained and gradually enhanced, hopefully further increasing student benefit.
3. Additional evaluations are needed for projects of different scale and scope within a course.

Questions for Continuing Research

1. How does the type of assignment prompt affect student group interactions and thus student learning? A follow-up study considering prompts along the inquiry continuum has been conducted and results are being analyzed.
2. What aspects of the project experience produced the results observed here? Many benefits are associated with group work alone, did aspects such as construction of the project or the introduction to design make additional contributions?
3. How do project experiences affect different types of students (for example male students vs. female students)?

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