Examining Interventions to Increase Classroom Community and Relevancy in an Early Career Engineering Course

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Abstract

The current NSF-funded project was designed to positively impact the retention of engineering majors in early career engineering courses. We build on prior work in this area through our focus on two important aspects of classroom instruction: classroom community and relevancy. In this two-year project, faculty from engineering and science education have teamed together to design, implement, and study a number of interventions related to classroom community and relevancy. As proxies for retention, we used three measures to examine specific constructs: engineering identity, engineering self-efficacy, and sense of community. In addition, we used the COPUS observational protocol to examine instructional differences between treatment and control courses.

In the first two iterations of the project, we examined the impact of micro-interventions aimed solely at increasing the students' sense of community in the early career course. These included, for example, a focus on classroom norms, strategies to increase peer-to-peer interactions, and peer testimonials to enable discussions of the challenges faced by first-year engineering students, among others. For the third and final iteration of the project, we examined the impact of interventions aimed at both classroom community and relevancy.

Based on the findings of this study and considering the context of the research plan, we have the following concluding observations. There were important instructional differences seen between the two courses as shown by the COPUS observational data. However, the effect of these differences on the three measured constructs was inconsistent. We measured a statistically significant difference in students' sense of community and engineering self-efficacy for the treatment section during the alpha iteration, but not during the subsequent beta or gamma iterations. Similarly, we found no significant difference in students' change in engineering identity between the treatment and control sections, for all iterations. It is likely the instrument used to measure identity was insufficient to measure changes over the time scale of one semester.

With that said, although tenuous, our findings provide evidence that an increase in classroom climate can effect students' engineering self-efficacy. It may be the "micro" nature of our interventions was not effective towards producing significant changes to students' sense of community, engineering self-efficacy, or engineering identity – in a large lecture-format introductory engineering course. Or, it may be the instruments employed were not sensitive to measuring the change. Nonetheless, while inconclusive, the findings of this study are provided for practitioners who may be interested in incorporating similar pedagogies into their classroom. In addition, the findings grow the knowledge-base and are available to researchers interested in extending the results into future studies.

Introduction

The current NSF-funded project [1] was designed to positively impact the retention of engineering majors in early career engineering courses. By some estimates, roughly half the students that initially enroll in an engineering program change their major. In this two-year project, faculty from engineering and science education have teamed together to design, implement, and study a number of interventions related to two aspects of classroom instruction:

1) classroom community and;
2) relevancy.

As proxies for retention, we used three measures to examine specific constructs:

1) engineering identity;
2) engineering self-efficacy and;
3) sense of community.

In addition, we implemented a classroom observational protocol to examine instructional differences between treatment and control courses.

In the first and second iteration of the project, we examined the impact of interventions aimed solely at increasing the students' sense of community in an early career course [2]. These interventions included, placing a focus on classroom norms, implementing strategies to increase peer-to-peer interactions, and the use of peer testimonials aimed at enabling discussions of the first year challenges. In the third and final iteration of the project, we tested additional interventions designed to increase the relevancy of the curriculum for the engineering students. These additional interventions included using anchored instruction, providing local engineering examples, and increasing the focus on the social implications of engineering. We utilized an experimental design to compare the control and treatment sections.

Problem Description

The curriculum and complex social norms of the classroom, campus, and home communities shape the identity of an engineering student [3]. These "norms" are the agreed upon behaviors and values which form their sense of identity within their community. Norms may be implicit or explicit; however, to exist as a norm, they must be commonly understood, reinforced, and taught [4]. Engineering norms can be described as engineering ways of knowing, thinking, and doing. As a result, many engineering curricula and pedagogies are delivered in "ways it has always been done". While this may benefit those who fit the norm, others whose identity are formed by a non-dominant race, ethnicity, gender, culture, or combination have to suppress their personal authenticity in order to fit in as engineering students and as future engineers [5]. This lack of inclusivity may result in the loss of potentially qualified engineers who do not fit the traditional mold. Thus, a change in culture is needed to expand the field.

Background

We describe engineering norms in more detail in a companion paper [1]. In summary, these engineering ways of knowing, thinking and doing are often highly prescriptive, conformist, meritocratic, and technocratic. Individual identities, non-normative perspectives, creativity, and social implications are weakly emphasized at best, or, nonexistent at worst.

A change of culture is a long and complicated process. A shift in core values requires an internal change in behaviors and practices as well as external exposure to and reinforcement of those behaviors and practices [6]. Research over the past several decades has identified numerous factors that reduce participation of underrepresented individuals during phases of the engineering pathway. We have identified and selected the following three factors from the literature to guide this study:

1) *Stereotype threat* is the anxiety individuals from a stigmatized group have that their behavior may confirm [7].
2) *Mindset*, categorized as either "fixed" or "growth", is a set of assumptions held by one or more people that is so embedded into the culture it creates an influence within these groups to continue to accept prior behavior [8].
3) *Sense of belonging* is the belief that one is part of a group. While the tendency is to relate a sense of lack of belonging to underrepresented students, the data suggest lack of belonging may be the strongest factor for *all* students [9].

Based on our review of the literature [1], [7]-[9], a students' sense of belonging (i.e. their sense of selves as engineers) is the precedent to mindset, internal and external bias, and feelings of stereotype threat. As a result, we aim to expand the formation of identity by fostering students' sense of belonging through interventions aimed at:

1) creating an inclusive classroom community; and
2) incorporating relevancy into course activities.

Research Plan

We implemented our study over three iterations (alpha, beta, and gamma), using a quasi-experimental design that includes a treatment course and control course for comparison, and we employ an outcome-focused approach consistent with the tenets of design-based research [10]-[13]. This project uses instruments validated by others to measure classroom community [14], self-efficacy [15], engineering identity [16], and classroom practices [16].

The engineering course that is targeted for this project is *Engineering Mechanics: Statics* (Statics). We selected this course because it represents students' first exposure to a highly technocratic engineering content and, consequently, the first "weed out" course for mechanical, civil, and environmental engineers.

We implemented a series of interventions aimed at building a sense of community in the classroom and instilling relevancy into the course concepts. Figure 1 provides an overview of the framework for these interventions. A description of each item follows.

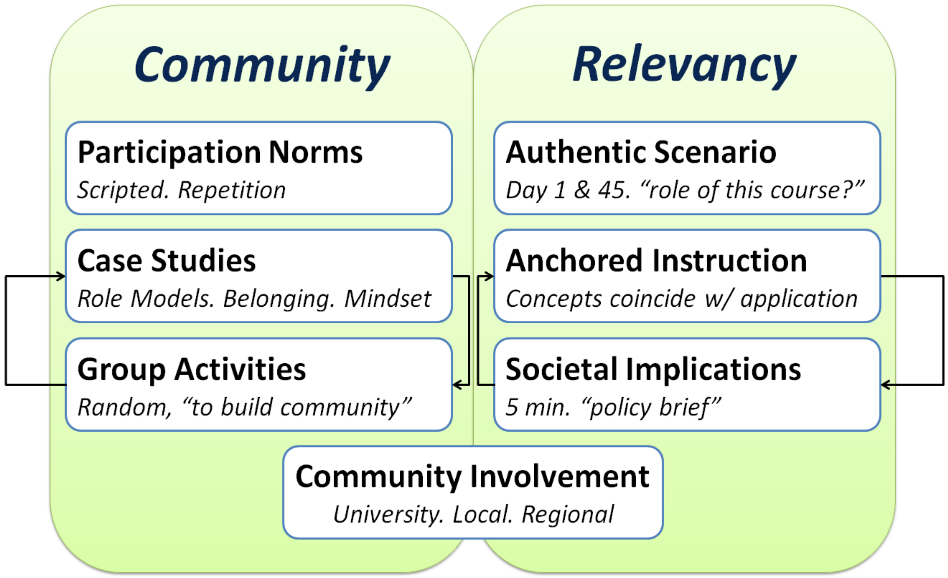

Figure 1. Framework for series of classroom interventions.

Participation Norms (Community)

Early in the semester, we explicitly discuss classroom norms and prominently post these norms in the classroom for repeated reference throughout the term. These norms include:

1) "our talk is focused on reasoning";
2) "our talk is respectful";
3) "our talk is equitable";
4) "our questions are important"; and
5) "our mistakes are valuable".

Case Studies (Community)

Case studies are presented after the first exam (a time when many may begin feeling discouraged). These testimonials are presented in the form of "Advice from Past Students" and were transcribed from interviews with upper classmen. The purpose of these case studies is to reinforce a message of a growth mindset [8] and instill a sense of belonging through the experiences of peer groups [20]. Implicitly, the purpose is to alleviate their concerns of whether or not they belong in engineering by showing them setbacks and adversity are commonly experienced by their peers.

Group Activities (Community)

Group activities are given approximately once a week in the class. Groups are separately randomized each time and students work together to solve a relevant statics problem. The purpose of this activity is to activate their learning and to help the students build their engineering communities. They meet many of their fellow classmates and use this information when forming study groups and/or reaching out to their peers for assistance.

Authentic Scenario (Relevancy)

An authentic project is assigned to pique student interest and demonstrate the applicability of the course. For this study, we used the 2007 collapse of the I-35W Bridge in Minneapolis, MN [19]. Students are asked to reflect on their past and current understandings in the form of reflection questions: "What engineering concepts do you need to explain the cause of the collapse?" "What role will this course play in preparing you to understand the cause of the collapse?" This allowed course concepts, often seen as abstract, to be directly applied to an authentic scenario.

Anchored Instruction (Relevancy)

Previous research shows a lack of relevancy to be a major contributing factor to students from all social groups leaving the engineering profession [21]-[24]. To combat this deficiency, we anchor a cluster of concepts to a single authentic scenario. For example, the first five concepts covered in this course (forces, moments, equilibrium, analytical model, truss analysis) are anchored to an analysis of the aforementioned I-35W Bridge collapse. After completion of a module, students are asked to complete the following reflection statements: "A *(concept)* is …" and "I use *(concept)* to understand the collapse of the I-35W Bridge by …" As a concluding exercise, students perform a truss analysis of the bridge and write a brief description of what they have done using the words: *force, moment, equilibrium, model*, and *truss analysis*. Table 1 is the concept summary table developed by student consensus throughout the first five weeks of the course:

Table 1. Summary of Concepts Anchored to the I-35W Bridge collapse (Spring 2018)

Concept:	*A ______ is …*	*For a I-35W bridge or components, I use _____ to …*
Force	*A force is … a weight, "push", or "pull" applied to object, or a pressure concentrated to a single point. A force contains both a magnitude [e.g. N or lb.] and direction.*	*Forces applied to the structure work together to create a total force (i.e. "resultant"). Sum of all applied forces and all reactive forces must equal zero for the structure to be in equilibrium. If one component lost, structure no longer stable.*
Moment	*A moment is … a "twisting force" or torque. [e.g. N-m or lb.-ft.]*	*For bridges or components, I use a moment to balance forces that cause twisting – so no twisting occurs and sum of all moments is zero.*
Equilibrium	*Equilibrium is … the balancing of all forces on an object.*	*For a bridge or components, I use equilibrium to find the reactions to the actions. Internal and external forces should balance, or equal zero when summed. Because if they don't balance, "unbalance" = "collapse"*
Model	*A model is … an idealized representation of object, with the info needed to do an analysis.*	*For bridge or components, I use a model to show given information, my assumptions, loads, and supports. These items are needed to determine the forces within the truss elements.*
Truss Analysis	*A truss analysis is … the steps taken to calculate the internal forces within a truss.*	*For a bridge or component, I use a truss analysis to determine the path the loads take from the bridge to the supports. If any of the parts within the path are not strong enough then the bridge will fail.*

<u>Societal Implications (Relevancy)</u>

A figure summarizing a contemporary engineering issue was projected on the screen before class (e.g. number of structurally deficient bridges in the U.S., events that led to the Ford Pinto failure, novel bridges, worldwide and regional water consumption, etc.) on a weekly basis. The figure was often accompanied with a thought provoking question (e.g. "What should we have done?" "What should we do next?"). In this way, as students find their seats, they were actively thinking and discussing broader professional or societal issues of the profession prior to class. We followed up with a quick group discussion during the first few minutes of class.

Community Involvement (Community and Relevancy)

Prior to class, a Flagstaff City Council meeting and agenda was projected on the screen. Students were asked to reflect on the associated engineering considerations, in terms of the impact on themselves, their professional understandings, and their community. The purpose of this activity and the previous was to appeal to students' sense of social activism and make tangible the direct correlation between students' quality of life and their local community.

Sample

Each semester, two sections of Statics are offered with approximately 60 to 90 students in each. For the 2015/2016 academic year, the course was comprised of 61% Mechanical, 22% Civil engineering students, and 17% others (e.g. environmental engineering majors, or majors seeking a minor). In addition, the class was approximately 80% male and 20% female; and 25% of the total population was from an underrepresented ethnic group. Thus, with respect to engineering disciplines, Statics represents a relatively broad data pool.

For all iterations, we gave pre- and post-assessments to the students, conducted classroom observations using the COPUS classroom observation protocol, and video recorded targeted class sessions to document student and teacher interactions. In addition, at the time of this writing we are conducting interviews with a purposeful sample of student groups and individuals. All data collection procedures were approved by the Institutional Review Board. Student assessment data was analyzed using *t*-tests and analysis of covariance (ANCOVA) techniques. This multi-method study will triangulate the findings of the quantitative and qualitative measures. We used the findings of each iteration to refine the subsequent treatment. Table 2 provides an overview of the control and treatment sections.

Table 2. Overview of Control and Treatment Cohorts

<table>
<tr><td rowspan="3">Section:</td><td>Term:</td><td>Spring 2017</td><td>Fall 2017</td><td>Spring 2018</td></tr>
<tr><td>Iteration:</td><td>alpha</td><td>beta</td><td>gamma</td></tr>
<tr><td>INTERVENTION:</td><td>COMMUNITY</td><td>COMMUNITY</td><td>COMMUNITY + RELEVANCE</td></tr>
<tr><td rowspan="2">1</td><td>Purpose:</td><td>Treatment</td><td>Treatment</td><td>Treatment</td></tr>
<tr><td>N =</td><td>53</td><td>66</td><td>92</td></tr>
<tr><td rowspan="2">2</td><td>Purpose:</td><td>Control</td><td>Control</td><td>Control</td></tr>
<tr><td>N =</td><td>66</td><td>70</td><td>60</td></tr>
</table>

It is important to note, we installed only the "community" interventions during the alpha and beta iterations of this study. Both the "community" and "relevance" interventions were installed during the gamma iteration. Also, the instructors for both the control and treatment groups were the same during the alpha and beta iterations. The instructor for the control was changed for the gamma iteration – due to department priorities unrelated to this project.

Quantitative Results

All interventions were implemented as described above. The results of these interventions are summarized as follows:

Classroom Community [14]. Instructors from both the treatment and control cohorts deployed this measure the second and second to last week of the semester. Results are summarized as follows.

- **Spring 2017**. A one-way ANCOVA found a **statistically significant difference** [$F(1,67) = 8.638$, $p = 0.005$] between the treatment and control groups community post-test scores controlling for pre-test scores. The treatment group score increased significantly (49.6 to 53.6) as compared to that of the control group (44.7 to 45.3).
- **Fall 2017**. A one-way ANCOVA **did not find a statistically significant difference** [$F(1,104) = 1.504$, $p = 0.223$] between the treatment and control groups community post-test scores controlling for pre-test scores. Both groups showed small but not statistically significant increase in community scores.
- **Spring 2018**. A one-way ANCOVA **did not find a statistically significant difference** [$F(1,89) = 0.84$, $p = 0.773$] between the treatment and control groups community post-test scores controlling for pre-test scores. The treatment group's community scores started and remained high (50.23 to 50.19) while the control group's community scores increased slightly (42.96 to 45.42).

Self-Efficacy [15]. Instructors from both the treatment and control cohorts deployed this measure the second and second to last week of the semester. Results are summarized as follows.

- **Spring 2017**. Both groups showed a decrease in self-efficacy scores as measured by the LAESE instrument. A two-sample *t*-test found a **statistically significant difference** ($p = 0.04$) between the treatment and control groups self-efficacy post-test scores controlling for the pre-test scores. This difference was due to a larger decrease in self-efficacy post-test scores of the control group as compared to the treatment group which remained relatively stable.
- **Fall 2017**. Both groups showed minor decreases in self-efficacy scores. A two-sample *t*-test **did not find a statistically significant difference** ($p = 0.74$) between the treatment and control groups self-efficacy post-test scores controlling for the pre-test scores.
- **Spring 2018**. Both groups showed no significant change in self-efficacy scores. A two-sample *t*-test **did not find a statistically significant difference** ($p = 0.45$) between the treatment and control groups self-efficacy post-test scores controlling for the pre-test scores.

Engineering Identity [16]. Instructors from both the treatment and control cohorts deployed this measure the second and second to last week of the semester. Results are summarized as follows.

- **Spring 2017**. A two-sample *t*-test **did not find a statistically significant difference** ($p = 0.58$) between the treatment and control groups identity post-test scores controlling for the pre-test scores. Both groups remained static in their engineering identity scores.

- **Fall 2017**. A two-sample *t*-test **did not find a statistically significant difference** (p = 0.75) between the treatment and control groups identity post-test scores controlling for the pre-test scores. Again, both groups remained static in their engineering identity scores.
- **Spring 2018**. A two-sample *t*-test **did not find a statistically significant difference** (p = 0.16) between the treatment and control groups identity post-test scores controlling for the pre-test scores. The treatment group remained static in their identity scores while the control group increased slightly.

<u>Classroom Practices [17]</u>. We assessed classroom practices separately for both sections approximately 8 to 10 times throughout the term, using the COPUS measure. Results show distinct differences in instructional strategies. Figure 2 presents a summary of these results from the beta iteration (alpha and gamma results were similar).

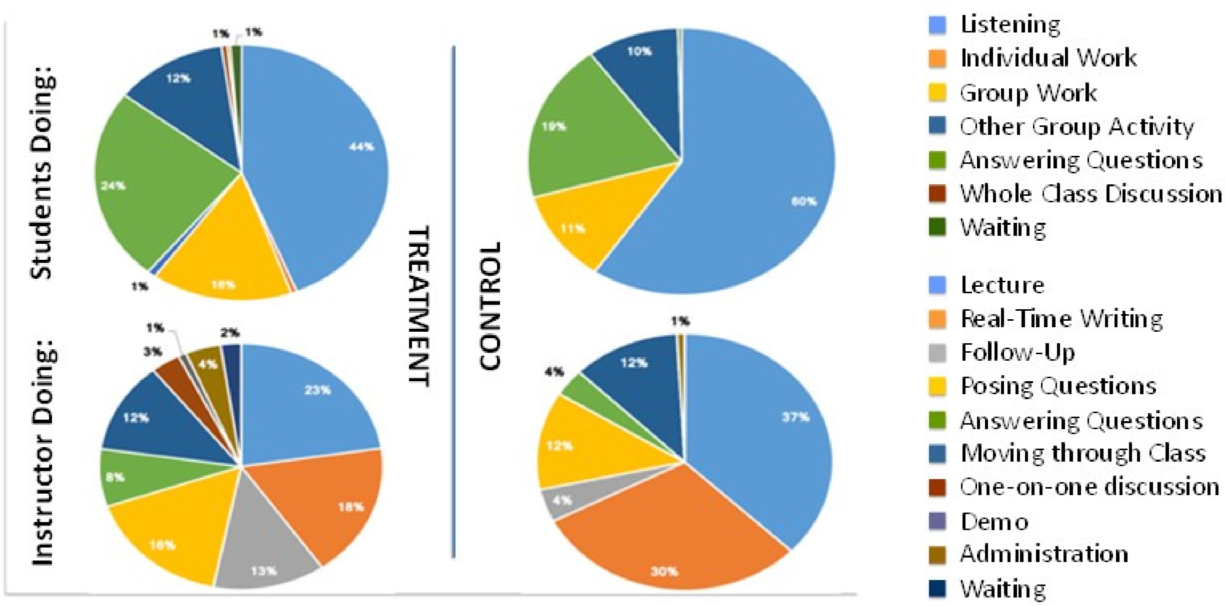

Figure 2. Summary of COPUS findings from Fall 2017 (similar results for Spring 2017).

Preliminary Findings and Conclusion

Our goal for this project has been to examine the efficacy of small-scale interventions, or micro-interventions, aimed at increasing the sense of community and relevancy in an early career "weed out" course for engineering majors. We have focused on micro-interventions in an attempt to provide engineering instructors with small but meaningful instructional changes that can begin to move the needle on the high attrition rate of students in the engineering majors. We have used the constructs of engineering self-efficacy and identity as proxies for attrition as they have been shown to be intricately linked. We have also utilized direct measures of classroom community and of instructional practices to examine the differences between the control and treatment sections.

Based on the findings of this study and considering the context of the above research plan, we have the following concluding observations. There were important instructional differences seen between the two courses as shown by the COPUS observational data. However, the effect of these differences on the three measured constructs has been inconsistent. For example, while moderate in size, we measured a statistically significant increase in the students' sense of community for the treatment section in the alpha iteration. That increase was not seen in the beta iteration. A similar pattern holds for the self-efficacy measure. In terms of engineering identity, little change was seen for either group. It could be that students' engineering identity was not affected in either group. However, it seems more likely that the instrument used was insufficient to measure changes over the time scale of a semester.

In the end, the results are inconclusive as the community and relevancy micro-interventions we implemented over the three iterations of the project showed variability in their effect on the three measures. However, we find tenuous evidence that an increase in classroom climate can affect the students' engineering self-efficacy as seen in the alpha iteration. In the other two iterations, we saw no significant change in community scores or self-efficacy scores. Again, the link shown here between community and self-efficacy is tenuous. However, it does provide momentum for further investigation of the link between the two constructs. In this project, the "micro" nature of the interventions may have been too small to affect the necessary change in scores consistently. In the future, a more robust or "macro" set of interventions may better connect the link between community and self-efficacy.

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