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Reshaping Engineering Classroom Norms to Expand the Profession

Dr. Robin G. Tuchscherer, Northern Arizona University

Dr. Tuchscherer currently serves as an Assistant Professor at Northern Arizona University where he has taught since 2011. Prior to academia, he accumulated eight years of professional experience as a practicing structural engineer and brings a practitioner's perspective to the academic and research setting. He teaches core undergraduate engineering courses, structural analysis, and reinforced concrete design. His primary research focus is related to improving our understanding of the design and behavior of concrete structures; and he is actively involved within the professional engineering community. Furthermore, Dr. Tuchscherer has also supervised sponsored research and educational reform initiatives related to the improvement of student learning.

Dr. Ron Gray, Northern Arizona University

Ron Gray, Ph.D. is an assistant professor of science education in the Center for Science Teaching and Learning at Northern Arizona University. He graduated from Oregon State University with a doctorate in science education. His work largely focuses on providing secondary science teachers the tools to design and implement learning experiences for their students that are effective and authentic to the discipline. Much of this work has been centered on model-based inquiry and the integration of scientific practices in a supportive and structured way. He has been funded by NSF and other agencies to conduct research on preservice teacher education, undergraduate engineering education, and community partnerships in secondary education.

Ms. Christine Allison Gray, Northern Arizona University

Christine Allison Gray is a doctoral student in the College of Education at Northern Arizona University. She also serves as a graduate assistant on the Reshaping Norms project in the College of Engineering, Forestry and Natural Sciences. Her research focuses on the influence of classroom climate on the development of undergraduate students' professional engineering identity.

Reshaping Engineering Classroom Norms to Expand the Profession

Overview of Grant

The National Science Foundation (NSF) funded this project (#1640328) under the Division of Engineering Education and Centers (EEC) program: *Research Initiation in Engineering Formation (RIEF).* The intent of this program is to initiate research projects on any topic that explores engineering formation from an interdisciplinary perspective [1]. In addition, NSF awards *RIEF* grants to engineering faculty who have not received prior funding in EEC to expand the community of engineering faculty conducting research in this area [1].

The two-year project began September 1, 2016.

Introduction

By some estimates, roughly half the students that initially enroll in an engineering program change their major. Attempts to fix this "leaky pipeline" rarely address the fact that the culture, rather than academics, may be driving students away. As they form their professional identity, students ask themselves, "What are the attributes inherent in being an engineer?" Far too often, the answer to that question is defined by outdated ways of knowing, thinking, and doing. Thus, to expand the profession, there is a need to identify and understand the impact of “socioengineering” norms in university programs.

The goal of *Reshaping Norms* project is to change the culture of an undergraduate engineering course in a manner that more broadly includes students from diverse social, cultural, and traditionally underrepresented backgrounds in Engineering. *Reshaping Norms* serves to incorporate pedagogies, strategies, and initiatives into the classroom that are founded on inclusiveness, encourage nonconformity, and promote student involvement within their local communities. The hypothesis underlying this proposal is:

Underrepresented engineering students who participate in classrooms that seek to create an inclusive community, and relevancy in the course, will have increased interest in the field and self-efficacy towards continuing in the profession.

Problem Description

An engineering student shapes their identity by the curriculum, and by the complex social processes within the classroom, campus, and home communities [2]. These “social norms” are the agreed upon behaviors, attitudes, values, etc. which hold ‘society’ together. They may be implicit or explicit. However, to exist as a norm, they must be commonly understood, reinforced, and taught [3]. Engineering norms can be described as “engineering ways of knowing, thinking, and doing”. In other words, “What are the attributes and qualities inherent in being an engineer?” The answer to this question is predominantly defined by the white male hegemony. As a result, students whose identity are more strongly formed by an alternative race, ethnicity, gender, culture, or combination have to suppress their personal authenticity in order to fit in as engineering students and as future engineers [4].

Engineering Norms

Engineering ways of knowing. Generally, engineering coursework is tightly bound in a way that each individual problem addresses a single technical concept. The singular objectivity of coursework devalues cognitive diversity, encourages students to think and be the same, and restrains the expansion of professional identity. Engineering programs are highly prescriptive. Prescriptiveness flattens individual identity and encourages conformity. In addition, despite recent emphasis on pedagogies that better engage students, the inertia of ritualization slows adoption of new approaches and bolsters "the way we've always done it".

Engineering ways of thinking. Engineering is defined by means of a dominant technicist ideology. However, communication skills, people skills, and the ability to navigate stakeholder values are as much a part of the profession as the "nuts and bolts" [5]. A technicist ideology favors students who identify with such and excludes students who identify with the more heterogeneous aspects of the profession. The idea that engineering can be collaborative, creative, and orientated towards goals of social good, and not just financial gain, are aspirational positions a student may adopt. However, for students whom these are core values, the absence of direct images that support these values can be decisive for whether or not they stay in, or leave, the major [5].

Engineering ways of doing. The culture within most engineering programs can be described as "work hard" and meritocratic. While having the positive effect of encouraging solidarity and "evening the playing field", too great a focus on these values may also have an unintended consequence of suppressing identity. In other words, constantly rewarding the right answer, coupled with a heavy workload, does not afford students the luxury to explore alternative professional identities; and implicitly excludes non-normative perspectives.

Barriers to Expanding a Professional Identity

A change of culture is not a quick process, requiring not only a change in behaviors and practices, but also exposure to and reinforcement of those behaviors and practices to shift core values [6]. Research over the past several decades has identified numerous factors that reduce participation of underrepresented individuals during phases of the engineering pathway. For the purpose of this project, the following factors are examined in detail: 1) stereotype threat; 2) mindset; and 3) sense of belonging.

Stereotype threat is the anxiety individuals from a stigmatized group have that their behavior may confirm [7]. Stereotype threat has a strong correlation to self-efficacy and attrition. For example, studies have been conducted in the past that show that both explicit and implicit awareness of stereotype is sufficient to reduce women and minority's intellectual performance – not only in test taking situations – but in ongoing college experiences [9]. Two strategies frequently cited for addressing stereotype threat are: 1) faculty and student awareness; and 2) exposure of students to diverse role models [8]-[10].

Mindset. Mindset 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. Hill et al. [8] categorizes mindset as either "fixed" or "growth". To illustrate, Hill et al. [8] cite a study where researchers followed several hundred women at an elite university through a semester of a calculus class. Women who reported that their classrooms communicated a fixed mindset were less likely to express a desire to take math in the future. Women who said that their classrooms promoted a growth mindset were more likely to continue to take math in the future. The researchers concluded that a students' motivational framework rather than their initial achievement determined their academic success [8]. In other words, a student feeling they simply do not fit in because they "aren't as smart" or "don't belong" has as detrimental an effect on their persistence in the program as academic performance. Thus, it is important to communicate "growth mindset" messages to students: 1) anyone can learn; 2) learning is a choice; 3) effort, hard work, and learning from mistakes is valued, etc.; and 4) by praising students for the process they use to arrive at conclusions rather than the conclusions themselves [8].

Sense of belonging. Marra et al. [12] observed 113 undergraduate students at a single institution over multiple years. According to the researchers, "the results suggest that academics are less of a reason for leaving engineering than the less tangible feelings and beliefs side of the equation". 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 [12], irrespective of social group. Strategies for creating a welcoming and inclusive climate within the academic setting include: 1) directing student-peer interactions; 2) broadening the scope of early course work; and 3) providing students with authentic learning experiences.

Reshaping Engineering Classroom Norms

At the heart of student identity formation is students' sense of belonging. Students' sense of themselves as engineers is directly related to their mindset, internal and external bias, and stereotype threats – in addition to social aspects, civic engagement, and heterogeneous nontechnical values. Thus, students' sense of belonging shapes socioengineering cultural norms in the classroom and in the profession. Reshaping these norms requires removal of barriers along with cultivation of students' sense of belonging. As such, *Reshaping Norms* serves to expand the formation of professional identity through interventions aimed at: 1) creating an inclusive classroom community; and 2) incorporating relevancy into course activities.

Research Plan

The engineering course that is targeted for this project is *Applied Mechanic Statics* (CENE 251). Two sections of Statics are offered each term with approximately 60 to 90 students in each section. 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; 25% of the total population was from an underrepresented ethnic group. Thus, with respect to engineering disciplines, Statics represents a relatively broad data pool. Generally, freshmen will take math and science classes their first year, and Statics their first term as sophomores. As a result, Statics is students' first exposure to a predominantly technocratic engineering context. Subsequently, this class also represents the first "weed-out" course for students in the engineering program.

The two-year project described in this paper will be designed and implemented over three iterations (alpha, beta, and gamma), using a quasi-experimental design that includes a treatment course and control course for comparison, and employing an outcome-focused approach consistent with the tenets of design-based research [13]-[16]. This project employs experimental measures which past researchers have designed and validated [17]-[20]. These measures assess classroom climate [17], engineering identity [18], self-efficacy [19], and classroom practices [20]. For both the alpha (Spring 2017) and beta (Fall 2017) iterations, the project team will give pre-post assessments to the students, conduct classroom observations using the classroom observation protocol, and video record targeted class sessions to document student and teacher interactions. In addition, interviews with the instructor and a purposeful sample of students will be conducted at the end of term. This multi-method study will examine in detail the quantitative and qualitative measures separately to triangulate the findings. Assessment data will be analyzed using paired samples *t*-tests. Throughout the term, this analysis will provide evidence of any change in the students' interest, self-efficacy, or both. The project team will use these findings to refine the treatment. If the treatment is functioning as intended, the team will conduct a pilot study in Phase 3 using the gamma version. If the treatment is not functioning as intended, the project team will complete a third enactment, analysis, and redesign cycle. The pilot study, slated for Spring 2018, will consist of two sections of Statics and will be conducted using a quasi-experimental design. Student assessment data will be analyzed using analysis of covariance (ANOVA) techniques. This analysis will provide evidence of any changes in the students' interest and/or self-efficacy in the field of engineering. The authors anticipate higher scores on both the interest and self-efficacy measures for all students, but especially those traditionally underrepresented in the field.

The authors plan for a series of interventions aimed at building an inclusive community within the classroom and relevancy within the course. Figure 1 illustrates a framework for proposed interventions. A description follows.

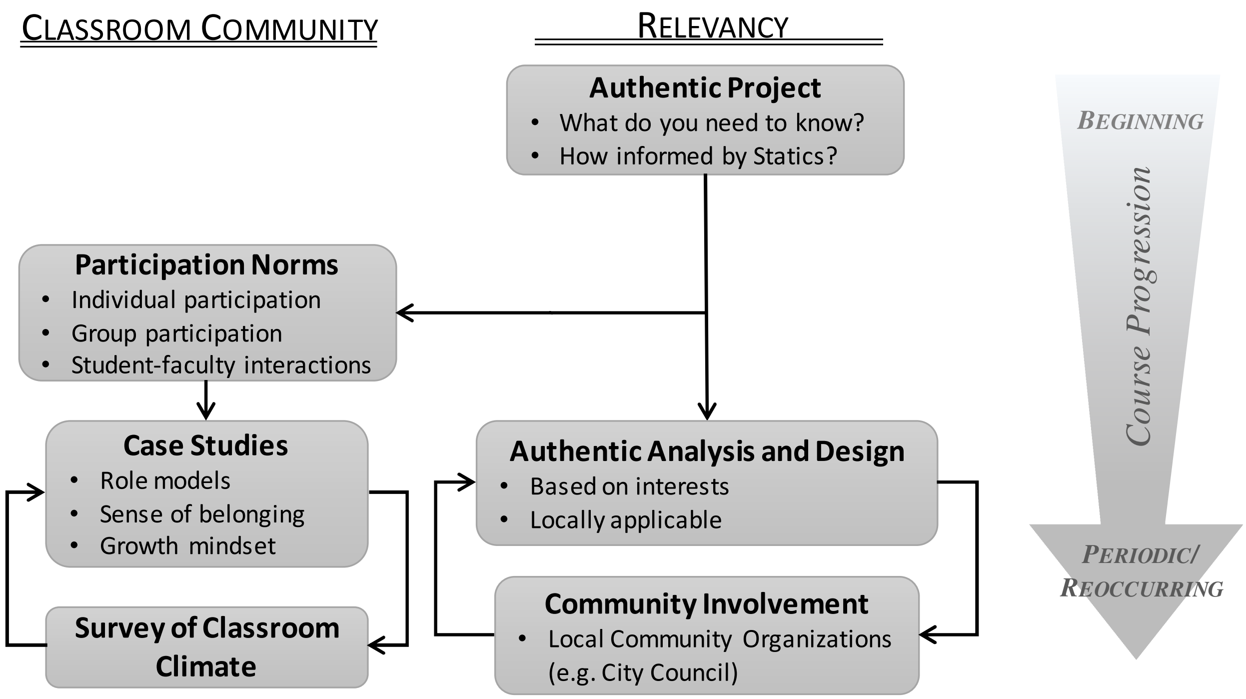

Figure 1. Framework for series of classroom interventions.

<u>Authentic Project (Relevancy)</u>

- On the first day of class, an authentic project is assigned to pique student interest and demonstrate the applicability of the course. Students are asked to reflect on their past and current understandings in the form of reflection questions. For example, "What engineering concepts do you need to know to complete the project?" "What role will this course play in preparing you to solve this type of problem?" Subsequent progress on the project will be tracked throughout the semester, coupled with discussions of professional issues, and culminating at the end of the term.

<u>Case Studies, Norms of Participation, Survey of Classroom Climate (Classroom Community)</u>

- Case studies are presented periodically throughout the semester in the form of "Advice from Past Students" (i.e. testimonials) by senior undergraduates and/or recent graduates across a broad range of groups. The purpose of these case studies is to reinforce a message of a growth mindset [11] and instill a sense of belonging through the broad experience of peer groups [21]. Implicitly, the purpose is to demonstrate that adversity is a common aspect of the college-adjustment process. Most students and their peers worry whether or not they belong in the discipline [22].
- Early in the semester, classroom norms of participation are explicitly established including, student-student and student-faculty interactions. In addition, classroom participation norms are monitored throughout the term and explicitly referred back to as needed. These 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".

- Students are surveyed periodically throughout the semester to assess the classroom climate [17]. This information is used to better customize the cases studies delivered throughout the term.

Authentic Problems and Community Involvement (Relevancy)

- Throughout the semester, authentic analysis and design scenarios will be presented to the students, coupled with discussion of the broader professional issues. As previous research shows a lack of relevancy to be a major contributing factor to students from all social groups leaving the engineering profession [8],[23]-[25].
- During the term, an assignment in the course will require students to attend a local community organization (e.g. City Council), and reflect on the associated engineering considerations, in terms of the impact on themselves, their professional understandings, and their community. The purpose of this is to demonstrate the heterogeneous aspects of the profession, appeal to students' sense of social activism, and make tangible the direct impact of the engineering profession to students' quality of life and local communities.

The above series of interventions will be refined, altered, lengthened, or shortened based on the findings of Phase 1 (alpha and beta iteration). After which, the project team will plan for implementation of the intervention in engineering classrooms in Phase 2 (pilot study). It is anticipated that these classroom interventions will have an immediate and positive impact on student learning and attrition, and a positive long-term influence on the traditional boundaries of engineering identity.

Preliminary Findings

At the time of writing, the project is completing its first iteration (alpha). The authors have installed all of the "community" interventions mentioned above for one section of Statics. Another section serves as the control cohort. The reason for installing the "community" interventions (and not the "relevance" interventions) is to parse their effect when the authors next incorporate both types. Community interventions included the following:

Classroom norms (i.e. *our talk is focused on reasoning; our talk is respectful; our talk is equitable; our questions are important*; and *our mistakes are valuable*) are posted in the classroom and the instructor periodically refers to them throughout the term. The research team has learned it is useful to script into the curriculum instances when the instructor should refer to the norms. In this way, through repetition, the instructor implants the norms into his/her vernacular and, subsequently embeds the concepts into students' identity.

Group activities including "think-pair-share", "exit passes", and in-class assignments are assigned about one to two times per week. The instructor places students in randomized groups for in-class assignments. For future terms, each in-class activity will include a conventional engineering problem, followed up with a reflective question focused on the more heterogeneous or broader professional considerations of the assignment.

“Advice from Past Student” testimonials were read by the students at the beginning and end of term. Students were asked to reflect on the advice that was personally meaningful, and/or reinforced their understanding of engineering.

Findings from the measures are summarized as follows:

Classroom Climate [17]. Instructors from both sections assigned this measure at the beginning and end of term. Results indicate students’ sense of community or belonging in the classroom moderately increased in the treatment group (49 to 53 out of a possible 80) and remained static in the control group (45 to 45). Similar results were found within the sub-scales.

Engineering Identity [18]. Instructors from both sections assigned this measure at the beginning and end of the term. Preliminary analyses indicate students’ increasingly identified as an engineer for the treatment cohort, and decreasingly identified as an engineer for the control cohort. Further analyses are being done on this measure.

Self-Efficacy [19]. Instructors from both sections assigned this measure at the beginning and end of the term. Results indicate students in the treatment cohort remained static in their self-efficacy scores (5.74 to 5.70 out of a possible 7.0) while the students’ in the control cohort decreased in their self-efficacy scores (5.67 to 5.14).

Classroom Practices [20]. The research team assessed classroom practices for both sections, using the COPUS measure. Based on the results of the measure, practices within the treatment cohort were more engaging, active, and elicited more responses from a broader subset of student groups, compared with the control cohort. For example, lecture was coded as 23% of all recorded codes for the instructor in the treatment cohort, and 38% of the recorded codes for the instructor of the control cohort, leading to a reduction in the frequency that students were coded as listening (44% in the treatment course and 60% in the control course). This shift allowed for more student participation and social interaction around engineering problems leading to, we hypothesize, a stronger sense of community in the course over time.

An item to note, approximately 10% and 25% of students withdrew from Section 1 (treatment) and Section 2 (control), respectively. Thus, while representative of this group of students’ persistence in the major, unfortunately, the authors were not able to fully collect post-survey data as outlined above. Nonetheless, based on preliminary results, the “community” interventions have had a decidedly positive effect on students’ sense of belonging within the engineering program. The authors anticipate a significantly more positive outcome to result from the “relevance” interventions slated for the second iteration.

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