Teaching Strategies that Incorporate Social Impacts in Technical Courses and Ease Accreditation Metric Creation

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Abstract

Background: Research has shown that students from underserved groups are more likely to persist when they see the link between their coursework and improving society [1], [2]. Simultaneously, human welfare and social impacts have become a part of accreditation protocols for engineering programs [2], [3], [4]. These two factors result in a need for faculty to strategically create inclusive classrooms where students 1) are engaged in the field of study through application to their personal, social, and global knowledge contexts and 2) are demonstrating proficiency on subject matter sufficient to demonstrate accreditation and programmatic requirements. In prior work the authors have shown strategies that exist in engineering classrooms today that may be utilized broadly to improve engineering education [5].

Purpose: In this paper the authors use a linguistic and cultural lens based on Crick's Model of Deep Engagement [6] to assess the articulation of engineering applications and coursework potential impacts on society, learning objectives, and measurable faculty commitment to equitable classroom practices. The authors believe the use of these strategies can assist in the improvement of engineering education and practice and lay a foundation for creating learning spaces that promote belonging. In this paper, the authors identify these strategies and examine how inclusive and equitable content delivery may impact student perception of technical courses and their position as learners, a known barrier to the integration of social impacts into technical training [7], [8]. This paper is a continuing investigation into rhetorical strategies used by faculty to communicate and integrate technical concepts and content in engineering classrooms and the impacts associated with those strategies on relevant metrics for accreditation compliance.

Method: Instructional delivery in engineering spaces is varied and deeply contextualized. The goal in this effort was to observe, document, discover, and build upon existing techniques faculty use to encourage sociotechnical thinking and foster a classroom culture of inclusivity. This work aimed to simplify documentation and dissemination of these techniques to other faculty and interested university groups and ease reporting responsibilities of faculty to Accreditation Board for Engineering and Technology (ABET) and other accreditation bodies. The authors first performed field observations and then conducted faculty interviews. Then observed a variety of engineering courses that intentionally applied inclusive techniques to varying degrees. These were then reviewed and coded independently by the authors and triangulation was used to ensure consistency in data interpretation and analysis. Finally, interview transcripts and anonymized student survey data from prior efforts were used to compare this work with prior known

indicators of inclusivity in engineering classrooms such as self-identified feelings of belonging and varied semantic approaches to engineering education [9].

Results: This paper is a work in progress. Prior work determined that 1) modeling the limits of expertise, 2) positioning humans over technology, and 3) application exploration/storytelling are rhetorical tools that can strategically be used to increase inclusivity in classrooms. The nature of qualitative work is that answers often result in more questions [10]. As such this follow-on work is aimed at understanding the impact that 4) encouraging risk-taking, 5) building positive student-centered learning relationships, and 6) prioritizing team building concurrently with technical assignments may have on increasing inclusivity, potentially through fostering student belonging while simultaneously aiding faculty reporting processes. The goal is to create a model where faculty concurrently increase their effectiveness in teaching and showcase that effectiveness to accreditation bodies. This will prepare instructional staff to meet requirements that faculty show competence in equitable teaching practices and the creation of inclusive environments.

Conclusion: In this paper the authors continued work in the identification and determination of sociotechnical teaching practices indicated by the dataset to complement the rhetorical strategies used by faculty emergent from our initial study and research report. The authors have demonstrated complementary possibilities for the following strategies: 4) encouraging risk-taking, 5) building positive student-centered learning relationships, and 6) prioritizing team building concurrently with technical assignments. While more work is needed, there are existing rhetorical practices and strategies that may be used immediately with minimal risk and great potential reward in the engineering education space.

Introduction

Engineering practice does not exist in a vacuum. Engineering education is the link that connects student understanding and products created to shape and improve our world [11]. It is uncommon for the contexts engineering problems exist in to be made explicit to students in educational spaces [12]. In recent years the importance of including these contexts is becoming apparent. From the lowering of student engagement in engineering programs over degree-seeking years [13], to the inseparable impact of the state of the world onto the state of the classroom (especially students who do not fit the tradition and dominant paradigm of white and male-presenting) [14]. Microaggressions have been revealed to have an intense net-negative effect on people from marginalized communities working and studying in academic spaces perpetuated by systemic social structures that reinforce white-body supremacy [15]. Work to counter legacy or *traditional* pedagogical practices where technical course topics are siloed from humanitarian efforts include the sociotechnical integration of human-centered design with engineering coursework [16], and discursive "micro-insertions" of ethics into technical courses for a potential net-positive effect [17].

In this paper the authors continue an effort to identify rhetorical practices as pedagogy and the impact of these techniques on underserved communities in engineering education [5] with the goal of demonstrating how these strategies ease accreditation processes and assessment methods for faculty while benefiting students. This is important due to the changing verbiage of accreditation requirements in the United States to ensure faculty can provide an "equitable and inclusive environment" [3, pp. 51]. How can faculty show they are providing these environments? In what ways are faculty already creating sociotechnical spaces in engineering programs?

In prior work the authors showed some of these strategies are already in place and must be documented in the larger body of knowledge around creating inclusive spaces in engineering education. The authors believe dissemination of these strategies may create a cornerstone from which to build praxis and make it easier for faculty to engage students while satisfying accreditation metrics. The strategies identified in previous efforts are: 1) modeling the limits of expertise, 2) positioning humans over technology, and 3) application exploration/storytelling are rhetorical tools that can strategically be used to increase inclusivity in classrooms. The authors show in this paper more strategies that may be used to positively impact student perception of technical courses as culturally separate from social issues [7] and position themselves as learners with agency and a right to participate in engineering education spaces [14].

The authors pay special attention to specific examples that educators can use immediately to thoughtfully incorporate social impacts into their engineering classrooms since, "...increased attention to "real-world" applications of engineering knowledge [is a potential] way of building competence in both engineering technical skills and engineering ethics" [18] which is one variation of the way social impacts may be integrated into technical coursework. Upholding the social issues as tantamount to technical rigor, the culture of disengagement inflicted upon students in undergraduate engineering education spaces [13] may stagnate or be reversed. These rhetorical strategies and discursive methods are portable for faculty who are tired of traditional lectern-style approaches to engineering education where the result is a "difficulty associated with crafting lectures with a depth and breadth of information" [19, pp. 88] that ultimately exhausts lecturers and creates an environment where students may easily go into automatic or tune out.

Study Design and Methodology

RQ 1.1: How do engineering faculty incorporate social impacts into their technical courses?

Setting

Faculty invested in improving their technical courses may consider looking at the integration of social impacts into their unique curricula. There is high potential in this approach to reap the benefits of increased student belonging, which leads to retention, which means more engineering graduates, and a more robust engineering community [20]. It is one way to demonstrate the relevance of engineering to society while simultaneously increasing the likelihood of success in future accreditation review cycles. Technical courses and their rigor do not suffer from the integration of social impacts [21] and the positive impact on students of this practice may increase their resiliency and ability to conquer difficult technical challenges upon industry entry.

This readiness is the motivation for the first-year engineering program studied at a west coast university. It is a novel, three-course sequence that allows first-year students to take engineering courses immediately in addition to their traditional first-year math and science coursework. It is the cornerstone course sequence that introduces topics such as How to be a successful student, What is engineering design, and Introduction to programming. The program is in its third full year and the longitudinal data on student belonging continues to be strong [9]. Studies focused on the integration of social impacts in engineering courses tend to lean toward the capstone [21] or upper division courses [7] and recent work has started to acknowledge the importance of cornerstone-to-capstone pipelines [22]. In engineering education, where first-year content is reflected in the rest of the curriculum, introducing design may give students tools to get a head start on the type of thinking necessary for success in their capstone projects. Curricula in this novel first-year program utilizes the Crick model of deep engagement [6] that demonstrates the layered contexts of engaging students. The personal, social, and global contexts within which learning takes place may be a roadmap for implementation of micro-insertions using rhetorical strategies, since "representations of reality [that] are constructed through articulation" will combat the discursive construction of engineering ethics and social impacts as separate from rather than integral to and imperative for productive society, [17, pp. 47], [23].

Recruitment

In this study the authors approached faculty who teach the novel first-year engineering program sequence, and general and electrical engineering courses. Faculty were recruited to participate in this study through introductory emails. Those who decided to participate were asked to open their classrooms to undergraduate research assistants who took field notes, and some opted into follow-up interviews. Five faculty members were selected for this collective case study that utilized observation and in-depth interviews with participants. Each faculty member's approach was observed during lecture and follow up interviews were conducted. Participant expertise is not identified to protect the anonymity of faculty but allowed for data collection of methods across diverse engineering backgrounds. Data that was collected was then independently coded then cross-checked by the authors for validity. A code book found in the appendix was created to parse the strategies identified in these classrooms into categories. These social impact themes and topic areas were used to categorize data into examples of the three contexts outlined by Crick [6] adapted to create a tool for identifying moments of sociotechnical integration, or the inclusion of social impacts during discourse on technical topics.

Conceptual framework

A subjective constructivist approach [10] was utilized because this study is recursive such that the authors review the data to improve our understanding, find more questions, and discover potential application areas. Subjective constructivist methodology (see Fig. 1) for education research indicates that the foundational stage consists of a set of best practices or theories on which to base an educational practice pilot and, subsequently, iterative versions of the initial model are progressively developed using data and analyses from the successive effort. In this study, each field observation session where a strategy was identified led to the discovery of multiple ways to incorporate social impacts in engineering classrooms.

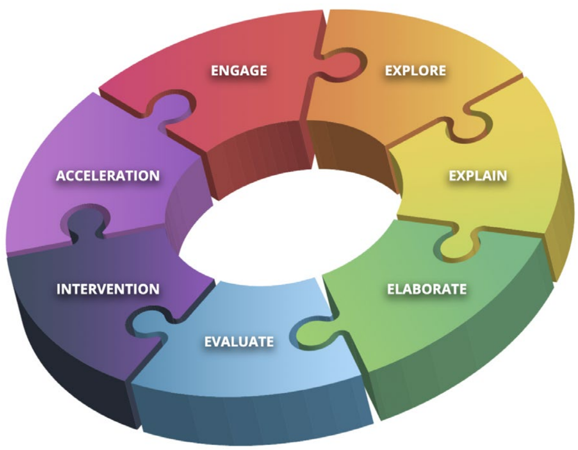

Figure 1. Image shows the extended "5E" [24] constructivist teaching model which demonstrates that knowledge is constructed upon foundational understandings [25].

After the first pilot round, in which best practices for creating inclusive learning environments in engineering education by applying rhetorical strategies for teaching students were identified and analyzed, the resulting data set, which included field observations and interviews with faculty practitioners who participated in piloted rhetorical strategies, was rich and suggestive. The following effective and inclusive teaching practices were emergent from this data:

- modeling the limits of expertise
- positioning humans over technology
- application exploration/storytelling

Having identified these practices, the next round of development and data collection focused on field observations and interviews of faculty practitioners who reported applying these strategies in order to investigate the question:

RQ 1.2. What are complementary associated teaching practices or behaviors that engineering educators who apply inclusive rhetorical strategies use to increase inclusivity in their classes through sociotechnical awareness?

Based on further exploration of the original data set, additional field observations and interviews the authors found that encouraging risk-taking in learners, building positive student-centered learning relationships in and outside classrooms, and prioritizing team building concurrently with technical assignments and course content were complementary practices. The present study sought to verify the impacts of these strategies as complementary and concurrently supportive of inclusive rhetorical strategies identified in the first phase of research in order to suggest practices that engineering educations use in their classrooms that are most conducive of inclusive environments and educational opportunities in which students engage authentically with both social and technical aspects of learning. The complementary practices indicated in the data set that were explored in this round of the research were:

- encouragement of risk-taking in learners
- building positive student-centered learning relationships in and outside classrooms
- prioritizing team building concurrently with technical assignments and course content

The following section details the process of analysis and interpretation that produced these emergent practices as well as implications for strategic focus on them by educators in engineering classrooms. Exploration in interviews of the insights behind faculty preparation of this material, or identification of it as emergent, brought further fine tuning of the topical areas where these strategies may apply. Field observations and interviews focused on faculty behaviors that encourage risk-taking in learners, build positive student-centered learning relationships in and outside classrooms, and prioritize team building concurrently with technical assignments and course content.

Results

The three contributions of this paper are compounded on prior work that determined 1) modeling the limits of expertise, 2) positioning humans over technology, and 3) application exploration/storytelling are rhetorical tools that can strategically be used to increase inclusivity in classrooms. Here the authors have demonstrated ways faculty are further working to engage students by, 4) encouraging risk-taking, 5) building positive student-centered learning relationships, and 6) prioritizing team building concurrently with technical assignments. Each of these new strategies compounds the impact of the prior discovery and are areas for the creation of novel assessment methods to verify the promotion of inclusion in engineering education spaces for accreditation bodies. Human-centered design includes an initial step for customer discovery to ensure a quality, useful product to the target market. It requires that the user is considered essential to the design process [26]. Similarly, educators must discover and address the needs of the students taking their courses.

Field notes from classroom observations and follow up interviews were analyzed for insight into class content delivery, faculty modes of engaging with students, physical classroom setup, peer interaction time per course period, and social impact themes. The main categories explored in the analysis are outlined in tables 1-3 in the appendix. The authors used Crick's [6] model of deep engagement to delineate contexts within which students confront and consume course material.

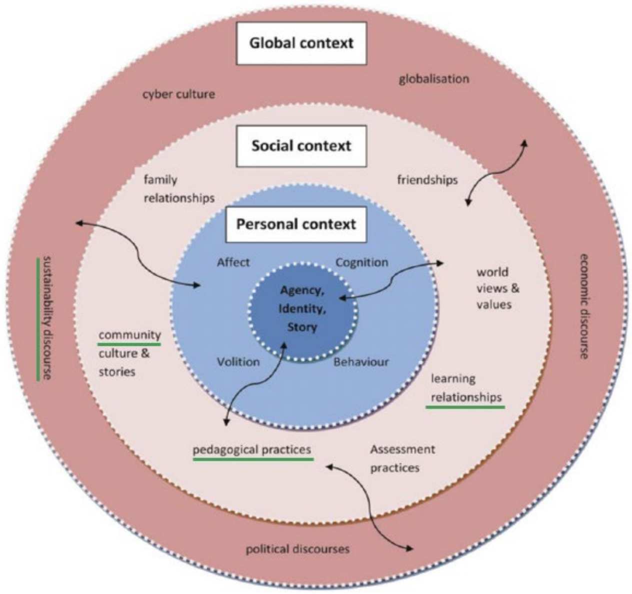

Figure 2. Crick's [6] model of deep engagement distinguishes the layers of understanding present. Each of these layers and the associated contexts are opportunities for increasing student engagement and agency in the classroom. They may also serve as a foundation for faculty interested in developing sociotechnical content relevant to their courses and assignments for the assessment of accreditation requirements.

Physical and structural conditions such as rows of chairs, projectors and lecterns at the front of the class, and the general immobility of classrooms limit the potential interaction between students and their peers or the teaching faculty [27]. Barriers to fully access some of these materials included large lecture halls with limited audio-visual amplification and the time limits associated with the class time.

Encouraging risk taking

The authors assume that while students in these courses likely had more information about the content than those performing field observation, that some of the struggles associated with taking field notes were likely also experienced by students in the class. The authors found that a simple, extended pause after asking a question can be a wonderful place to start promoting student engagement. Usually (eventually) someone spoke up to start a dialogue when the silence was allowed to linger. Active learning strategies are the next step, shown to increase student engagement and knowledge retention [28] active or cooperative learning strategies consist of pauses and time for students to reflect on and further absorb course content. These methods are varied by discipline and take many forms, but the result is a delineation from traditional lectures [29] to combat fatigue experienced by both students and educators [19].

Building positive student-centered learning relationships

As noted in Montfort [9], the majority (over 90 %) of the new student population in the first-year engineering course sequence somewhat or strongly agreed with the sentiment that their experience in the first-year program made them feel like they belonged. The survey specifically asked the following question: "I feel like I belong in the College of Engineering Community." (Q1). This survey data continues to be collected with one difference. The questions prior to this question were reordered. In particular, the first dataset asked specific questions about students' experience in the novel first-year engineering courses, and after Q1 prompted them to enter a specific example in their courses which positively or negatively impacted their feelings of belonging (Q2). For the second data set, the questions prior to Q1 were about their general experience in the college with prompts such as "I can really be myself…" and "Faculty want me to be successful." As such, the response of students who somewhat or strongly agreed with Q1 varied between 68-75% over the year. This was significantly lower than the first year's results.

The responses to Q2 highlighted themes which relate to Crick's [6] model of engagement including the observable excitement of professors and teaching assistants about course content, enjoying engineering and computer science problem solving, and hands-on activities. Positive feedback from the students to the participants of the pilot study may help faculty understand their impact on student engagement and agency.

Prior results identify faculty's practices of 1) modeling the limits of expertise, 2) positioning humans over technology, and 3) application exploration/storytelling. The follow up work presented in this paper demonstrated new strategies, but also continued to clarify insights from prior work. Modeling the limits of expertise and application exploration/storytelling reemerged in new field observations. For example, one faculty participant modeled the limit of their expertise during a lecture. They made a mistake and apologized to the class, "So I circled this one…so this solution is not [correct] because I messed up." The lecturer joked while correcting their mistake and acknowledged the mishap in an approachable and humble way. The result was a focus on the process for solving problems and acknowledgment that even someone who has many years of experience and practice needs to use the approach being taught. Another example, specific to storytelling, occurred where a faculty participant talked about their work experience and how the course content was directly applicable to work they had been assigned in industry, and how frustrating multiple layers of complexity can be when engineers have to tackle real world problems. These data combined, presented here and in prior work, showcase an improving landscape for both faculty teaching introductory engineering courses and students experiencing engineering content.

Prioritizing team building concurrently with technical assignments

Every course in the first-year engineering sequence has some groupwork component attached to it where the goal is for students to share a collective perception, need, aim, experience interdependence, interaction, and cohesiveness (Davies, 2009). The findings from this effort demonstrate ways rhetorical strategies assist in creating an environment where students experience collaboration with the aim of fully engaging in groupwork as part of the class. One participant faculty member dedicated an entire class to student collaboration on a final project. The instructor walked around the room and answered questions the whole class period. Students were initially quiet, then started to actively engage with each other and the instructor. The previously quiet and low energy classroom became louder as more students utilized the time to explore the material and their assignment.

More than in specific student groups working on assignments or projects, the overall effectiveness of these rhetorical strategies is in creating an atmosphere where the entire class creates and maintains a cohesiveness. As shown in prior work [5] this cohort-type model is driven by faculty in their preparation, presentation, and perpetuation of social impacts into first-year l technical courses.

Discussion

The preliminary results of modeling the limits of expertise, positioning humans over technology, and application exploration/storytelling relate to both the personal and social contexts described in Crick's [6] model. The personal context the student experiences may be reinforced or challenged with the social classroom context. Faculty who represent themselves as having specific, but not exhaustive, expertise allow space in the room for differing opinions and ideas. Faculty who strive to position humans over technology decrease the pressure associated with the social and global contexts of interaction with computers and complex systems. Application exploration/storytelling humanizes and brings familiar concepts that often are siloed in engineering education from social impact areas [5].

Risk-taking is encouraged through the faculty pausing and creating room for students to assert their own ideas in a setting with minimal risk. That minimal risk is due to the faculty proactively modeling the limits of their own expertise and positioning humans over technology. The combination of these two rhetorical strategies is powerful and allows for semi-structured class time that in part alleviates some of the overhead of creating strict lectures. Faculty may also contribute to this by very clearly outlining the expectations for the course and giving clear examples of collaborative work and how it differs from plagiarism, ensuring students are well-informed when taking risks and thinking critically about course content in ways that are not scripted by the instructor.

Student-centered learning relationships rely on the faculty allocating time for peer interactions and walking around the room to enthusiastically eavesdrop on new ideas and add advice or guidance as needed. Released expectations of quiet classrooms (occasionally) allowed students to form connections and create relationships where a sense of community and belonging emerged.

Prioritizing team building concurrently with technical assignments emphasized the agency of the students to drive their own experiences. All previously identified rhetorical strategies fostered this through active learning and or groupwork in varying class sizes and formats.

Conclusion/Future Work

The goal of this research is to identify strategies that are portable between fields, and easily accessed and implemented by engineering faculty. In this work-in-progress paper the authors identified sociotechnical teaching practices driven by rhetorical strategies indicated by the data set to complement the rhetorical strategies used by faculty emergent from our initial study and research report. In the prior work it was shown that 1) modeling the limits of expertise, 2) positioning humans over technology, and 3) application exploration/storytelling rhetorical tools may be used to increase inclusivity in classrooms. These mechanisms may also be used to communicate technical concepts, integrate social impact content in engineering classrooms, and become the foundation for the creation of metrics to show compliance to accreditation bodies. In this paper, the authors have demonstrated similar complementary possibilities for more strategies. These include 4) encouraging risk-taking, 5) building positive student-centered learning relationships, and 6) prioritizing team building concurrently with technical assignments.

These rhetorical strategies were found to benefit instructors as well as students beyond the most obvious way the authors have presented concerning metric creation for accreditation review. When instructors use these strategies in their classrooms the students respond with feedback in real time. One faculty participant incorporated this type of feedback into the lecture, saying, "Tell me if you understand or not…I have been told I'm going…fast" leaning into the constructivist model of knowledge formation and offering opportunities for students to know if they are behind, they are not alone.

The creation of metrics to demonstrate effectiveness of these strategies must be based in the context of these strategies, a one-size-fits-all approach would decontextualize the curriculum and work against successful incorporation of social impacts into technical courses. Concurrent development of curriculum and accreditation assessment assignments will decrease overhead for course design and improve quality. This may be done during initial course design or at any stage of revision or improvement. Limitations to this work include a small sample size of faculty participants and continued program rollout.

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Appendix — Coding tables

Table 1. Social impact themes and the topic areas used for coding field note data using Crick's [6] model of deep engagement as a first-level filter: **Personal Contexts**.

Showing humanness	Viewing mistakes as opportunities (number of occurrences TBD)
	Modeling limits of expertise
Personal experience/personal understanding	Learning/new experiences in a new environment
	Bias reduction (accepting/celebrating difference)
	Engineering Identity (internalization of aspects of being an engineer)
Worldview	Human agency/student agency

Table 2. Social impact themes and the topic areas used for coding field note data using Crick's model of deep engagement as a first-level filter: **Social Contexts**.

Structural conditions	Imposed risks and harms	Centering impacted communities
	Technical/social dualism	Prioritizing people over technology
Teaming	Team building	
	Friendships	
	Learning relationships	Study buddies/Peers in class
		Collaboration over competition
		How do relationships between faculty and students impact student engagement?

<table>
<tr><td></td><td></td><td>Building trust</td></tr>
<tr><td rowspan="5">Listening contextually</td><td rowspan="2">Bias reduction through understanding</td><td>Minimizing unconscious bias</td></tr>
<tr><td>Fostering awareness of commonalities and differences</td></tr>
<tr><td rowspan="2">Community culture/sharing stories/sharing experiences</td><td>Storytelling</td></tr>
<tr><td>Encouraging mistakes</td></tr>
<tr><td colspan="2">Contextualizing engineering problems</td></tr>
<tr><td rowspan="4">Student agency/mobilizing power</td><td rowspan="2">Sociotechnical approaches</td><td>Individual impacts</td></tr>
<tr><td>Teammate impacts</td></tr>
<tr><td rowspan="2">Home knowledge</td><td>Personal experiences correlated to larger social context (home knowledge application)</td></tr>
<tr><td>Human-centered design</td></tr>
</table>

Table 3. Social impact themes and the topic areas used for coding field note data using Crick's model of deep engagement as a first-level filter: **Global Contexts**.

<table>
<tr><td rowspan="3">Listening contextually</td><td>Sustainability discourse</td><td>Minimal impact</td></tr>
<tr><td colspan="2">Economic discourse</td></tr>
<tr><td>Political discourse</td><td>Policy and engineering/tech advancement</td></tr>
<tr><td>Agency and mobilizing power</td><td colspan="2">How can engineers (students/faculty) design solutions that do more good than harm?</td></tr>
</table>