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Paper ID #16904

Foundations of Social and Ethical Responsibility Among Undergraduate Engineering Students: Project Overview

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Introduction

It is widely recognized that technical professionals play critically important roles in serving the public, supporting the success of private sector enterprise, and addressing global grand challenges. As a result, providing engineering students with training in ethics, social responsibility, and allied topics is advocated by a variety of stakeholders, mandated in ABET accreditation requirements, and largely presumed by professional associations and licensing bodies. Many formal courses and programs have in turn been created to promote professional responsibility and ethical integrity among engineering graduates. Other interventions (e.g., service learning programs) have also been developed to more broadly challenge engineering students to develop as engaged citizens and community members. Yet there has been a notable lack of research on measures and understandings of social and ethical responsibility among undergraduate engineering students. Further, few studies have looked at how such indicators change over time and are impacted by specific kinds of learning experiences. As a result, faculty and administrators often have little evidence to guide creation of high-impact courses and programs. Other recent research also suggests that the impacts of such interventions may be blunted by pervasive "cultures of disengagement" in many engineering schools.[1]

This NSF-supported CCE STEM research project aims to shed additional light on these issues, with an emphasis on three main objectives: O1) Characterize patterns of ethical development among undergraduate engineering students, O2) Identify specific context variables (e.g., climate and culture of programs and institutions) and types of interventions (e.g., formal ethics instruction, service learning programs, etc.) that have positive (or negative) impacts on foundational measures and understandings of social and ethical responsibility, and O3) Identify specific student characteristics that can be leveraged to grow programs oriented toward social and/or ethical responsibility, while increasing program alignment with – and impacts on – participating individuals. As these objectives suggest, the findings from this project are intended to help guide ongoing efforts to positively impact the social and ethical commitments of engineering graduates, including through research-based recommendations for curricular reform.

In this paper we give an overview of this research project, with particular emphasis on the longitudinal, mixed-methods study design being leveraged in support of the objectives given above. More specifically, we present our research questions, study contexts, target subject populations, and procedures for quantitative and qualitative data collection and analysis, as well as some possible limitations to our approach. We additionally discuss the novel, ambitious, and comparative nature of this project given that its collaborators and research subjects are drawn from four U.S. engineering schools, and we review our progress to date and plans for bringing the project to completion over a five-year timeline. This paper will likely be of particular interest to scholars who teach and/or research engineering ethics, social responsibility, and allied topics.

Social and Ethical Responsibility

Our project is focused on *social and ethical responsibility*, broadly construed, and primarily in the context of engineering education and professional practice. On one hand, this phrase is meant to include engineering ethics and professional integrity in a more conventional sense, such as reflected in ABET accreditation criterion 3.f, which states that engineering graduates should have "an understanding of professional and ethical responsibility."[2] However, we are also intentionally concerned with the two major areas of ethical concern described by Herkert[3], namely "micro-ethical" considerations that are mainly focused on individual conduct, as well as "macro-ethical" issues that involve larger questions of collective social responsibility, including social justice and allied themes.[4-5] We additionally recognize that these aspects of professional identity and behavior are neither isolated or static. Instead, they dynamically interact with other salient considerations, such as personal beliefs, values, morality, academic integrity, etc., and are also frequently influenced by group-level climate and culture in organizations, programs, and teams. Thus, we seek to characterize perceptions of social and ethical responsibility among engineering students, as well as whether and how they change over time. By looking at a diverse group of students, universities, and experiences, our study aims to not only identify specific interventions that have the biggest measurable impacts on students, but also explore how these efforts are inflected by a wide variety of demographic (individual and institutional) differences.

Study Design and Project Plan

Aligned with the larger project objectives and aiming to address gaps in the extant research literature, the study design for our project is focused on the following two research questions:

RQ1) What do engineering students perceive as responsible (and irresponsible) professional conduct, and what do they perceive as just (and unjust) professional work practices?, and

RQ2) How do foundational measures and understandings of social and ethical responsibility change during a four-year engineering degree program, both in general and in relation to specific learning environments and experiences?

To address these questions, we are conducting a longitudinal, multiphase, mixed-method study design[6] to collect quantitative and qualitative data from undergraduate engineering students at four universities, as summarized in Figure 1 and described in more detail below. More specifically, a QUAN→QUAL approach will be used for the first study phase, followed by repeat QUAN survey measures during mid-point and Phase 2 data collection, as well as longitudinal or exit interviews (QUAL) conducted during Phase 2. This mixed-methods approach is "premised on the idea that the use of quantitative and qualitative approaches in combination provides a better understanding of research problems than either approach alone."[7] Such approaches typically include multiple and complementary sources of evidence throughout the process, thereby respecting and even leveraging contrasting research paradigms or "worldviews."

Study Contexts, Participants, and Recruitment

To improve transferability of results, our study includes four university with different geographic locales and university types, including public research-intensive (Purdue University), public

research-intensive and project-based (Arizona State University), private research-intensive (Brigham Young University), and public undergraduate-serving (Colorado School of Mines). As described in more detail below, each participating school also has programs and experiences that are of particular interest for this study, including service-learning courses and organizations, and degree options and/or coursework that provide intensified formal instruction related to ethics, social responsibility, and allied topics (e.g., biomedical engineering). We have obtained IRB approval for all data collection activities. To encourage high response rates and quality data, we are also providing appropriate compensation with increasing incentives as the study progresses to maintain participant commitment throughout the longitudinal study.

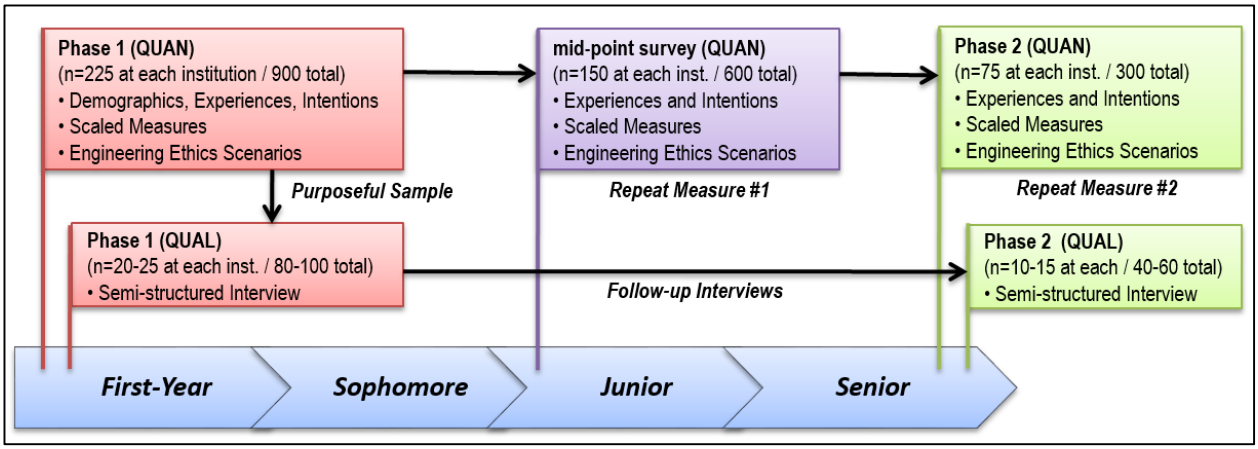

Figure 1. Overview of Data Collection Plan

Phase 1: Baseline Evidence

We are currently in Phase 1 of the study, which includes a large-scale survey of first-year engineering students (goal of n=900 total responses) to collect demographic information, scaled survey constructs, and scenario-based measures that are related to the core aims of this study. The component parts of the survey are described in more detail below. Special efforts have been made to secure a sample that is gender- and ethnic-diverse, as well as stratified to include large numbers of students who both are and are not likely to receive intensified exposure to considerations of social and ethical responsibility during their degree programs.

Initial analysis of the survey data is underway. This data has also been used to identify and recruit three types of interviewees for the study, namely those who will likely complete engineering degrees with: 1) a traditional and more narrow technical focus, 2) a curricular service-learning component, and 3) enhanced formal instruction in engineering ethics. To account for study attrition, we are in the process of conducting 20-25 interviews at each school (or 80-100 interviews total) using a semi-structured interview protocol focused on RQ1.

The remainder of the first year and entirety of the second project year will involve intensive analysis of the Phase 1 study data. The research team has begun analyses of the survey data to identify baseline scores among the main target populations, while also looking at possible relationships in the data (e.g., to what extent do demographic characteristics and prior

experiences predict student orientation toward social and ethical responsibilities).[8] Additionally, the interview data will be systematically analyzed and coded during this period using appropriate qualitative methods, including thematic analysis and phenomenography. During the second and third project years, Phase 1 findings will be disseminated via appropriate venues (e.g., conference papers, journal articles, etc.).

Mid-Point Survey

In order to better understand student development during a four-year degree trajectory, the survey questionnaire will again be administered to as many of the original Phase 1 participants as possible at the beginning of their junior year. While the study design accounts for some attrition, we will also provide appropriate monetary incentives to encourage repeat measures. To increase the likelihood of statistically significant findings in our final sample, our target for mid-point data collection is at least 600 participants.

Phase 2: Longitudinal Evidence

The second major study phase (beginning of Year 4) will involve a third and final round of data collection which includes both the survey and interview components. The survey questionnaire will be administered for a third time to as many of the mid-point participants as possible. Again, we have monetary incentives to encourage repeat measures. To increase the likelihood of statistically significant findings, our target is at least 300 complete sets (triads) of survey data.

The research team will also conduct follow-up interviews with as many of the original interviewees as possible during their fourth year, working toward a target of 10-15 follow-up interviews at each school, or n=40-60 total matched interview pairs at all sites. The research team will target recruitment efforts to ensure a roughly even distribution of study subjects among the four data collection sites and three study groups. The goal of these groupings is to compare a "baseline" population of students with counterpart groups who are exposed to types of learning experiences of special interest for this study, e.g., service learning (as a more indirect and implicit approach to cultivating social and ethical responsibility) or intensified ethics instruction (as a more direct and explicit approach).

The remainder of the fourth project year and beginning of the fifth project year will focus on analysis of all study data (from Phase 1, mid-point, and Phase 2). Efficient and timely analysis of this data will be enabled by the relatively long gap between the two main data collection periods, which will allow for Phase 2 data analysis procedures to be in place and ready for deployment when Phase 2 data collection begins. In contrast to Phase 1 data analysis, Phase 2 will allow us to focus on both research questions, namely by providing a snapshot of foundations for social and professional responsibility among engineering students as they approach graduation (RQ1), as well as allowing us to investigate how these measures and understandings *change* during a four-year degree program, especially in relation to specific kinds of learning pathways and experiences (RQ2).

Data Sources

This project will involve collection of the following sources of quantitative and qualitative data:

Demographics, Experiences, and Intentions: During Phase 1 we are collecting demographic information from all study participants, including gender, ethnicity/race, international student status, intended major, etc. During the mid-point and Phase 2 administrations, we will collect relevant information such as GPA, academic major(s) and minor(s), and intended career plans. During all three data collections, we will also ask respondents to report spiritual/religious orientation, other relevant experiences (e.g., service learning, mission work, community service, volunteer activities, extracurricular activities, co-op/internship/work experiences, conferences, workshops, etc.), and completion of related coursework, certificate programs, etc. This information will mainly be used to perform within- and across-group comparisons and modeling of the larger quantitative data set, as well as for targeted recruitment of interview subjects.

Scaled Measures: We will use the following measures of social and ethical responsibility for our large-scale data collection efforts, which include:

- *Political and Social Involvement Scale (PSIS):* This 11-item Likert scale asks respondents to rate the personal importance of a series of statements related to themes like volunteering, racial understanding, and influencing political structures (e.g., "Helping others who are in difficulty).[9]
- *Distributive Justice Beliefs*: This 8-item Likert scale survey evaluates perceptions of distributive justice beliefs (e.g., "People generally deserve the things that they are accorded") for self and others.[10]
- *Ethical Climate Index (ECI):* This 19-item instrument (short form version) covers collective moral sensitivity, collective moral judgment, collective moral motivation, and collective moral character.[11]
- *Engineering Work/Practice Considerations*: This Likert scale survey asks respondents to rate the importance of seven considerations of engineering work (e.g., technical, environmental, social, etc.). If respondents indicate any of them are extremely important, they are asked why they did so.[2,12]
- *Macro-Ethics*: Multiple-choice and Likert-scale items to evaluate thinking and knowledge related to various macro-ethical and professional responsibility themes adapted from another study of ethics education.[13]
- *Moral Attentiveness:* Set of 7 items drawn from the Reflective and Perceptual sub-scales of the instrument.[14]
- *Moral Disengagement*: 24 item scale that measures eight interrelated moral disengagement mechanisms.[15]

Engineering Ethics Scenarios:

- *Ethics Knowledge Questions:* We are using the same five knowledge/scenario questions that were employed in the earlier SEED research project.[16-17] The format of these items is similar to questions that appear on the Fundamentals of Engineering (FE) exam. They are multiple-choice format; each has a preferred answer.
- *Engineering Ethics Scenarios*: We have adapted three situational-judgement situations focused on ethical issues in engineering practice adapted from prior work by Jesiek et al.[18] Each multiple-choice question has a strongly preferred answer as validated by experts.

Interviews: The primary source of qualitative data for this study originates from longitudinal, semi-structured interviews conducted with engineering students, with first interviews occurring during their first semester or year and follow-up interviews in their eighth semester. The Phase 1 interviews are underway. The interview protocol is aligned with the research questions, informed by relevant quantitative findings, and organized around four major themes: 1) How do students understand what counts as social and ethical responsibility, both in general and in engineering specifically?, 2) What kinds of formal and informal learning experiences have shaped their perceptions of social and ethical responsibility (e.g., coursework, service-learning, etc.)?, 3) What memorable ethical issues have they encountered (as individuals, students, aspiring professionals, etc.), how did they handle these situations, and what did they learn?, and 4) What are their major personal and professional goals, and how are these related (or not) to broader considerations of ethics, integrity, morality, social responsibility, etc.? The second and third themes in particular will utilize critical incident interviewing techniques to help elicit real-world experiences, perceptions, and situations from our research subjects.[19] As a final strategy for evaluating how engineering students perceive and approach situations involving questions of social responsibility or ethics, we include questions and probes around select scenarios from the survey to provide additional insight to why they choose the responses they did.

Data Analysis Plan

Our plan for data analysis begins with systematic approaches to separately analyzing both the quantitative and qualitative evidence. However, data integration opportunities will also be systematically explored and pursued during all phases of the project.

Quantitative data analysis for this project will focus on the demographic/background information and scaled measures described above, and organized around three partially distinct analytic approaches. First, within- and across-group comparisons will be performed for the static phase 1, mid-point, and phase 2 data sets using appropriate statistical techniques (e.g., ANOVA), with the goal of identifying significant demographic and/or other predictors for each individual measure, as well as levels of correlation between the measures (e.g., factor analysis). Second, we will look at all three data sets (e.g., via repeated measures t-tests) to examine whether there are significant changes in the individual measures over time. Finally, we will more comprehensively look at and model interactions among all measures and variables, including over time, through use of latent variable modeling and structural equation modeling approaches. Other statistical techniques may also be employed depending on exploratory results. Ultimately, the goal of this analysis is to leverage the quantitative data to examine key associations and questions such as:

1) How do measures of social and ethical responsibility among engineering students compare to results for other population(s) reported in the literature, both upon entering and leaving their respective degree programs?
2) Do certain demographic characteristics, prior experiences, etc. predict weaker or stronger foundations for social and ethical responsibility (e.g., as reflected in lower or higher scores on PSIS, Justice Beliefs, etc.)?
3) What characteristics and measures predict student participation in programs oriented toward social and ethical responsibility, e.g., formal ethics instruction, service-learning, etc.?

4) Does student participation in certain kinds of formal and/or informal learning experiences have measurable impacts on any foundational measures (e.g., PSIS, Justice Beliefs, etc.)?
5) Do different institutional and programmatic contexts have measurable impacts on foundational measures of social and ethical responsibility, as well as how these measures change over time?

Preliminary results from analysis of Phase 1 survey data can be found in a parallel conference paper.[8]

Qualitative data analysis for this project will focus on providing explanatory depth and "thick description"[20] for patterns and trends observed in the quantitative data sets, as well as allowing identification of novel trends and phenomena of interest not readily evident or detectable in other project data. To achieve these objectives, two methodological approaches will be used.

First, *thematic analysis*[21] will be used to code prominent themes in the data following best practices across the six analysis steps recommended by Braun & Clark: getting familiar with the data, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and reporting results. [22] Given the study questions and interview protocol, likely themes for this analysis include definitions of social and/or ethical responsibility, types of ethical situations most often encountered by students, types of learning experiences viewed as most relevant by students, changes in perceptions of social and/or ethical responsibility, etc. This analysis approach is proposed in part because it accommodates identification of themes both inductively and deductively.[23] It can also generate novel insights, enable systematic study of similarities and differences in data, and allow both social and psychological interpretations.[22]

In addition, we plan to use *phenomenography* to identify different ways of experiencing social and/or ethical responsibility in engineering education and practice. Phenomenography has its roots in educational research in Sweden, arising from recognition that the qualitatively different ways in which learners experienced or understood a phenomenon were related to the qualitative differences in the outcome of that learning.[24-25]

The reliability and validity of all qualitative research procedures will be further enhanced by following established best practices such as memo writing to generate and integrate codes, interdisciplinary triangulation, and incorporation of different researchers' interpretations.[26-27]

About the Participating Institutions and Target Programs

Purdue University is a public, land-grant institution founded in 1869 in West Lafayette, IN, and today classified as a very high research activity university. Purdue's College of Engineering has 15 degree programs and more than 7,700 undergraduates students. While many Purdue engineering students follow more traditional curricular pathways, large numbers also participate in credit-bearing service-learning programs such as Engineering Projects in Community Service (EPICS, ~500 students/semester) and Global Design Teams (~75 students/year). Additionally, all students in Purdue's biomedical engineering program (~96 entering students/year) receive intensified ethics instruction through a 3-credit curricular requirement. Recruitment of students at

Purdue will occur in the first-year engineering (FYE) and learning community programs, which provide common and special-interest courses to incoming students.

Brigham Young University (BYU) was founded in 1875 and is located in Provo, Utah. One of the largest private universities in the United States, BYU provides a comprehensive education to nearly 33,000 full time students from all 50 states and 115 countries. BYU students complete an academically rigorous course of study and also pledge to uphold the highest standards of conduct and adhere to the values of the university's sponsoring organization, The Church of Jesus of Christ of Latter-day Saints. To achieve a balanced education, all BYU students complete 14 religion credits in addition to general education and major requirements. The Ira A. Fulton College of Engineering and Technology at BYU has 10 degree programs and more than 3,600 students. The college prepares graduates by focusing on five key areas: Technical excellence, Leadership, Global Competence, Character Development, and Innovation. All engineering and technology students take a 3-credit curricular required global leadership class focused on leadership, ethics, and global competence. In addition, some degree programs provide additional instruction in ethics. Recruitment of subjects at BYU will be facilitated through a leadership workshop offered each semester to new engineering and technology students.

Arizona State University (ASU) and its associated College of Technology and Innovation at (CTI), located on the Polytechnic campus of Arizona State University, strives to fully embody the values of engaged learning, use-inspired translational research, deep engagement with industry, and entrepreneurship. The CTI is home to more than 2,000 students studying in undergraduate and graduate majors. The college is organized into five academic units (Engineering, Applied Sciences and Mathematics, Technological Entrepreneurship and Innovation Management, Engineering Technology, and the Morrison School of Agribusiness and Resource Management), which thrive under the guidance of more than 100 faculty members with deep expertise in many of the most important technological challenges that society faces.

The *Colorado School of Mines* (CSM) is a public teaching and research institution in Golden, CO that focuses on education and research in engineering, science, mathematics, and economics. CSM emphasizes practical, hands-on experiences and an interdisciplinary approach to solving the world's challenges related to the earth, energy, and the environment. CSM offers 15 Bachelor's degree programs and 21 Master's and Doctoral degree programs through its Colleges of Applied Science and Engineering; Engineering and Computational Sciences; and Earth Resources Science and Engineering. CSM's curriculum also engages students in humanities, ethics, and social sciences. Students can earn a minor in Public Affairs through the 21-credit hour McBride Honors Program, which integrates STEM, liberal arts, public policy, anthropology, and experiential learning to give students a well-rounded education. Additionally, students can earn an 18-credit hour Humanitarian Engineering Minor, which emphasizes how engineering can contribute to co-creating just and sustainable solutions for communities.

Summary

We believe findings from our longitudinal, mixed-methods study will have considerable potential to enhance ongoing efforts to cultivate social and ethical responsibility among future engineers, including by investigating differences in perceptions and experiences among underrepresented groups. Comparing data from each study phase will provide strong evidence regarding how student perceptions of social and ethical responsibility change from the beginning

to the end of a four-year degree program, including through relevant interventions, and in relation to different institutional and programmatic contexts and cultures. As we continue in the study, our dissemination efforts will especially focus on identifying and promoting curricular interventions found to be especially effective at cultivating social and ethical responsibility, and providing recommendations so programs can better align their efforts with predominant student views and perceptions

Acknowledgement

This material is based upon work supported by the National Science Foundation under Grant No. 1449370. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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