Characterizing Disengagement in Undergraduate Education at MIT

by

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Abstract

Recent studies have identified a decline in the public welfare concerns of graduates from top US engineering programs, including MIT. As technology ethics becomes a more prevalent topic of public discussion, there is increasing interest in identifying ways higher education can effectively train ethically and socially responsible change-making technologists. While academic institutions have already begun making investments to revamp research and education to address these concerns, such efforts must come paired with a better understanding of the decline in student engagement to issues of ethics, social responsibility and public welfare. This thesis explores the problem of characterizing the trend of student disengagement at MIT. Using survey data of three undergraduate cohorts, we investigate the role of an MIT undergraduate education in the development of students' competencies and long-term engagement-related outlooks. Finally, we provide a comparative analysis of select academic models for fostering more engaged engineering graduates.

Thesis Supervisor: Julie Shah
Title: Associate Professor

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Chapter 1

Introduction

Throughout history, scientific advancements have been key to revolutionizing society. The Fourth Industrial Revolution, grounded in the recent advancements in computing and big data, has seen the intersection of disciplines such as media, business, medicine and law with engineering, computing and Artificial Intelligence (AI) [30]. The introduction of such technologies has allowed for more efficient and tailored experiences in nearly every aspect of our lives, but has also raised concern for its unintended ethical and societal implications.

Such implications, specifically regarding computing and AI, have become a pervasive topic of public discussion. Indeed, the disengagement of engineers and technologists from public welfare concerns has proven to be a matter of grave social, political, and economic concern. The Cambridge Analytica scandal of 2018 [16] sparked public debate about the importance of user privacy and the ethics of microtargeting as we witness a transformation in the nature of political campaigns in the digital age. Troubling cases in which technology perpetuates socioeconomic injustice are exemplified by algorithmic bias in decision-making systems used in law enforcement and healthcare such as the COMPAS Recidivism Algorithm [4] and the Optum healthcare algorithm [18]. Furthermore, with robots and autonomous systems beginning to replace humans at increasingly alarming rates, the future of work has never been more uncertain [30]. Alongside technology regulation, the need for ethics and social responsibility training has never been greater.

Longstanding efforts have been made to prevent the misuse of technology by more concretely defining the role of engineers and scientists in society. Since the early nineteenth century, the engineering profession has recognized its responsibility to monitor the practices of its professionals [7, 23]. Acknowledgement of such responsibilities is seen in ethics codes defined by the Association for Computing Machinery (ACM)[2], Institute of Electrical and Electronics Engineers (IEEE) [13] and National Society of Professional Engineers (NSPE) [22]. Furthermore, documents such as the IEEE's Ethically Aligned Design and National Academy of Engineering's Grand Challenges for Engineering Report deliver a "vision for prioritizing human well-being" [14] and articulate the profession's commitment to solving societal problems [24].

However, beyond documents and codes, developing the next generation of ethically and socially responsible technologists requires equipping them with the competencies and outlooks to address societal challenges. Institutions of higher education must imbue technologists with the social consciousness and competencies, alongside technical skills, to uphold their professional responsibility to the public welfare. The Massachusetts Institute of Technology (MIT) - a global leader and institution at the forefront of engineering, computing and AI - is no exception in this regard.

1.1 Problem Statement

Engagement and public welfare are broad terms used to capture the obligation of the professional engineer to "hold paramount the safety, health, and welfare of the public" [22]. Under this canon, the professional engineer must go beyond simply protecting the public in his or her own engineering work. The professional engineer must further consider ethical and societal implications and serve as an agent for change in cases where the profession may undermine the public welfare. The culture of disengagement in engineering is defined as the "constellation of beliefs, meanings and practices" [7] that influence the way members of the engineering profession understand their professional responsibility to the public. This culture frames the conceptualization of what it means to "think like an engineer," the considerations that go into formulating what defines an "engineering problem" and the metric for evaluating the "success" of one's engineering contributions [7, 9]. Such epistemic cultures dictate what concerns and considerations are relevant to the "primary" responsibilities of an engineer, ultimately resulting in a set of concerns being considered "tangential" to the design, development and implementation of technological solutions [7, 9]. Through this process, disengagement may mean that public welfare concerns - including issues of equality, privacy, security, ethics, bias, fairness, history and politics - are excluded from the realm of what defines an engineering problem [7].

This culture of disengagement provides the theoretical context for recent studies that have revealed a troubling trend in the public welfare considerations of graduates from top US engineering programs - including MIT. The findings, based on an analysis of longitudinal student survey responses of incoming first years and graduating seniors, identify a decline in students' public welfare considerations of engineering work over the course of their undergraduate programs [7].

As technology becomes a more integral part of society's fabric, the engagement of engineers and computer scientists with concerns outside of those considered strictly "technical" is crucial. So how can we better understand and characterize recent trends of student disengagement? What can academic institutions do to foster more engaged graduates?

1.2 Opportunities and Goals

With an understanding of their role in training ethically and socially responsible technologists, leading academic institutions across the country have begun making significant investments to revamp research and education efforts. On the west coast, Stanford University launched the Institute for Human-Centered AI to cultivate an "interdisciplinary, global hub" with a commitment to "studying, guiding and developing human-centered AI technologies and applications" [34]. On the east coast, Harvard University introduced its Embedded EthiCS initiative to train its computer scientists to effectively "think through the ethical and social implications of their work" [27].

Announced in October 2018, the MIT Schwarzman College of Computing represents a $1.1 billion commitment to address the global opportunities and challenges presented by computing across industries and academic disciplines. The founding of the MIT Schwarzman College of Computing is undoubtedly a big leap into the future for an institution that has already been at the forefront of engineering, computing and AI. More importantly, the College will further enable MIT to "emerge as a global leader in the responsible and ethical evolution of technologies that are poised to transform society." The MIT Schwarzman College of Computing will [19]:

- *Reorient MIT to not only deliver the latest advances in computer science and AI but also discover the power of computing in every field of study on campus, while ensuring that the future of computing is shaped by insights from other disciplines.*
- *Create 50 new faculty positions located both within the College and jointly with other academic departments across MIT.*
- *Provide a structure for collaborative education, research, and innovation in computing across all of MIT's schools.*
- *Provide a structure for collaborative education, research, and innovation in computing across all of MIT's schools.*
- *Educate students in every discipline to be "bilingual," so they can responsibly use and develop computing technologies to help make a better world.*
- *Transform education and research in societal, public policy, and ethical considerations relevant to computing.*

The MIT Schwarzman College of Computing's mandate to "[ensure] the future of computing is shaped by insights from other disciplines" and educate students to "responsibly use and develop computing technologies" demonstrates a commitment to interdisciplinary study and social responsibility [19]. However, such investments must come paired with an understanding and characterization of the decline in student engagement to issues of ethics and social responsibility. Using MIT - a leader in engineering education and institution at the forefront of computing and AI - as a case study, we investigate:

- The role of an undergraduate education in developing students' engagement-related outlooks and competencies

- The relationship between competency development and engagement-related outlooks
- The state of existing internal and external curricular and co-curricular models for achieving more ethically and socially-responsible engineering graduates

1.3 Contributions

There are three main contributions of this thesis. First, using cross-sectional survey data of three undergraduate cohorts (class of 2014, 2016 & 2018), we examine the trend of disengagement at MIT by analyzing the role of an undergraduate engineering education on the development of students' public welfare-related outlooks and competencies. Second, we investigate the interaction between students' outlooks and competencies to understand how the competencies developed as undergraduates shape students' long-term engagement outlooks. Lastly, we provide a comparative analysis of different curricular and co-curricular models used by select peer academic institutions to achieve more ethically and socially-responsible engineering graduates.

Ethics and social responsibility training has been the focus of recent education and policy initiatives. However, the efficacy of such efforts and initiatives relies upon a deep understanding of the gaps and limitations of current practices in higher education. The contributions of this work in characterizing recent trends of disengagement will ultimately be a key step towards enabling engineering programs to effectively foster more engaged graduates.

1.4 Outline

The remainder of this thesis is as follows. Chapter two provides relevant background research on the theoretical context of the culture of disengagement, and presents the findings of a recent study on the public welfare considerations of graduates from top US engineering programs. Chapter 3 defines core competencies and outlooks of engaged engineering professionals, and presents the data, methods and findings in the quantitative analysis of the survey data of three MIT undergraduate cohorts (class of 2014, 2016 & 2018). Chapter 4 presents an internal scan and external benchmarking analysis of the current state of academic models for ethics and social responsibility training developed and practiced by select peer institutions. The final chapter concludes with a discussion of the contributions of the work, its limitations, and steps for future work.

Chapter 2

Background

The work presented in this thesis builds upon research on the culture and trend of disengagement in undergraduate engineering education programs. The second part of this work leverages research on computer and engineering ethics education.

2.1 Engineering and Society

Engineering - affecting nearly every aspect of our lives - has helped drive technological advancement and sustainable economic growth while addressing some of society's greatest challenges. The breadth and depth of the engineering discipline is reflected in the 1.72 million college-educated individuals employed in the US across the 18 job categories identified by the NSF as engineering occupations [26]. Irrespective of the formally-defined engineering occupations or offering of college majors, engineering best serves its purpose to society "when it is involved in the formulation of the response to a social need, rather than just being called to provide a quick technological fix" [31].

Arguing that the practice of engineering does not lie outside the domain of societal interest, the role of engineering in society is cleverly visualized in Figure 2-1 by Nichols and Weldon in 1997 [20]. They argue that the intersection of need with knowledge is complex, but the overlap represents the domain of engineering, with the contention that the central focus of the engineering profession is the application

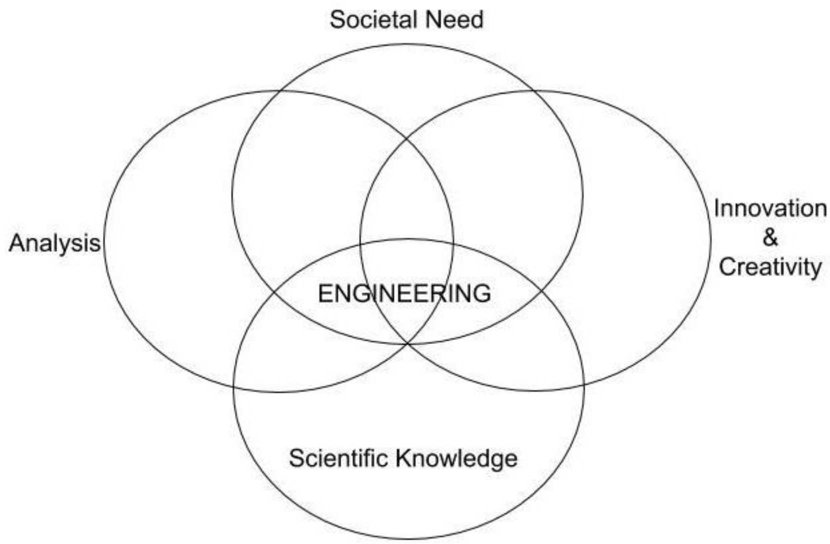

Figure 2-1: The Role of Engineering in Society [20]

of scientific knowledge to societal needs. The analogy is further extended by superimposing the distinction between the creative and analytical capacity, acknowledging that one may pursue creative efforts without involving analytical skills, and vice versa [20, 32]. The resulting intersection of knowledge and need with both creative and analytical capability represent innovative and analytical real world problem solving and engineering design.

We further extend this analogy by proposing a subset to the intersecting region of societal need and scientific knowledge, presented in Figure 2-2. This region represents applications of scientific knowledge in such a way that is ethically aligned and socially responsible. Now, the intersection of all sets represents the application of scientific knowledge to societal need by leveraging creative and analytical capacity and ensuring the consideration of public welfare concerns and the societal implications of engineering work. While this region illustrates the ideal role of engineering and the individual engineer in society, the problem of engineers' disengagement from public welfare concerns and the societal implications of engineering work suggests this isn't always the reality. Presently, engineers usually engage in discussions regarding the societal implications of technology during times of disaster or public outcry [7]. This is exemplified by the recent 2018 Boeing 737 Max software malfunction [33] or the

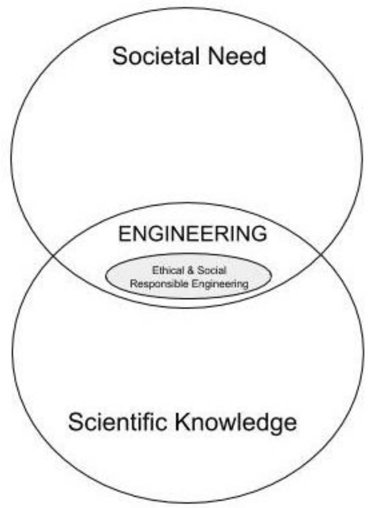

Figure 2-2: Ethical and Socially Responsible Engineering [20]

Ford Pinto Case of the 1970s [29]. Such selectivity in engagement to issues of public welfare can be attributed to the fact that public welfare considerations are often considered "tangential" to the primary professional work of engineers [7]. Reactionary efforts, better known in recent years as "whistleblowing," as seen with the Challenger Disaster of 1996 [35], demonstrate avenues for members of the profession to prioritize and ensure their responsibility to the public health, safety and welfare. Yet, while whistleblowers are agents for change in the field, proactive - not just reactive - contemplation of "the broader social impacts of engineering work" must be considered in the scope of engineers' day-to-day responsibilities [7].

Interestingly, the notion of disengagement is primarily prevalent amongst American engineers - perhaps due to the importance of culture to professional practice, as emphasized by Cultural Studies Scholars [36]. For instance, French engineers and German engineers are noted to be more deeply engaged in bureaucratic life and often participate in public debates about the long-term societal impact of the technologies they create [7, 10]. However, US engineers largely distance themselves from nontechnical social debates, seeming "particularly disengaged with concerns for the impact of their work on public welfare" [7, 17]. One may argue that user-centered design principles and the consideration of stakeholder requirements are already an integral part of the design and development of many technological systems and products. However, public and social welfare concerns are distinct from considerations about the "end users" of technological systems products. Such concerns further extend the common considerations that go into addressing user or stakeholder needs by prioritizing public health, safety, well-being and considering issues pertaining to equality, privacy, fairness, and technological risks and benefits [7, 21].

2.2 Depoliticization and Dualism in Engineering

The culture of disengagement identifies public welfare concerns as tangential to the primary function of engineering. Consisting of three main ideological pillars - depoliticization, dualism and meritocratic ideology [7] - we explore the first two.

First, the ideology of depoliticization frames any "non-technical" considerations such as social and political concerns as irrelevant in order to eliminate the bias which may otherwise influence "pure" or "real" engineering work [7, 8]. While engineering innovations and contributions advancing public welfare are encouraged and positively viewed, the ideological frame of depoliticization "casts public welfare issues as irrelevant to "real" (technical) considerations in day-to-day engineering work" [7, 6]. Second, the ideology of "technical/social" dualism fosters a cognitive separation of the competencies associated with "technical" and "social" aspects of engineering work, ultimately devaluing the "social" competencies [7]. In turn, the "most valued realms of engineering work are those that allow engineers to bracket social considerations most extensively" [7]. Thus, in comparison to "technical competencies, public welfare considerations are devalued as they are, by definition, on the 'social' end of this dualism [6, 7].

Such instances of depoliticization and social/technical dualism are evident in MIT's engineering educational culture. The MIT School of Engineering has distinguished itself as a leader in engineering education, with U.S. News & World Report giving the top spot to MIT's undergraduate engineering programs since 1983 [5]. In addition to the strength of the school's engineering program, Institutional efforts are also made to prioritize the humanistic aspects of undergraduates' education at MIT. As part of MIT's General Institute Requirements (MIT), all undergraduates must complete the Humanities, Arts and Social Sciences (HASS) Requirement. The requirement consists of eight subjects of at least nine units each in the humanities, arts, and social sciences. However, disengagement may mean that such requirements are considered "tangential" to the "primary" coursework of nearly 70 percent of the Institute's undergraduate majors identifying as engineers.

2.3 Culture of Disengagement

Despite institutional requirements seeking to instill a greater sense of social responsibility and concern for public welfare, depoliticization and the technical/social dualism likely means that "students bracket these concerns as external to their understanding of their professional duties" [8]. This culture of disengagement provides the theoretical context for a recent study that has identified a troubling trend in the public welfare considerations of graduates from four top US engineering programs - including MIT [7].

The findings, based on an analysis of student survey responses of incoming first years and graduating seniors, reflects a decrease in student interest in the public welfare considerations of engineering work over the course of their undergraduate programs. Ultimately, the key takeaways and implications of the study are as follows:

- Engagement with public welfare concerns declines over the course of students' engineering education [7].
- Among respondents who enter engineering jobs, interest in public welfare concerns does not return after leaving college [7].
- Engineering programs' engagement-relevant cultural emphases influence how strongly students believe in these engagement measures. [7].
- Uniformity observed across diverse school contexts suggests that a culture of

> disengagement is not just a product of individual organizational climates, but rather may be a profession-wide phenomenon. [7].

This study, however, has two main limitations. First, little is done to examine the effects of engineering education programs on students' public-welfare related competencies, and how such programs ultimately emphasize and contribute to the development of such competencies. Second, there is little to say about how competencies developed during undergraduate education programs shape students' long-term engagement-related outlooks.

With these limitations in mind, we are motivated to explore methods to better understand - specifically at MIT - the effects of the undergraduate engineering education program on developing student public-welfare related competencies, and how the development - or lack thereof - of such competencies ultimately shapes students' long-term public welfare-related outlooks.

Chapter 3

Characterizing Disengagement

The Accreditation Board for Engineering and Technology, Inc. (ABET) defines engineering as "the profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind." ABET further identifies that while engineering sciences "have their roots in mathematics and basic sciences," they also "carry knowledge toward creative application" [1]. One can conclude that while analytical skills are a key part of the profession, they are not sufficient for a complete engineering education. So what are the core competencies and outcomes engineering students of all disciplines should attain through their journey into the engineering profession?

3.1 Defining Competencies and Outlooks

Through a thematic analysis of core engineering education outcomes laid out by professional societies and ABET, we identify a set of broad categories framing target outlooks and competencies of members of the engineering profession. We begin by defining a set of six target competencies, guided by ABET and NSPE's criteria for target student outcomes that "engineering students of all disciplines who become licensed professional engineers should attain" [25]:

Competency	**Outcome(s)**
Science, Reasoning & Problem Solving	Identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics [1] Develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions [1]
Effective Communication	Communicate effectively with a range of audiences [1]
Diversity & Cultural Competence	Function on multidisciplinary teams [25]
Interpersonal Skills & Leadership	Function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives [1] Apply principles of leadership [25]
Social Understanding	Understand the impact of engineering solutions in global, economic, environmental, and societal contexts [1] Design a system, component, or process to meet desired needs within a broad set of constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability [1]
Ethical Reasoning	Recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts [1]

Table 3.1: Defining Core Competencies

The target competencies presented in Table 3.1 motivate the formulation of target attitudes and outlooks of engaged members of the engineering profession. These outlooks define students' perspectives, as entering engineering professionals, on their role in society by assessing the importance of a set of engagement outlooks, including:

Engagement Outlooks	**Description**
Science & Innovation	Contributing to science and innovation
Leadership	Being a leader in one's community or respective field
Relating & Global Awareness	Engaging with diverse cultures and backgrounds
Service & Engagement	Engaging with one's community through service and as an active citizen

Table 3.2: Defining Core Outlooks

This research will seek to understand predictors for student disengagement in undergraduate education at MIT. The findings from this analysis will ideally serve as a key step to identifying gaps in existing education programs and informing next steps for engineering programs seeking to foster more engaged graduates.

3.2 Data and Method

The sample in this study consists of 1,570 students, examining the 2014, 2016 and 2018 administrations of the Senior Survey carried out by MIT Institutional Research (IR). In the Senior Survey, undergraduate fourth-year students are invited to answer and surveyed on a range of topics. The survey asks students describe their plans after college, to rate their satisfaction with various aspects of their education, to indicate how their abilities changed since enrolling at MIT, and how they financed their education.

This analysis presented in this section specifically examines the question batteries on the *self-assessment of skills*, on *long-term goals and values*, and on *student engagement*. The study file also includes key demographics, including: students' major field (Engineering = 1); international status (international = 1); underrepresented minority (URM) status (URM = 1); family income (dichotomous indicators for low, mid and upper income); and gender (female = 1). Leveraging student responses from these cross-sectional surveys, we seek to better understand:

- The role of MIT in developing students' engagement-related outlooks and competencies
- The relationship between competency development and long-term engagement-related outlooks

Controlling for demographics, we examine how competency development over the course of a four-year undergraduate education predicts students' long-term engagement outlooks. In our analysis, we use ordinary least squared (OLS) models for all multivariate analyses involving continuous dependent variables. We use linear probability models (LPM) for all multivariate analyses involving dichotomous dependent variables (*Science and Innovation Index*; *Ethical Reasoning Competency Index*). Standardized/Beta coefficients for all models presented in the following section are available in the appendix.

3.3 Dependent and Independent Measures

In what follows, outlook and competency indexes are composite measures providing thematic groupings of the specific set of outlook and competency measures tracked in the administrations of the survey. The introduction of composite measures allows for indexes to be treated as continuous data [11]. These index measures represent the mean values of the specific measures tracked for each student observation. For the

Engagement-related Outlook Indexes

*Science and Innovation Index**
• Contribution to science and innovation (dichotomized)
Relating & Global Awareness Index
• Learning about other cultures and nations • Getting to know people from diverse backgrounds • Living or working abroad
Leadership Index
• Being a leader in my community • Being a leader in your field
Service & Engagement Index
• Participating in politics or community affairs Working for social and political change • Volunteering • Doing work that is in accordance with my philosophy or religion

Table 3.3: Outlook Indexes

purpose of comparison, we introduce reference indexes (marked with '*'), which are meant to represent more typical areas of strength for the Institute, such as science, reasoning and problem solving.

For the engagement indexes, student attitudes regarding public welfare engagement are derived from importance when asked, *"As you think about your future, how important is each of the following to you?"* Respondents answered on a scale of 1 to 4 (1 = *Not important at all* to 4 = *Essential*). The defined set of engagement-related outlooks for this study are presented in Table 3.3.

Competency Indexes

*Science, Reasoning and Problem Solving Index**
• Understand and use quantitative reasoning and methods • Think analytically and logically • Understand the process of science and experimentation • Think critically • In depth knowledge of a field or discipline
Effective Communication Index
• Write clearly and effectively • Communicating well orally
Diversity and Cultural Competence Index
• Relating well to people of different races, nations and religions • Developing global awareness
Interpersonal Skills and Leadership Index
• Functioning effectively as a member of a team • Leadership skills • Constructively resolving interpersonal conflicts
Social Understanding Index
• Placing current problems in historical/cultural/philosophical perspective • Understanding the complexity of social problems • Evaluating the role of Science and Technology across society
Ethical Reasoning Index
• Developing or clarifying a personal code of values or ethics

Table 3.4: Competency Indexes

Student engagement-related competencies were also tracked. Students are asked, *"To what extent has your experience at MIT contributed to your knowledge, skills, and personal development in the following areas?"*.Respondents answers on a scale of 1 to 4 (1 = *Very little or none* to 4 = *Very much*). The defined set of competencies for this study are presented in Table 3.4.

3.4 Findings

We begin with an exploratory analysis of our dataset of 1,570 observations. The descriptive information presented provides information on students' public welfare outlooks and competency measures.

3.4.1 Descriptive Analysis

Table 3.5 below presents measures of centrality and dispersion for basic demographic information as well as students' engagement-related outlook and competency index measures.

Figure 3-1 shows average values for student competency index measures. The figure illustrates that in this sample, competencies within the *Science and Reasoning Index* were most developed over the course of students' undergraduate education at MIT. Least developed competencies include *Social Understanding Index* and *Effective Communication Index*. This figure shows the relative strengths of MIT's undergraduate education program in emphasizing and developing students' more "technical" competencies such as science, reasoning problem solving in comparison to engagement-related competencies, such as social understanding, effective communication, and cultural competence.

We first investigate how student's public welfare beliefs vary by a range of demographics that we track - gender, URM, and family income - as well as field of study (engineering versus non-engineering) and cohort. In table 3.6, we predict the four engagement-related outlooks using these demographic measures.

Table 3.5: Means and Standard Errors for demographics, outlooks, and competencies (N = 1,570)

	Mean	*SE*
Engineering (1 = yes)	0.703	0.012
URM (1 = yes)	0.131	0.009
International (1 = yes)	0.084	0.007
Female (1 = yes)	0.553	0.013
Outlook Index Measures *(1 - Not important at all to 4 = Essential)*		
Relating & Global Awareness Index	2.413	0.019
Leadership Index	2.584	0.020
Service & Engagement Index	2.160	0.017
Science and Innovation Index (dichotomy)	0.699	0.012
Competency Index Measures *(1 = Very little or none to 4 = Very much)*		
Science, Reasoning & Problem Solving Index	3.423	0.014
Effective Communication Index	2.701	0.021
Diversity and Cultural Competence Index	2.778	0.021
Interpersonal Skills and Leadership Index	2.946	0.018
Social Understanding Index	2.662	0.020
Ethical Reasoning Index (dichotomy)	0.573	0.012

Overall, we find engineering majors and international students, on average, demonstrate stronger emphasis on the importance of contributing to science and innovation as compared to non-engineering majors and non-international students. Literature suggests that "women and underrepresented racial/ethnic minorities are more sensitive to social justice concerns because of their own likelihood of experiencing injustice"

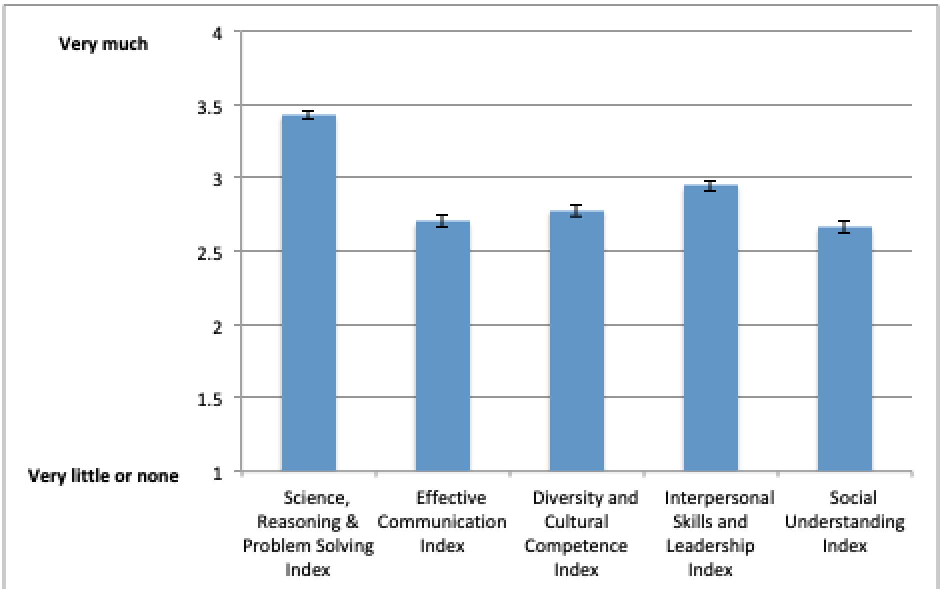

Figure 3-1: Student Competencies (N = 1,570)

[7, 12, 15]. In line with this claim, we find that women, URMs and low income students demonstrate stronger outlooks on relating and global awareness measures than non-URM, high income, male students. Low income students additionally demonstrate stronger outlooks on service and engagement than higher income students. Finally, in line with the culture of disengagement observed in higher education and the engineering profession, we find that engineering majors are less likely to demonstrate stronger outlooks on service & engagement measures than non-engineering majors. What's most surprising in the models presented in table 3.6 is the lack of systematic difference in engagement outlooks by cohort, suggesting that these findings may not necessarily be a function of time or cohorts, but rather a product of the overall undergraduate program and experience.

We motivate a similar investigation into how students' competencies vary by demographics - gender, majors, URM, and family income - as well as field of study. In table 3, we predict the six engagement competencies using demographic measures and field of study.

We find females are less likely than male respondents to develop competencies in science, reasoning and problem solving. Low income students - along with in-

Table 3.6: OLS Predicting Engagement Outlooks at Time 2 using Demographic Measures

	Science & Innovation Index	Relating & Global Awareness Index	Leadership Index	Service & Engagement Index
	Unstandardized Coefficient	*Unstandardized Coefficient*	*Unstandardized Coefficient*	*Unstandardized Coefficient*
Engineering	0.0619** (0.0255)	-0.0284 (0.0417)	0.0834* (0.0448)	-0.0804** (0.0381)
URM	-0.0473 (0.0362)	0.212*** (0.0592)	-0.0293 (0.0636)	0.0992* (0.0541)
International	0.122*** (0.0438)	0.140* (0.0716)	0.116 (0.0770)	0.00278 (0.0654)
Female	-0.00637 (0.0235)	0.199*** (0.0385)	-0.0667 (0.0414)	0.0512 (0.0352)
Income Category = 1, Low income	0.0263 (0.0329)	0.115** (0.0538)	0.0162 (0.0578)	0.111** (0.0492)
Income Category = 2, Mid income	-0.00700 (0.0311)	-0.0279 (0.0508)	-0.139** (0.0546)	-0.0509 (0.0465)
Year = 2014	-0.0302 (0.0296)	-0.0143 (0.0484)	-0.0280 (0.0521)	-0.0373 (0.0443)
Year = 2016	-0.00877 (0.0288)	-0.0311 (0.0471)	-0.0148 (0.0506)	0.0194 (0.0430)

Engineering is reference category for major, non-URM is reference category for URM status, non-international is reference category for international status, male is reference category for gender, high income is reference for income category, 2018 is reference category for year.

Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$ (two-tailed test)

ternational students - demonstrate stronger development of effective communication, diverse and cultural understanding, social understanding, and ethical reasoning competencies in comparison to higher income and non-international students. Contrary to the lack of systematic difference observed in the prediction of student outlooks, we note that class of 2014 demonstrated weaker development of social understand competencies than the class of 2018.

What's most surprising in the models presented in table 3.7 is the relationship between engineering majors and competency development. Namely, there is no sys-

Table 3.7: OLS Predicting Competencies using Demographic Measures

	Science, Reasoning & Problem Solving Index	Effective Communication Index	Diversity & Cultural Competence Index	Interpersonal Skills & Leadership Index	Social Understanding Index	Ethical Reasoning Index
	Unstandardized Coefficient	*Unstandardized Coefficient*	*Unstandardized Coefficient*	*Unstandardized Coefficient*	*Unstandardized Coefficient*	*Unstandardized Coefficient*
Engineering	0.00603 (0.0310)	-0.0580 (0.0447)	-0.0909* (0.0466)	0.173*** (0.0404)	-0.135*** (0.0438)	-0.0477* (0.0274)
URM	0.0159 (0.0440)	0.111* (0.0634)	0.0355 (0.0662)	-0.00301 (0.0574)	0.0270 (0.0621)	-0.0204 (0.0389)
International	0.0500 (0.0532)	0.262*** (0.0767)	0.275*** (0.0801)	-0.0630 (0.0695)	0.165** (0.0752)	0.131*** (0.0471)
Female	-0.0730** (0.0286)	-0.0427 (0.0413)	0.0327 (0.0431)	0.0707* (0.0374)	-0.0500 (0.0404)	0.0255 (0.0253)
incomecats = 1, Low income	-0.0141 (0.0400)	0.232*** (0.0576)	0.127** (0.0602)	-0.0103 (0.0522)	0.123** (0.0565)	0.0971*** (0.0354)
incomecats = 2, Mid income	-0.0399 (0.0378)	0.0480 (0.0545)	0.00817 (0.0569)	-0.0482 (0.0493)	-0.000766 (0.0534)	0.0164 (0.0334)
Year = 2014	-0.0588 (0.0360)	-0.0414 (0.0519)	-0.0432 (0.0542)	-0.00957 (0.0470)	-0.110** (0.0508)	-0.0257 (0.0318)
Year = 2016	0.0111 (0.0350)	-0.0141 (0.0505)	0.0414 (0.0527)	0.0312 (0.0457)	0.0552 (0.0494)	-0.0315 (0.0310)

Engineering is reference category for major, non-URM is reference category for URM status, non-international is reference category for international status, male is reference category for gender, high income is reference for income category, 2018 is reference category for year.

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1 (two-tailed test)

tematic difference in engineering and non-engineering majors in the development of science, reasoning and problem solving competencies, reinforcing the idea illustrated in figure 3-1 which demonstrated the relative strengths of MIT's undergraduate education program in emphasizing and developing students' more "technical" competencies. Furthermore, while engineering majors show strong development of interpersonal and leadership skills, most troubling is the negative relationship with students' development of social understanding competencies.

From the above set of models, we find - in line with literature [7, 12, 15] - that females, URMs and low-income students show stronger measures on engagement-related outlooks, and also demonstrate stronger development of engagement-related competencies in comparison to non-URM, male, high-income students. Most notable from this analysis is the finding that while there is no systematic difference in development of science, reasoning and problem solving competencies across field of study, engineering majors are more likely than non-engineering students to demonstrate stronger science and innovation outlooks but weaker emphasis of service and engagement outlooks and weaker development of social understanding competencies.

3.4.2 Outlook and Competency Measures

With a baseline on competencies and outlooks, we are now motivated to better understand how the competencies students develop over their undergraduate years shape their long-term engagement-related outlooks. The implications of this are particularly grave, as studies have shown that among respondents who enter engineering jobs, interest in public welfare concerns does not return after they leave college [7].

Thus, to get a sense of how competencies shape long-term engagement outlooks, we use students' competencies - reflecting the extent to which student's feel they have developed a set of competencies throughout their time as undergraduates - as predictors for outlooks. In doing so, separate models were used to predict the four engagement outlooks with each of the six competency index measures, controlling for demographic measures, cohort and field of study. We present the results of this analysis in Table 3.8.

The results of our analysis reveal interesting insights. Overall, we observe correlations between student competencies and engagement-related outlook measures. We find that the development of engagement-related competencies such as interpersonal and leadership skills, diversity and cultural competence, and social understanding showed greater likelihood of developing and emphasizing service and engagement outlooks.

Development of cultural competencies and social understanding competencies also demonstrated greater emphasis on relating and global awareness, while leadership, effective communication and cultural competencies showed greater emphasis on lead-

Table 3.8: OLS Predicting Engagement Outlooks using Competency Measures

	Contributing to Science	Relating & Global Awareness Index	Leadership Index	Service & Engagement Index
	Unstandardized Coefficient	*Unstandardized Coefficient*	*Unstandardized Coefficient*	*Unstandardized Coefficient*
Science, Reasoning & Problem Solving Index	0.255*** (0.0233)	-0.0744** (0.0373)	0.155*** (0.0399)	-0.115*** (0.0348)
Effective Communication Index	0.0349** (0.0157)	-0.0315 (0.0251)	-0.0612** (0.0269)	-0.0140 (0.0235)
Diversity and Cultural Competence Index	0.0250 (0.0184)	0.301*** (0.0295)	0.105*** (0.0315)	0.136*** (0.0275)
Interpersonal Skills and Leadership Index	-0.0364* (0.0195)	0.0397 (0.0313)	0.288*** (0.0335)	0.110*** (0.0292)
Social Understanding Index	0.0142 (0.0200)	0.0712** (0.0320)	0.0178 (0.0343)	0.148*** (0.0299)
Ethical Reasoning Index (dichotomy)	-0.0295 (0.0274)	0.0222 (0.0438)	0.0600 (0.0469)	-0.0110 (0.0409)

Models control for demographics, cohort year, and field of study.
Engineering is reference category for major, non-URM is reference category for URM status, non-international is reference category for international status, male is reference category for gender, high income is reference for income category, 2018 is reference category for year.

Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$ (two-tailed test)

ership outlooks. Science, Reasoning & Problem Solving competencies, while fostering stronger outlooks on contributing to science and leadership, also demonstrate stronger outlooks on leadership.

However, most interesting and noteworthy is the finding that development of science, reasoning and problem solving competencies suggest less emphasis on engagement related outlooks, such as relating & global awareness, as well as service and engagement. This finding suggests that as students are integrated into the engineering profession and culture of disengagement identified in engineering, the subsequent emphasis of academic programs in the development of specific competencies shapes long-term outlooks. In the case of MIT and our sample, emphasis of undergraduate programs in developing students' science, reasoning and problem solving competencies, over engagement-related competencies, contributes to students' disengagement to public welfare concerns, such as issues of service and engagement, and relating and global awareness.

Chapter 4

Benchmarking and Comparative Analysis

Engineers are assumed to develop their understanding and commitment to public welfare through engineering education, "the structural location where neophytes are first socialized into the culture of their profession" [21, 7]. Motivated by the importance of undergraduate education in shaping the long term outlooks of engineering professionals, ABET reconfigured its accreditation procedures in 1997 to promote such commitments [1]. The efforts require engineering programs to promote "an understanding of professional and ethical responsibility," and "the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context" [7, 21].

4.1 Computing Curricula: Ethics and Social Responsibility

Within the computing education domain, there have been long standing efforts to teach courses on ethics and social responsibility. Such efforts are reflected in the ACM/IEEE-CS Joint Task Force on Computing Curricula and its evolution over time. Since Computing Curricula '78, the notion of a course on "Computers and

Society" - primarily focusing on social impacts of computing - was entertained as an advanced elective. More recent ACM/IEEE-CS curricular guidelines, such as Computing Curricula 2001 and 2013, continue to highlight the importance of computer ethics by requiring core hours of instruction in this area [3].

Presently, computer and engineering programs meet ethics curricular requirements through a range of educational models. These may include embedding discussions of ethics in CS/engineering courses across the curriculum, teaching standalone ethics courses in the engineering program, or requiring students to take an ethics course taught outside the school of engineering or by engineering faculty, such as in Philosophy [28]. However, beyond strictly curricular models, what other approaches exist for institutions to foster more ethical and socially responsible graduates?

4.2 Internal Scan

MIT has distinguished itself as a leader in engineering education [5]. However, development of new curricular and co-curricular efforts requires a deep understanding of existing efforts. While not comprehensive, Table 4.1 presents an internal scan meant to provide a high level overview of existing internal models for achieving ethics and social responsibility training in the curriculum and throughout the undergraduate experience.

4.3 External Benchmarking

An important aspect of curating effective interventions is a deeper understanding of models and existing efforts developed and deployed by leading institutions. In what follows, we provide a high level overview of key teaching and research initiatives addressing issues of ethics and engagement in computing and engineering education employed by different peer-caliber institutions (with an emphasis and focus on engineering). We focus primarily on efforts with a focus and emphasis on incorporating policy, ethical and societal implications into the training of its students. The docu-

Table 4.1: Internal Scan of Ethics and Social Responsibility Training Efforts

Domain	Model	Overview	Selected Example(s)
Coursework	Standalone courses with a primary focus on exploring ethics, social responsibility and public welfare-related topics in technology and engineering	Courses offered both within the School of Engineering as well as other schools with a central focus on exploring issues pertaining to social impact, policy, economics, ethics and business in the context of engineering, computing and AI. While technical concepts are introduced and discussed, the primary focus of such coursework is to encourage students to analyze and assess the societal interactions and implications of technology.	-MAS.S64 Ethics and Governance of AI -2.900 / 6.904: Ethics for Engineers -6.s062 Ethics and EECS -15.S14: Global Business of Artificial Intelligence and Robotics -6.S978: Privacy Legislation: Law & Technology -6.805 / STS.085: Foundations of Internet Policy -24.131: Ethics of Technology
	Courses embedding topics pertaining to ethics, social responsibility and public welfare in their core engineering curriculum	Courses offered within the School of Engineering or School of Science with a primary focus on building science, reasoning and problem solving competencies, but embedding key modules exploring societal implications of science and technology such as ethics, policy, fairness, and law.	-6.033 Computer Systems Engineering -6.835 Intelligent Multimodal Interfaces -Course HST.956 Machine Learning for Healthcare -6.170 Software Studio -6.894 Interactive Data Visualization -IDS.012[J] Statistics, Computation and Applications
	Courses with a strong emphasis on Project Based Learning (PBL)	Student-centered pedagogy allowing students to acquire a deeper knowledge through active exploration of and interaction with real-world challenges and problems	-2.009 Product Engineering Processes -6.811 Principles and Practices of Assistive Technology -15.399 Entrepreneurship Lab
Concentrations, Majors, Threads	Interdisciplinary and cross-departmental endeavor with integrative, project-centric learning (programs or majors)	Interdisciplinary and cross-departmental endeavor allowing for integrative, project-centric learning (programs or majors) and enabling students to combine disciplines that may not have formalized crossovers available in the curriculum	-New Engineering Education Transformation (NEET) -10-ENG SEE Concentration -21E / 21S Major (Humanities & Science | Engineering) -Computing & Society - HASS Concentration
Standalone programs / initiatives	Standalone curricular and non-curricular programs in the form of electives, extracurricular activities, courseworks, and research.	Standalone programs, not required as part of the engineering curriculum, provide students the opportunity to develop social competencies and explore issues of ethics and social responsibility.	-Experiential Ethics Summer Program -Gordon Engineering Leadership Program -Science Policy Initiative (SPI) -Collaborative Machine Intelligence Competition -Hack for Inclusion -Data for Black Lives -Technology and Policy Program (TPP) -IDSS PhD Program in Social & Engineering Systems

ment further categorizes these institutions and their initiatives with respect to their methodologies.

Table 4.2: External Benchmarking

Domain	**Model**	**Selected Example(s)**
Curricular	Embedding discussions of ethics and social responsibility in a number of core engineering/CS courses across the curriculum	-Harvard Embedded EthiCS Teaching Lab
	Teaching standalone computer ethics courses housed in engineering/CS department	-Brown University: Cybersecurity Ethics; Data, Ethics and Society; CS for Social Change. -Georgia Tech: CS Ethics Core Requirement -University of Colorado Boulder: Ethics, Humanities, Social Science and Writing -University of Texas at Austin: Ethical Foundations of Computer Science -Cornell University - Societal and Ethical Issues in AI
	Requiring students to take an ethics/humanities course taught outside the CS department or by non-CS faculty, often in Philosophy	-UMass Lowell: Social Responsibility and Ethics - requirement fulfilled with range of courses in different departments -MIT: HASS requirement -Georgia Tech: Core Area C -Stanford University: Ways of Thinking/Ways of Doing requirement
	Interdisciplinary majors and academic programs blending disciplines	-MIT -New Engineering Education Transformation (NEET) -Stanford Ethics in Society Program -Carnegie Mellon University (CMU): EPP Department
	Interdisciplinary offering of courses cross listed and co-taught by faculty in engineering, policy, philosophy, etc.	-Stanford: Computers, Ethics and Public Policy (SIGCSE March 2020) -MIT/Harvard University: Ethics and Governance of AI
	Project-based Learning (PBL)	-Colorado School of Mines (Engineering, Design and Society) -University of Wisconsin-Madison: Undergraduate Projects Lab
Co-curricular	Research Centers and Initiatives with interdisciplinary research interests and broad focus on the societal implications of technology, computing and AI	-Harvard Berkman Klein Center -MIT Media Lab: Ethics and Governance of Artificial Intelligence Initiative -CMU: CyLab Security and Privacy Institute -NYU: AI Now Research Institute -University of Michigan: Artificial Intelligence Lab -UC Berkeley: Center for Law and Technology -UPenn: Center for Ethics and Rule of Law -Princeton University: Center for Information Technology Policy
	Recently founded departments, schools or colleges	-Stanford Human-Centered Artificial Intelligence -Duke University The Lane Family Ethics in Technology Program
	Segments within existing departments or programs • Housed under Humanities • Housed under STEM	-Harvard Law: Berkman Klein Center for Internet and Society -Harvard Business School: Digital Initiative and Innovation Lab -Stanford Law: Center for Internet and Society -Stanford Medical School: Center for Artificial Intelligence in Medicine and Imaging -CMU College of Engineering: Department of Engineering and Public Policy -CMU Department of Philosophy: Ethics and Artificial Intelligence -Cornell University Bovay Program for Ethics in Engineering -Santa Clara University Markkula Center for Applied Ethics

The goals of the qualitative external benchmarking analysis are to:

- Identify, map and characterize the range of existing approaches and methodologies developed and utilized by peers
- Provide holistic assessments and generate external benchmarking analysis

The analysis presented in Table 4.2, while not comprehensive, is meant to capture the diversity of academic curricular and co-curricular models seeking to integrate ethics and social responsibility training in engineering and computing education. The findings from the analysis in Table 4.3 broadly reveals the following interesting models:

- Centers and Initiatives with interdisciplinary research interests fusing disciplines such as law, policy, and medicine with engineering and computing. A central focus of these centers and initiatives is ethical and social responsibility training, and investigation of societal implications of technology, computing and AI.
- Newly founded classes, teaching pedagogy, concentrations/majors, departments, schools or colleges with a strong focus and emphasis on interdisciplinary study and a commitment to ethical and responsible computing and AI. Such efforts are reflected in the development of interdisciplinary curricula co-taught by faculty from different disciplines, hands-on project based learning approaches, and academic tracks (majors/minors/concentrations) fusing disciplines.

Future directions for research include an assessment on the efficiency and efficacy of such programs and models as interventions for achieving more engaged, and socially responsible engineering adn computing graduates.

Chapter 5

Discussion

Breakthroughs in science and engineering have seen the increasing role of engineering and computing technologies in nearly every aspect of our lives. While the introduction of technologies in society has promoted productivity and efficiency, there has been much concern for the ethical and societal implications of such technological innovations. With recent studies additionally identifying a decline in the public welfare concerns of graduates from top US engineering programs, including MIT, the need for ethics and social responsibility training has never been greater.

This thesis explored the problem of characterizing the trend of student disengagement to issues of ethics, social responsibility and public welfare at MIT . Using survey data of three undergraduate cohorts (class of 2014, 2016 and 2018), we investigated the role of an MIT undergraduate education in the development of students' competencies and long-term engagement-related outlooks. Finally, in an effort to guide next steps for ways to remedy cultures of disengagement in higher education, we provided an internal scan and external benchmarking analysis of select academic models for fostering more engaged engineering graduates.

5.1 Contributions

There are three main contributions of this thesis. First, using cross-sectional survey data of three undergraduate cohorts (class of 2014, 2016 2018), we examined the trend of disengagement at MIT by analyzing the role of an undergraduate engineering education on the development of students' public welfare-related outlooks and competencies. Our analysis revealed that competencies within the Science and Reasoning Index were most developed over the course of students' undergraduate education at MIT, while the Social Understanding Index and Effective Communication Index were least developed. This confirms the relative strengths of MIT's undergraduate education program in emphasizing and developing students' more "technical" competencies such as science, reasoning & problem solving in comparison to engagement-related competencies, such as social understanding, effective communication, and cultural competence. However, our analysis also showed no systematic difference in engineering and non-engineering majors in the development of science, reasoning and problem solving competencies. Our analysis also revealed that - in line with existing literature [15, 7, 12] - females, URMs and low-income students show stronger measures on engagement outlooks, and also demonstrate stronger development of engagement-related competencies in comparison to their non-URM, male, high-income counterparts. Most notable from this analysis is the finding that engineering majors demonstrate stronger science and innovation outlooks but weaker outlooks on service, engagement and social understanding competencies in comparison to their non-engineering counterparts. What's most surprising is the lack of systematic difference in engagement outlooks by cohort/year, suggesting that these findings may not necessarily be a function of cohort year, but rather a product of the overall undergraduate education program and experience.

Second, we investigated the interaction between students' outlooks and competencies to understand how competencies developed as undergraduates shape students' long-term engagement outlooks. The implications of this question are particularly grave, as studies have shown that among respondents who enter engineering jobs, interest in public welfare concerns does not return after they leave college [7]. The results of our analysis reveal correlations between the competencies that students develop during their time as undergraduates, and their long-term engagement-related outlooks. Namely, we find that development of public welfare-related competencies such as interpersonal and leadership skills, diversity and cultural competence, and social understanding suggest stronger emphasis on service and engagement-related outlooks. As one may expect, diversity and cultural competence and social understanding competence showed stronger relating and global awareness outlooks. Finally, in line with the culture of disengagement and depoliticization observed in engineering, development of Science, Reasoning & Problem Solving competencies - while fostering stronger outlooks on contributing to science and leadership - suggested students are less likely to value relating & global awareness, as well as service and engagement.

In all analyses using linear probability models (LPM) for dichotomous dependent variables (*Science and Innovation Index*; *Ethical Reasoning Competency Index*), all OLS modes were rerun as logistic regression models. The results showed identical results. Given the interpretability of OLS coefficients compared to logit coefficients, OLS model results are presented in this thesis. Standardized/beta coefficients are available in the appendix for all models presented in this work.

Lastly, we provided a comparative analysis of different curricular and co-curricular models deployed internally and by peer academic institutions to achieve more ethically and socially-responsible engineering graduates. While not comprehensive, this analysis seeks to provide a better understanding of existing internal efforts, and shed light on different models developed and deployed by peer institutions. By revealing the current state of efforts internally and providing an external benchmark, the findings from this analysis will ideally serve as a key step to identifying gaps in existing education programs and informing next steps for fostering more engaged graduates.

5.2 Limitations

The survey datasets used in this study provided self reported indicators of students' outlooks and competencies on a range of public welfare-related measures. These datasets provided cross-sectional comparisons that allowed us to examine systematic differences and effects in outlooks and competences. However, we recognize that survey data doesn't capture the individual stories and experiences in ways that qualitative data such as interviews can.

5.3 Future Directions

The limitations of the work outlined in the previous section motivate directions for future work. First, supplementing insights from the quantitative analysis of student survey responses, qualitative forms of research such as focus groups and interviews can be essential to better understanding unique stories and student experiences. As a future line of research, we are interested in better understanding what contributes to the development of specific competencies more than others, and how the offering of undergraduate programs contribute to the emphasis of certain competencies over others.

Additionally, leveraging longitudinal data with information on student competencies and outlooks as incoming first year students, we also motivate the investigation of how student competencies and outlooks change over time, and how outlooks as first years shapes the competencies students choose to emphasize and develop as undergraduate. Such investigation can shed light on not only how students competencies and outlooks develop and are shaped near the end of their education programs, but how they change over the course of their undergraduate programs.

The analysis and benchmarking of existing efforts presented in this work is simply meant to capture the diversity of academic curricular and co-curricular models seeking to integrate ethics and social responsibility training in engineering and computing education. However, better understanding and assessing the efficacy and efficiency of existing programs and initiatives - both internally and externally - through interviews and further survey research could be an important step in defining how educational programs can successfully foster more engaged graduates.

Appendix A

Tables

Table A.1: OLS Predicting Engagement Outlooks using Demographic Measures with Beta Coefficients

	Science & Innovation Index	Relating & Global Awareness Index	Leadership Index	Service & Engagement Index
	Standardized Coefficient	*Standardized Coefficient*	*Standardized Coefficient*	*Standardized Coefficient*
Engineering	0.0616**	-0.0171	0.0473*	-0.0535**
URM	-0.0348	0.0945***	-0.0123	0.0488*
International	0.0741***	0.0511*	0.0399	0.00112
Female	-0.00690	0.131***	-0.0412	0.0371
incomecats = 1, Low income	0.0219	0.0580**	0.00769	0.0620**
incomecats = 2, Mid income	-0.00586	-0.0141	-0.0662**	-0.0284
Year = 2014	-0.0315	-0.00903	-0.0166	-0.0259
Year = 2016	-0.00908	-0.0195	-0.00871	0.0134

Engineering is reference category for major, non-URM is reference category for URM status, non-international is reference category for international status, male is reference category for gender, high income is reference for income category, 2018 is reference category for year.

*** p<0.01, ** p<0.05, * p<0.1 (two-tailed test)

Table A.2: OLS Predicting Competencies using Demographic Measures with Beta Coefficients

	Science & Innovation Index	Relating & Global Awareness Index	Leadership Index	Service & Engagement Index
	Standardized Coefficient	*Standardized Coefficient*	*Standardized Coefficient*	*Standardized Coefficient*
Engineering	0.0616**	-0.0171	0.0473*	-0.0535**
URM	-0.0348	0.0945***	-0.0123	0.0488*
International	0.0741***	0.0511*	0.0399	0.00112
Female	-0.00690	0.131***	-0.0412	0.0371
incomecats = 1, Low income	0.0219	0.0580**	0.00769	0.0620**
incomecats = 2, Mid income	-0.00586	-0.0141	-0.0662**	-0.0284
Year = 2014	-0.0315	-0.00903	-0.0166	-0.0259
Year = 2016	-0.00908	-0.0195	-0.00871	0.0134

Engineering is reference category for major, non-URM is reference category for URM status, non-international is reference category for international status, male is reference category for gender, high income is reference for income category, 2018 is reference category for year.

*** p<0.01, ** p<0.05, * p<0.1 (two-tailed test)

Table A.3: OLS Predicting Engagement Outlooks using Competency Measures with Beta Coefficients

	Contributing to Science	Relating & Global Awareness Index	Leadership Index	Service & Engagement Index
	Standardized Coefficient	*Standardized Coefficient*	*Standardized Coefficient*	*Standardized Coefficient*
Science, Reasoning & Problem Solving Index	0.310***	-0.0547**	0.107***	-0.0931***
Effective Communication Index	0.0619**	-0.0338	-0.0617**	-0.0165
Diversity and Cultural Competence Index	0.0460	0.335***	0.110***	0.166***
Interpersonal Skills and Leadership Index	-0.0579*	0.0382	0.261***	0.117***
Social Understanding Index	0.0245	0.0745**	0.0175	0.171***
Ethical Reasoning Index (dichotomy)	-0.0319	0.0145	0.0368	-0.00792

Models control for demographics, cohort year, and field of study.
Engineering is reference category for major, non-URM is reference category for URM status, non-international is reference category for international status, male is reference category for gender, high income is reference for income category, 2018 is reference category for year.

*** p<0.01, ** p<0.05, * p<0.1 (two-tailed test)

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