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Title of Thesis: Formal Ethics and Social Impact Training and Instruction's Influence on Undergraduate Engineering Students

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ABSTRACT

Engineering is a career which has an express purpose to benefit the public. To ensure the protection and safety of the public, technical schools, universities, and colleges have course requirements to prepare students for their careers. The learning outcomes of these courses have been outlined by the Accreditation Board for Engineering and Technology (ABET). Education and training in ethics and social impacts (ESI) have increased in the last twenty-five years since the implementation of ABET EC2000, which changes their previous criterion to include more outcome-based evaluation to programs under their accreditation (Barry & Ohland, 2011). To better understand how ESI impacts students' comfort with tackling ethical issues and the impact of their work, universities have been conducting research and surveying students using various methods. In this study, biological engineering undergraduate students and agricultural and biorenewable systems management undergraduate students were surveyed before formal instruction for ESI and post-instruction to see if undergraduate students' answers to self-reflection surveys indicate how much their formal curricular experiences, co-curricular experiences, and perceived importance of ESI influenced their ESI development. The analysis of short-response answers and ranked questions will follow a modified method of the SEED survey conducted by Finelli et. al., (2012). After conducting a Wilcoxon Rank-Sum Test, students' responses to Likert questions probing for comfort in using ESI in decision-making statistically significant increases were found (p-value<0.05). Students were more knowledgeable on ethical frameworks, using them in definitions, after formal ESI instruction. Findings from this study encourage the continued research of students' reflections of ESI instruction.

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Chapter 1

Introduction

Engineering is an expansive career that encompasses many aspects of society and the operations of civilization. In order to make certain that incoming young professionals are ready for the workforce, colleges, universities, and technical institutions have requirements for their curriculum. The requirements for undergraduate students stem from the influence of etiquette from professional societies of engineering disciplines like Civil Engineering, Electrical Engineering, and Biomedical Engineering, to name a few. The Accreditation Board for Engineering and Technology (ABET) establishes an accreditation process for institutions to outline the requirements of engineering curriculum to guarantee new engineers have the technical skills to begin working and providing engineering services. An important aspect of professional development, engineering education, and ABET accreditation is ethics and undergraduates' understanding of engineering's social impacts.

Many changes and improvements to engineering ethics and social impacts education have been made between the year of 1995, before the implementation of ABET EC2000, and in 2005 on expanding the required courses on ESI development (Barry & Ohland, 2011). Since then, there have been studies conducted to assess the impact of curriculum on students (Barry & Ohland, 2011; Borenstein et al., 2009; Finelli et al., 2012). Improvements and deeper understanding of the influences and implications of micro-insertions into preexisting engineering courses, professional development electives, increased collaboration with humanities, as well as engagement in clubs, volunteering, and co-curricular activities are all goals of recent scholars in engineering education

(Bielefeldt et al., 2018; Bielefeldt et al., 2020; Cech et. al. 2022; Finelli et al., 2012; (Polmear et al., June 2020).

Agricultural and biological engineers have established a professional code of ethics introduced by the American Society of Agricultural and Biological Engineers. Intriguingly, the current, most up to date code of ethics for agricultural and biological engineers does not include a declaration of environmental protection like some of the other engineering societies (American Institute of Chemical Engineers (AIChE), 2012; American Society of Civil Engineers (ASCE), 2020; American Society of Mechanical Engineers (ASME), 2012). Agricultural and biological engineers learn to work with the environment every day, so this skill could be seen as redundant to add to the Fundamental Cannons of the ASABE code of ethics. However, there should be an update to the code of ethics to include a Cannon on environmental protection as many other societies have implemented their own. Not only would this be vital to professional development, but an example which incoming and career engineers can use as standard.

This thesis uses techniques from literature to analyze student feedback to gain insights about undergraduate students' understanding, perceived comfortability, and engagement with their peers and community based on ethics and social impacts. This research stems from an interest in how students in highly technical fields of study learn ethics and social impacts. As an undergraduate student at Penn State University, I have had the opportunity to learn about ethics during my four years through integrated segments in my various courses. From my first year, first semester, my chemistry 110 course and the corresponding lab taught us the importance of note taking and proper data acquisition which correlates itself to the ethics of objectivity, transparent communication, and truth in research. My honors communications and rhetoric class had projects that allowed us to explore the ethics of the educational systems within public, private, and schools

of choice. While I personally have not wanted to get into the teaching sector, I have family that are, which has prompted me to want to know more about how we use curriculum and assessment to gauge how students are absorbing knowledge about various subjects and learning outcomes.

Ethics and the philosophy of right and wrong are argued to be a skill taught and influenced by upbringing and parental figures in early childhood (Schweiger, 2023). Within my research into engineering ethics and cultivating theses skills myself has highlighted the fact that instilling that people, especially engineers, have a responsibility to be ethical is the biggest barrier to learning (Ferdman & Ratti, 2024). This same mindset is one that I held for most of my early years in higher education. Ethics and the difference between right, wrong, and the in-between is common sense, and some do not have the skill. However, these abilities of moral reasoning and identification can be honed with practice and reflection. Through my research into engineering ethics education, I have found studies that have swayed my previous notions that skills of this nature could not be refined through guided training. I see promise in ethics education in the university setting and hope that this thesis may add to the discussion of engineering ethics education strategies.

Further Background Information

Engineering has been an important aspect of our societies for millennia. Apprenticeships have a long history in engineering, with a majority of early engineering education coming from mentorships provided by experienced industry engineers. In the early stages of engineering societies, the earliest being the informal Society of Civil Engineers in 1771, promoted not just technical knowledge, but professional behavior and etiquette (Mitcham, 2009). Modern engineering, as it is known today, evolved in the early 20th century with the direct implementation

of professional codes, or Codes of Ethics, for the different disciplines of engineering. The first engineering society to create a Code of Ethics was the American Institute of Electrical Engineers in 1912. They were followed by the American Society of Civil Engineers who wanted to distance themselves from the occupational builders and military engineers, thus implementing their Code of Ethics in 1914 (Groen et al., 2016). Codes or Cannons are a set of principles which frame etiquette and ethical behaviors for interactions with customers, employers, stakeholders, and other professional engineers. Defining how such professional engineers should be acting with their vocations began to establish an identity for the engineering societies and beyond.

Chapter 2

Literature Review

What is the Curriculum doing?

Background of engineering ethics education and recent efforts to increase ESI. Engineering undergraduate students have four years, eight semesters, to learn everything they may need to design, manage, and pilot the necessary tasks of a young professional in the engineering world. For many disciplines of engineering, the times tables for courses are tightly packed with technical requirements, project design courses, capstones, and general education requirements. The ABET EC2000 was created by the Accreditation Board for Engineering and Technology that changes their previous criterion to include more outcome-based evaluation to programs under their accreditation (Barry & Ohland, 2011). Criterion 3.f., [now 3.4] outlines that accredited programs must include professional instruction on engineering ethics and global, social, cultural, environmental, and economic impacts (ABETa, n.d.; Barry & Ohland, 2011). Since the implementation of ABET's EC2000 requisites, university faculty and department instructors have been advocating for different strategies to get engineering ethics into the preexisting curriculum of classes, like capstone and design courses, or new courses that specialize in professional development, ethics, and social impacts which students can take. This section highlights the various ways the engineering curriculum has adapted to include ethics and social impacts (ESI) to meet the requirements set out by ABET in EC2000 and later renditions.

Various studies have been conducted to gauge undergraduate students' ethical background and find that there is a need for ethical development training in engineering curriculum. The Student Engineering Ethical Development (SEED) survey is designed to probe students'

understanding of ethical development through influences like student characteristics, formal curricular experiences, and co-curricular experiences. Through implementing their SEED survey, Finelli et al. (2012) found that when surveying the 3,914 college engineers across majors like, aerospace, civil, computer and software, mechanical and many others, they have lower ethical reasoning levels than their peers in other majors. These scores fall into the range that Finelli et al. (2012) found average for university students, this encourages further research into areas of improvement for ESI instruction and training for engineering students. Smith et al. (2021) in their study continues with this notion that after graduating, engineering alumni engage less with social action, clubs and volunteer activities in their universities and community, compared with other graduates. They go on to posit the idea and theory of the "culture of disengagement," where engineering students detach themselves form the social and global impacts of their engineering practices (Smith et al., 2021). Similarly, Cech (2014), found at the four universities sampled in their article, that engineering students are less engaged in public welfare and do not understand the consequences of technologies even as far as not valuing the welfare of the public in university or after gaining a profession. The theory of cultural disengagement was argued by Cech as a driving factor in 2014 study. Cech evaluated two universities which were "pedagogically innovative" and two with "traditional" engineering programs and found the same disengagement with ethics and social issues. This finding suggests that even with the explicit changes to curriculum in the innovative university, further commitments to public welfare are not seen, linking the process of disengagement to engineering culture as a whole rather than specific to institutions' climate (Cech, 2014). Kim et. al (2021) found that engineers' moral disengagement scores had no statistically significant differences from the first year of study to the fourth in the same institution. Although, engineering students are more likely to participate in actions considered "displacement of

responsibility" more often that others (Kim et al., 2021). According to this study, displacement of responsibility is defined as, "viewing one's actions as the result of social pressures or dictates rather than taking personal responsibility for those actions" (Kim et al., 2021).

What is working? Why? Miñano et al. (2016) conducted a study in Madrid which obtained statistically significant differences from their first test, before entering an ethics course, with the final test, during a final examination. The students in the second semester study increased their scores in at least one learning dimension and 25 percent improved their score in all learning outcomes (Miñano et al., 2016). The course Miñano et al. (2016) assessed was created based on the curriculum guidelines of the Association for Computing Machinery (ACM) and the new required course for first year engineering students called "Social, Legal, Ethical, and Professional Issues." The course used active learning methodologies like debates, case discussions, monographs, and expert lectures. Overall, the improvements in learning outcomes for students in this course inspires hope that other institutions will be able to replicate this at their universities.

Another study that shows some encouraging outcomes to ethics and societal impact training is Check et al. (2022)'s study on the public welfare responsibility training for engineering professionals. They surveyed 120 engineers in the United States with, and without, training in their undergraduate schooling on public welfare impacts from engineering to gauge how they handled ethical issues. Engineers in the study that had received training self-assessed that they felt more prepared and comfortable tackling these issues than engineers that had no formal training (Cech et al., 2022). The implications of Cech et al.'s (2022) study and the various results from assessing ethics implementation and tactics to the curriculum is paramount, but there should be understanding of what students are retaining in the course but also how they behave in their

professional careers. Surveys for alumni from engineering university programs should be encouraged to expand the breath of this research.

Approaches to integrate ESI into curriculum. Across the literature there have been suggestions to balance ESI additions and technical requirements in an engineering student's course load to meet the new criterion. These tactics include incorporating new inclusions in existing courses, professional readiness classes and ESI training, and promoting co-curricular activities outside of the traditional classroom setting (Bielefeldt et. al., 2021; Bielefeldt et. al., 2020 Finelli et al., 2012; Martin et al., 2021). Professional codes, case studies, and industry experiences from faculty are commonplace in engineering ethics curriculum. Philosophical ethical theories are not as common in engineering ethics education due to the focus on applied ethical frameworks when learning through case studies as the broad teaching tool of ESI development (Bielefeldt et al., 2019). Entire courses can be created to focus on the professional readiness of students and outline ethical theories, but this runs into the barrier of time in an engineering undergraduate's four years (Basart & Serra, 2011). Integration of ethics and social impacts into an already existing class curriculum, such as a section of a few lectures focusing on the ethics of the content or subject at hand could adapt the already dense course load to new learning outcomes. Outside the regular course instruction, instructors could advise students to join or volunteer in clubs focusing on ethical decision making and design. However, this reliance on co-curricular activities has been identified in some engineering ethics literature for its mixed opinions on the strategy. Professional readiness training, workshops outside of regular class hours, or dependence on co-curricular activities to teach and expose students to ethical decision making and applied ethical frameworks have been questioned for their detachment from the base curriculum (Cech et al., 2022; Polmear et al., 2021). Similarly, other studies to implement ethics education have led to undesirable outcomes like in the

study conducted by Borenstein et al. (2009), they found that a full course in professional ethics had a small impact on the probed learning outcome of moral reasoning while the engineering course with a micro-insertion on ethics had no effect. They argue that course curriculum has an affect on the outcomes, however, there was no indication of what types of curriculum or strategies would improve outcomes (Borenstein et al., 2009). Further studies into micro-insertions by Hess and Fore (2017) and Polmear et al. (June 2020), argue that the ethics components in engineering classes, micro-insertions, may be desired to the other strategies. However, the implementation of this strategy requires that department faculty have an understanding and combined effort for improving ESI education. To get the most out of these additions, these changes must be met with enthusiastic faculty and advisors willing to be ethical mentors for undergraduate students. Department-wide understanding must be made to implement changes as the literature suggests that the interpretation of the ABET 3f. from EC2000 and the 3.4 criterion for 2025-2026 can vary from institution to institution (Polmear et al., 2021), leading to a lack of structure during accreditation visits (Barry and Ohland, 2011). So, faculty might face internal curriculum troubles that bleed into the learning outcomes of undergraduate students. Although, the loose structure of implementing different strategies for students benefit could give faculty flexibility in the face of barriers, to still meet the ABET criterion.

Engineering ethics education is interpreted and enacted through a combination of many things such as engineering society codes, theoretical ethics frameworks, and case studies to name a few. As discussed in the background information, engineering society codes are an important milestone for engineering ethics as a whole. In their conference paper, Cech et al. (2022) argues that with the context of engineering codes, professionals must consider how their work impacts the public and society. One of the first cannons across disciplines of engineering codes of ethics is

to “hold paramount the safety, health, and welfare of the public” (American Institute of Aeronautics and Astronautics (AIAA), 2025; American Society of Agricultural and Biological Engineers (ASABE), 2020; American Society of Civil Engineers (ASCE), 2020; American Society of Mechanical Engineers (ASME), 2012; Institute of Electrical and Electronics Engineers (IEEE), 2020). This is further expanded upon in each society’s code of ethics, but these driving principles specify that engineers have a responsibility to inform the public, employers, clients, and the many other people they may work with if they find ethical issues that impact public health, safety, or welfare (Cech et al., 2022). Codes of Ethics have made immense contributions to how infrastructure, technology and materials are introduced to society, the responsibility of engineers is vast, but these codes are not without their criticism.

While the engineering societies’ code of ethics can be a set of guiding principles, the reliance of their use in educational settings is seen as holding engineering ethics back by some. The static nature, vague word choice, and detached nature of codes can lead to their misuse and lack of direct criticism (Fore and Hess, 2019; Snieder and Zhu, 2020). Codes of ethics are preventative in nature (Ferman and Ratti, 2024; Fore and Hess, 2019) which can lead to the reactionary world of engineering feeling at a loss when they cannot guide young professionals on the new, transforming, circumstances engineers find themselves in. While practicing engineers reference codes little, or never at all, when making ethical decisions (Brey & Jansen, 2015; Smith et al., 2021; Snieder & Zhu, 2020), because of their prevalence and traditional nature, however, there have been numerous faculty that use professional codes in their curriculum (Diana Adela Martin and Conlon, 2023; Polmear et al., 2020; Polmear et al., 2021). Codes of ethics, while imperfect, are the foundation to introducing engineering ethics to undergraduates. These codes have adapted over time adding new Cannons and clarifications as needs have changed.

Measurement of ESI Outcomes

Formal assessment on the learning outcomes of engineering ethics education is nuanced due to the subject of ESI itself. ESI influences society, the environment, workplace relationships, and professional etiquette. The basis and groundwork of ethical values and understanding of social implications come from early childhood (Schweiger, 2023). Different measurements, assessment protocols, and processes have been created to evaluate students' awareness of ESI, retention of instruction on ESI, and how different curriculum effects students learning outcomes. Some of these protocols, methods, and assessments found in the literature can be found detailed in this section.

Altogether, many of the assessment protocols attempt to measure the identification of ethical problems (DIT, ESIT, HLRMS, CIT, and PMEAR) and behavior (CIT, SEED, DIT, and ESIT) while having unique ways of measuring other parameters like stakeholder perspectives, ethical outcomes, or motivations (4DDD).

Self-assessment and interview. The Critical Incident Technique, CIT, involves interviews with the study participants (Hess et al., 2017). A majority of the interviews involved the participants to recall incidents from memory. All of these are then categorized into smaller groups which have similar factors, consequences, or effects. Perspective shifts are noted as critical incidents or events (Hess et al., 2017). Limitations of this assessment protocol include participant bias due to recalling the event from memory, which may skew the details of the ethical issue or outcomes, shifts in perspective are good as a first step in more ethical practices, however, ethical actions might be a better direct comparison tool.

Self-assessment, Focus Groups and Interviews, and Written assessments. Student Engineering Ethical Development (SEED) surveys are a great way to assess the characteristics, curricular experiences, and co-curricular experiences of students as they relate to ethics and ethical

decision making (Finelli et al., 2012). These surveys are based on self-reflection which relies on the belief that students are truthful in their self-assessment. Self-assessment is not the only way to gain understanding of student outcomes. Expansions into tests and measurements of steps of ESI development as a student competes cases studies or other tasks outlined by the protocol. Questions similar to the Fundamentals of Engineering (FE) exam are used to assess student knowledge as well as responses to the Defining Issues Test 2 (DIT-2).

Case Studies. The Engineering and Science Issues Test (ESIT) is a moral reasoning development measure that was adapted and based on six case studies from the Defining Issues Test (DIT). This test was created by Borenstein et al. (2019) to be an engineering- and science-specific measure for ethics research (Nihat Kotluk & Tormey, 2023). The DIT is a widely used measure for moral development. It measures four steps of ethical decision making; recognizing the ethical problem, ethical evaluation, moral intention of behavior, and ethical action and behavior itself (Miñano et al., 2016). There is a more current version of the DIT called the DIT-2, but it is limited in its engineering ethics applications (Miñano et al., 2016).

Rubric. The four domain development diagram (4DDD) was created by Dr. Linda Vanasupa to investigate the learning settings in which ethics and moral development can thrive. The four domains that are analyzed are cognitive, affective, psychomotor, and social with the center of a student's learning being their motivation cycle (Bielefeldt et al., 2020). The PMEAR Rubric measures five components, recognition, information, analysis, perspective, and resolution of the ethical issue. This measure is a more open-ended assessment tool created by researchers in engineering and various interdisciplinary fields (Miñano et al., 2016). The Higher-Level Moral Reasoning Skills, HLMRS, measures five things, professional engineering knowledge and

framing, multiple perspectives, perspectives of stakeholders in analysis, finding similarity in past cases and articulating how they are similar, analysis of moral reasoning (Goldin et al., 2015).

Assessment tool critiques and work to be done. These assessment tools have been created in the wake of ABET's EC2000 to assess the learning outcomes of new introductions of ethics into engineering undergraduate courses. Miñano et al. (2016) criticizes the DIT and ESIT assessment tools because they are limited to moral reasoning and judgement, which they argue is not a significant skill needed for professional engineering ethics. However, some argue the tests guide students through ethics case studies and begin the process of forming ethical decision-making skills (Borenstein et al., 2019). So, it was surprising to see the critique of these types of assessments. These assessment methods and protocols have been applied and evaluated on a variety of different sized study groups (Bielefeldt et al., 2020; Hess et al., 2017; Finelli et. al, 2012; Miñano et al., 2016). Like all studies and research, there needs to be more replicable studies conducted with them. Learning more about the degree at which these different assessment tools reveal how engineering students are retaining the information from their ethics courses, training, and experiences is a major component for ABET improvement and universities' continued innovation.

Hess and Fore, (2017) systematically reviewed literature on engineering ethics interventions in the United States and identified three learning outcomes across various institutions in their study. First, ethical sensitivity or awareness which focuses on improving student's alertness of ethically problematic situations that they may encounter in their future careers (Hess & Fore, 2017). Second, ethical judgment, decision making, or imagination which focuses on teaching and helping students to reason or act ethically through the implementation of professional codes and discussion of ethical theories (Hess & Fore, 2017). And, finally, ethical courage, confidence, or

commitment. Students must have a disposition or tendency to be ethical in practice and construct the norm of fairness in the students (Hess & Fore, 2017). They further describe that teaching codes of ethics is good for memorization and the awareness aspect of the first and most prominent learning outcome, ethical sensitivity or awareness. In a later paper, Hess and Fore would criticize engineering codes of their static nature (Fore and Hess, 2019). However, they must see the foundational need for codes. Learning outcome two expects students to be capable of making ethical and informed decisions with moral imaginations (Hess & Fore, 2017). These learning goals, while comprehensive, leave out or do not emphasize the greater additions to the ABET 3.4 criterion of "impact of engineering solutions in global, economic, environmental, and societal contexts" (ABET, 2024). This discrepancy could be due to the Hess and Fore's review being published in 2017; while the ABET criterion had the phrase "global, economic, environmental, and societal context" in the EC2000 framework, these aspects may not have been fully materialized in curriculum until recently.

Further understanding on the context of students. "Learning is situational," (Lee et al., 2020), so engineering ethics is no different. The influences of situational factors need to be considered when assessing students. The relationships the students have with the engineering world at large, faculty interactions, industry influences, and year of study can all greatly impact learning and understanding of students. These could be impacting the engagement, responses, and interpretations of students during assessment. Sunderland (2013) further cautions that ethics becoming a learning outcome that needs to be measured could be squandering the curiosity of engineering students. Ethics and moral reasoning are complex, and adding a number grade to moral or ethical values could be discouraging students from engaging, or leading them to, as discussed before in Smith et. al.'s study (2021), moral disengagement. Hope for the moral engagement of

undergraduates is not lost. As previously alluded, the study of how we evaluate engineering students' understanding of ESI is a flourishing field. Commitments to ESI have only grown, and with it more insight to how students are impacted and take their knowledge into the professional setting. With this influx of curriculum there has been an expansion into working in cross-disciplinary teaching methods.

Other Avenues for ESI Skills

At institutions, large or small, connecting with others in different subjects, majors, or disciplines in the same field can give perspectives that would otherwise be unforeseen remaining in technical heavy course loads or strict academic course suggestions. Diversifying learning settings, pedagogy, and instructors can bring students insight that can greatly impact their skills like communication, public speaking, and leadership as well as enrich their ESI development.

Cross-disciplinary action and engagement across different subjects like humanities and STEM, can help engineering students' engagement and understanding of ethics and social impact (Lee et al., 2020). Being uncomfortable is something technical engineering students may be afraid of when taking classes in ethics and social impacts because there is no one right answer to an instructors' questions (Basart & Serra, 2011). However, conflict and perseverance are skills that are important for student learning and ethical development. Engineers serve the public, and engineering curricula should allow students to conceive their role to further their ethical and moral reasons for becoming an engineer (Sunderland, 2013). Sunderland (2013) continues that reflection and cross-disciplinary engagement aids ethics courses from just being another requirement to an

active, core part of becoming an engineer. Bielefeldt (2021) acknowledges through their interview process that, broadly, there are multiple ways and understandings of social justice and ESI topics, but these can be added similarly to ethics in course curriculum for the betterment of engineering students.

Co-curricular activities such as service groups, clubs, internships, co-ops, and volunteer experiences are common among engineering undergraduate students. These opportunities can place students in mentee roles with industry professionals, faculty in engineering departments, and community leaders. Advisors and faculty do impact students and how they traverse their learning during undergraduate. In Bielefedt et al.'s 2020 study on civil engineering students, they consider the role professional mentors play in an undergraduate's learning experience. Speakers at club events, sponsors for projects, and working with communities can add to ethical reasoning impacts on students. This relationship with industry professionals that they can gain in co-curricular activities also may expose them to other disciplinary experiences. Co-curricular activities assessed in the SEED survey (Finelli et al., 2012), fall into a similar space as cross-disciplinary activities, engagement, and interpersonal influences that have begun to be discussed in the latest engineering ethics paradigm. However, Polmear et al. (2020) continues to expand that even with the studies on disciplinary and faculty influences on ethics instruction, the nuanced interactions of these factors have not been fully qualified. While conducting a study on Civil Engineering students and how co-curricular activities impact their learning Bielefeldt et al. (2020), found in their results that while these activities can introduce and even teach students about ESI topics and ethics, the learning can be inconsistent across campuses and groups of the same type. These findings are not to say that there have not been some discoveries of increased ethical and ESI outcomes in students due to co-curricular engagement, just that it is not at the level it can be across universities.

Guidance and mentoring from advisors can influence how impactful these experiences can be for students. Co-curricular groups in which there was higher numbers of ethics topics were those of underrepresented groups in engineering, such as Society of Women in Engineering and National Society of Black Engineers (Bielefeldt et al., 2018). Bielefeldt et. al. (2018) goes on to suggest that joint activities with these groups and the engineering discipline specific professional societies would expose more undergraduate engineers to ethics and ESI topics. There is strong evidence that service opportunities and activities with volunteer groups can impact the ethical and social reasoning of undergraduate students (Bielefedt et. Al., 2020; Cech et al., 2022), but it should not be a factor that then removes the need for improved ethics instruction in base curriculum. While it is common amongst engineering students to be in co-curricular activities, there are some that cannot be due to time constraints, financial reasons, family planning, and other responsibilities. So, completely relying on ESI to be taught to undergraduate students in this manor is leaving these students excluded. Further expansion in this area, however, could give insight to improve engineering ethics education.

Further Influences of ESI Instruction

Engineering has a history of being seen as a field which focuses on technical skill alone. However, engineering is also research, business, a service to the public, and affects other realms like politics, economics, and cultural influences (Basart & Serra, 2011; Ferdman & Ratti, 2024). The approach of rationality when it comes to the teaching of ethical frameworks is similar, professional codes, black and white case studies, and moral principles being the common paradigm. Ethics has similar assumptions that it should be a completely rational process, however

it keeps students and young professionals from being prepared to make decisions with levels of uncertainty (Miñano et al., 2016). There has been a shift to think about emotional engagement, empathy, and ethics of care perspectives in engineering ethics education (Fore & Hess, 2019; Hess et al., 2017; Nihat Kotluk & Tormey, 2023). Basart & Serra (2011) argue that the stereotypical model and western backbone of the engineer is individualistic (Smith et al., 2021; Polmear, June 2020) and the heroic warrior, is not the approach engineering should be using in our interconnected world. While technical skill and strong will is needed to perform the tasks necessary for design and progress, understanding the needs, values, and perspectives of the those impacted by the design and progress is critical (Polmear et al., 2020; Janna van Grunsven et al., 2023). In another study conducted by Angela Bielefeldt (2021), the faculty that taught ESI topics, such as social justice and poverty, found the education of students in ESI in undergraduate and graduate programs was not enough compared to their non-ESI or -SJP (social justice and/or poverty) faculty. This outcome, like previous studies by Bielefeldt, illustrates the need for education on these welfare topics for engineers. Hess et al. (2017), a professor in engineering education at Purdue University, argues that even though there are swaths of scholarship on empathic development, and finding creative ways in connecting it to engineering, specifically developing it in undergraduates, graduates, and young professionals would be beneficial.

According to Bielefeldt et al. (2018), an element of engineering ethics education to note is the differences in instruction due to factors such as gender or minority status. In class activities can vary from having a female instructor to male instructor. Underrepresented minorities are more likely to teach about ESI and social justice topics in co-curricular clubs and service opportunities (Bielefeldt et al., 2018). These influences of demographic groups on curriculum and co-curriculum could aid in the implementation of ethics in undergraduate courses in diverse faculties. Ethical

situations can appear everywhere, so incorporating ethical decision making in technical spaces and courses could have better outcomes for students' comfortability in their reasoning and aptitudes. A traditional and baseline preface to make students comfortable with ethics in their profession is the introduction of engineering society codes.

Chapter 3

Research Questions

The engineering ESI education research conducted was informed by the following research question:

Research Question: Do undergraduate students' answers to self-reflection surveys indicate how much their formal curricular, co-curricular, and perceived importance of ESI impact their ESI development?

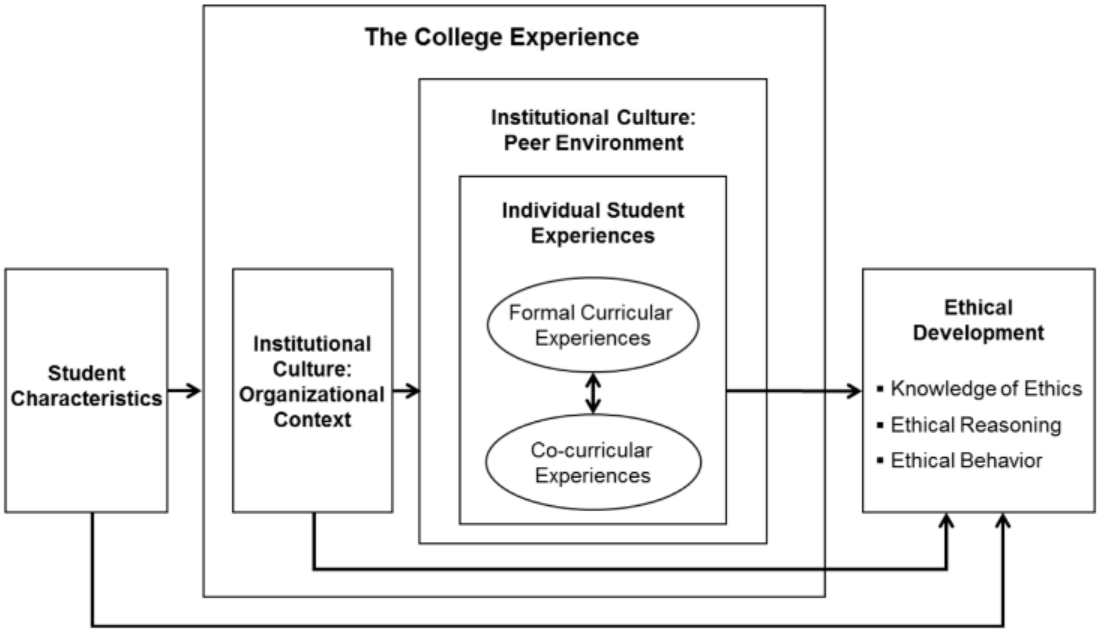


Figure 1: Conceptual framework of a student's ethical development during college (Finelli et al., 2012).

The research question will be answered by following a modified version of the analysis conducted for Finelli et al.'s 2012 SEED survey, analysis of the short-answer responses from the pre-instruction survey and post-survey, and the changes in frequency of agreement or disagreement

to the ranked questions from the pre-instruction survey and post-survey. An outline can be found in the methodology section of this thesis.

Chapter 4

Context of Study

The study of engineering students' perspective on ESI knowledge, feelings, and comfort took place in The Pennsylvania State University's Agricultural and Biological Engineering department's second technical and professional development course, BE 392. The Pennsylvania State University is a Land Grant university in the state of Pennsylvania in the United States of America. Students participating in the study have completed three to four years of an undergraduate engineering or biorenewable systems management degree. The study consists of two phases, a pre-survey to gauge prior knowledge, engagements, and feelings on ESI before the formal instruction of ESI curriculum. With the timeline of the course, a mid-survey will be given to the students after a majority of the ESI instruction has been given in BE 392. The mid-survey with the same questions as the pre-survey to gauge changes in thinking, knowledge, and comfortability as well as questions pertaining to the teaching, retention, and overall perception of the BE 392 class's ESI curriculum. The goal of the surveys will be to answer the research question and expand the discourse on engineering ethics and social impact education. The broader impact of these surveys will inform changes in ESI instruction going forward for the BE 392 course.

Chapter 5

Methodology

The study was conducted in the Agricultural and Biological Engineering department through the required technical development course for biological engineering and agricultural and biorenewable systems management students. This course is not the biological engineering students only exposure to ESI topics and development, however, BE 392 is the first required course that involves more than a weeklong micro-insertion. Similarly, agricultural and biorenewable systems management students have other chances to get ethics instruction from other courses at Penn State, however this is the first required course.

The study involves two self-assessment surveys, one before formal ESI instruction and another after most of the ESI instruction is finished. Students in the class are asked to fill out the surveys anonymously with the only identifying characteristic being their major. These surveys were created based on the items in the SEED survey (Finelli et al., 2012). The surveys can be found in the Appendix, A for the pre-survey and B for the mid-survey. The SEED survey addresses multiple dimensions of students' influences on their ethical development:

- Student characteristics and experiences prior to university (student characteristics).
- Ethical development with the intention to probe how a student articulates and defines ESI (ethical development)
- Co-curricular activities are they in if any (co-curricular experiences),

- Any ethical courses or training they have participated in (formal curricular experiences).
- How comfortable or confident they feel about using ESI to make decisions (Formal curricular experiences and ethical development).

Changes and adaptations can be found in table 1.

Additional questions address (not based on the SEED survey):

- If students know the impact of their work on the environment.
- How ESI influences how students interact with peers and clubs.
- How instruction in BE 392 influenced previous ranked questions.

The latter is due to the inclusion of environmental impacts to many professional codes and engineering curriculum. This specific probe is also due to the close relationship agricultural and biological engineers, agricultural and biorenewable systems management students, and faculty in the Agricultural and Biological Engineering department have with the environment. These outcomes from the pre-survey will be compared to the outcomes of the mid-survey to gauge differences after formal instruction in a classroom setting. As articulated before, both the pre-survey and mid-survey will be assessed using modified methodologies based from the SEED survey.

Table 1: Items on surveys conducted (pre and mid) in comparison with SEED survey items (Finelli et al., 2012)

Conducted Pre and Mid Survey	SEED Survey
Student Characteristics • Demographics: Major • Other previous experience: Participation in research with a faculty member, internship, or co-op experience, full-time work, study abroad, or pre-college summer program.	• Demographics: Class level, gender, race and ethnicity, specific engineering major, current college GPA, cumulative high school GPA, full time/part time status, previous educational experience, citizenship, primary language, and political orientation • High school (i.e., secondary school) behavior: Participation in service in high school, cheating on tests in school, or cheating on problem sets in high school • Other previous experience: Participation in research with a faculty member, internship, or co-op experience, full-time work, study abroad, or pre-college summer program.
Formal curricular experiences • Perception of importance of ethics instruction • Satisfaction with quality of ethics instruction • For each of the nine pedagogies (e.g., presentation by professor or role playing), items measuring settings in which it might have occurred (e.g., introductory engineering course, out-of-class workshop, or senior design/capstone)	• For each of the nine pedagogies (e.g., presentation by professor or role playing), items measuring settings in which it might have occurred (e.g., introductory engineering course, out-of-class workshop, or senior design/capstone) • For the most influential experience, the cognitive depth (using Bloom's taxonomy) and the likelihood of that experience impacting a future ethical decision. • Perception of importance of ethics instruction • Satisfaction with quality of ethics instruction
Co-Curricular experiences • For each of the five engineering activities (e.g., engineering design team or professional engineering student society) and ten non-engineering activities (e.g., student	• For each of the five engineering activities (e.g., engineering design team or professional engineering student society) and ten non-engineering activities (e.g., student

government, varsity athletics) items measuring • Participation • Participation as an elected or appointed leader • Participation in volunteer service of the group	government, varsity athletics) items measuring • Frequency of participation • Participation as an elected or appointed leader Participation in volunteer service of the group
Ethical development • Knowledge of ethics: Defining ethics and social impacts • Positive ethical behavior: Items about frequency of taking courses because of the community service component and participating in K-12 outreach or volunteer service projects	• Knowledge of ethics: Ethics questions like the ones on the Fundamentals of Engineering Examination • Ethical reasoning: The PI, MN, P, and N2 scores on the DIT-2, calculated by the Center for the Study of Ethical Development • Positive ethical behavior: Items about frequency of taking courses because of the community service component and participating in K-12 outreach or volunteer service projects • Negative ethical behavior: Items about frequency of cheating in college

In comparison to the SEED survey, there were some changes made to lower the number of questions for the students to answer due to this survey being a supplement in the BE 392 course. Priority was set on certain features and comparisons before and after formal instruction. Demographic information about the students was reduced to a minimum due to the content of the survey not focusing on these identity features. So, gender, class year, GPA, full time/part time status, previous educational experience, citizenship, primary language, and political orientation were not collected. For formal curricular experiences our survey probed the perception of importance of ethics and social impacts instruction and the satisfaction the students have with the instruction they have received. These two variables will be further expanded due to the results gained by the pre-survey and mid-survey. Like the SEED survey we asked about the places (e.g. course, group, or activity) in which students have had prior ethics and social impact instruction.

Cognitive depth of these activities and student's experiences was not measured with the pre-survey. Participation in the five engineering activities, and ten non-engineering activities were probed to see if participation influenced ethical development in the pre- and mid-surveys, Appendix A and Appendix B. Finally ethical development in the pre and post surveys is based on the student's ability to define ethics and social impacts in their own words, how they would argue the importance of ethics, and if they indicated positive ethical behavior. Questions based on the Fundamentals of Engineering Examination and DIT-2 were not used for our study.

The survey conducted for this thesis also includes some questions to aid in evaluating the ethics instruction for the BE 392 course. These questions are to gauge the level of which students enrolled in the class have prior knowledge, willingness to discuss ethical issues, and if they have built their network based on their ethical values. For a visual observation, language patterns and word occurrence will be assessed for the short answer questions. Levels of agreement and disagreement will be evaluated and compared to how they answered the short answer questions and if there are changes in the mid-survey results. These comparisons will be displayed using the Gephi software to show connections and occurrence (Bastian M. et. al., 2009).

Python, WORDij, and Gephi. To further understand what each piece of software is doing, the Python code will be included in Appendix C and the logs from the WORDij analysis will be included in Appendix C. Python is a programing language that supports modules and packages that are free to use. For this study Python was run through Anaconda and Visual Studio. Python's main purpose is to "clean" responses by converting the text to lowercase and removing punctuation. The columns, individual questions, are then complied into one string, connecting all the responses together. The responses will then be put in a text file for ease of import into WORDij.

The program called WORDij is a software for semantics analysis, one of which combines the frequency of words and word pairs (Danowski, J. A., 2013). The program will allow the import of a file or multiple files as a source. Then a Drop List can be chosen, these can be browsed from the existing drop list files or the import of your own. A Drop List is a set of words that can be ignored by the software when creating word pairs and counting word frequency. WORDij also permits the software to drop words and word pairs if they are used less than an indicated number of times. Finally, there are advanced options to the software, however none of these were used in this study. After analyzing, log files will be created to show the choices made for the analyzation, CSV files that have word frequency and word pairs, and dot net files that can be imported into Gephi for visualization. This software is free to download if the use is for research and not commercial purposes.

Gephi is used to show the frequency of words as well as word pairs from the open-ended responses. This is an additional tool used to visualize the final analysis of the data. Gephi has many applications as a network analysis tool (Bastian M. et. al., 2009). For this study, the undirected connections were used from the WORDij data to create Fruchterman Reingold layouts for each of the open-ended questions.

Data Collection

Survey composition and dissemination. Both surveys were given to students through the required course load of the BE 392 course. The first was completed by February 10th before their first lecture on ESI. The surveys are a mixture of short answer responses, listing, and circling a

range of agreement or disagreement to a question. All responses are anonymous and only connected to the major that they provide on the form. This identification is only to ensure that biological engineering students and agricultural and biorenewable systems management students can be analyzed separately. All data is collected from the responses on the pre-survey before formal ESI education and the post-survey after the ESI portion of the course.

Analysis of open-ended questions. The responses were parsed to ensure that they did not have any extra spaces, symbols, or jumbling to make insertion into the coding software have limited issues. Some fixes that were made were apostrophes for contractions, extra symbols at the end of sentences due to participants hitting enter in response boxes, and extra spaces in responses. No responses where changed for misspelling or grammar. Python was used to clean the responses, remove punctuation and put all words into lowercase. The Python code can be found in the Appendix C. The text files were then put into the WORDij software to find frequency of words and word pairs. Logs from the WORDij software can be found in the Appendix C. WORDij is a software for semantics analysis, one of which combines the frequency of words and word pairs (Danowski, J. A., 2013) that can be visualized in the Gephi software (Bastian M. et. al., 2009).

Likert scale questions. The Likert scale questions will be used in conjunction with the open-ended questions to assess student ethical development using the modified SEED methodology. Furthermore, differences between the pre-survey responses and mid-survey responses will be analyzed using the Wilcoxon Rank-Sum Test to evaluate if the two dependent samples differ significantly from each other. The Wilcoxon test is non-parametric so a normal distribution for the response is not needed (Mathias, 2025). Trends of the Likert scale questions based on prior formal ethics experience from the pre-survey and be found in Appendix A. Trends of the Likert scale questions based on major from the mid-survey can be found in Appendix B.

Participants

Students fall into one of two categories, biological engineers and agricultural and biorenewable systems management; both have further classifications themselves, however, for the purpose of this study the only category which will be expanded upon is biological engineers. At the Pennsylvania State University biological engineering undergraduate students can have one of three options or focuses. These are agricultural engineering, food and bioprocessing, and natural resources. As engineers, the requirements for math, physics, chemistry, engineering design, engineering mechanics and applied calculus, statistics, and general education requirements are the same or similar. In the sixth semester of their undergraduate biological engineers will begin option or focus specific courses. These might include Machines for Agricultural and Bioprocessing (BE 306), Fundamentals of Cells and Molecules (BME 201), or Principles of Soil and Water Engineering (BE 307). These focuses continue into the eight semester. Agricultural and biorenewable systems management students deviate from these requirements in their third semester to begin classes on agrobusiness, life-cycle analysis, food health, and marketing.

The participants are in one of the two sections of the course. Differences in the responses based on sections will not be assessed in this study. The separation of the two sections is based on student choice, other scheduling factors, and smaller class sizes. Both biological engineers and agricultural and biorenewable systems management students are mixed between the two sections of the course and meet on separate days.

Table 2: Participant Information Table

Major	Option	Number
Biological Engineering	*Agricultural Engineering*	2
	Food and Bioprocessing	3
	Natural Resources	2
		7
Agricultural and Biorenewable System Management	-	12
Total		**19**

Source: Identity Information from Surveys

ESI Instruction in BE 392

The BE 392 course covers ESI topics from February 10th, when the pre-survey was due, to April 7th. For the purposes of this study the survey assessing instruction was due March 24th. This is not the end of all the ethics instruction in this course, however, a majority of the content has been covered up to this point. Further, analysis should be done after all ethics instruction in complete, however that is out of the scope of this study.

Introduction to ethics. Students receive an introduction lecture on the dimensions of ethics, environmental ethics, as well as the ethics of sustainability and sustainable development. The different dimensions of ethics outlined in this section are; Meta ethics, the origin of morality, moral fact, and morals due to perspective, Normative ethics, how one ought to act on a personal level which encompasses virtue ethics, deontological ethics, consequentialist ethics, and care ethics, Comparative ethics what people believe is right and is relative to generational culture, and finally

Applied ethics on how moral knowledge is put into action and applied. Under applied ethics the course begins to explain professional ethics and the ethics of the environment (Costello, 2025).

Environmental ethics is further explained by "what life forms are regarded as having moral status, whether humans are deserving of superior status to other life forms on the basis of cognitive abilities" (Costello, 2025). The difference between instrumental value and intrinsic value is discussed based on environmental ethics. Anthropocentrism, that centers humans and their needs before Earth's resources, Zoocenterism, in which humans should care about the environment not just due to negative consequences but because all living things have the right to live, Biocentrism, which argues thar all living things have moral standing conscious or not, and finally Leopold's land ethics, that argues to include soils, waters, plants, and animals are included in moral community (Costello, 2025).

Environmental ethics leads into the final part of the introduction of ethics with the ethics of sustainability and sustainable development. The history of sustainability is outlined along with the interconnectedness with food production, greenhouse gas emissions, food waste, availability of water, and cultural preferences and traditions (Costello, 2025).

Out of class assignments. For the first assignment on ESI, before the next lecture, students were asked to watch various videos to better understand their own values. A video describing the differences between morality, law, and ethics is assigned with the task to take notes for an in-class discussion. Further, a video on values in ethics and a personal values test to help students define their values for the second part of the assignment. The second part is a reflection on their top three values. Students are asked to explain why these values are in their top three, if the exercise was helpful, if they learned anything new, and if they thought the exercise helped if their values were

challenged in the workplace. During the week of March 3rd, all students and the instructor sat in a circle and shared one value identified in this exercise and what it means to them.

In the next assignment, students were asked to read the NSPE Code of Ethics for engineers and *Ethics and Engineering* "An Introduction" by Behnam Tabei. These readings prepared students for in-class discussions on engineering ethics and applied ethical principles on case studies. While students were not asked to make notes on questions or topics to bring into class, they were expected to contribute to conversation and discussion.

Adding to the previous assignment, students were asked to read various professional ethics and code of ethics before class on the 24th of March. These Code of Ethics were the NSPE Code of Ethics for engineers, the National Association of Environmental Professional's Code of Ethics and Standards, the American Society of Agricultural and Biological Engineering Code of Ethics, and finally the American Society of Civil Engineers Code of Ethics. To attract class discussion students were asked to make note of one similarity between the Codes of Ethics and one difference. Over the two weeks that included professional ethics, two case studies were presented and discussed. Time was taken to review differences in codes of engineering ethics and that of the environmental professionals. The latter mentions policy development because of known threats to the environment more than is mentioned in engineering (Costello, 2025).

For final assignment before the mid-survey, students were asked to read "The Honorable Harvest" in *Braiding Sweetgrass* by Robin Kimmer. They were then asked to write a discussion post on how they would apply Honorable Harvest in their life, name an ethical framework that is discussed in the reading, what factors may influence how society feeds its people, and finally identify another important point in the reading and describe why it was important (Costello, 2025).

In-class assignments. Discussions amongst the students about the readings and assignments done outside of class are a large part of the led conversations on ESI. Dialogues are facilitated by the instructor with student input highly encouraged. Another in-class assignment was an environmental ethics and agriculture and food sustainability workshop. This workshop is about the ethics of food system production, food security, and food sovereignty. Ethical frameworks highlighted in the workshop are Consequentialism, Deontology, and Virtue ethics with further discussion of the environmental ethics described in the introduction lecture on ethics from a few weeks before (Costello, 2025). All students are a part of the workshop and are encouraged to participate in the discourse. These discussions occurred over two class periods for ~30-45 minutes each. In the first, the class was organized in a round-table discussion around food, agriculture, sustainability, and sustainable development and centered the ideas of agroecology and particularly Kimmerer's animist perspective. Students were asked to not only share their personal perspectives, but to imagine the food system if Kimmerer's ethics were what guided the food system. The following week, students were asked to individually identify a tangible facet of a sustainable food system and then create a supporting argument with one of the ethical perspectives from class, followed by sharing these thoughts within their teams (Costello, 2025).

Further ESI Instruction. These are all of the in-class, out of class, and lecture components of the ESI instruction in BE 392 up until the mid-survey was given to students. Further instruction is given, however with the timeline of the study all instruction could not be given before the second survey was released. Another assignment on ethical decision making is set to be due April 7th, to continue training on case study analysis and further study into ethical framework application.

Limitations

The survey perspectives are limited to the students who filled out and participated in both surveys. Self-assessment surveys require the respondents to answer based on reflection of their actions, feelings, and sense of self. Due to the two different styles of questions on the surveys, short answer questions are the only place to express their views further than agreement or disagreement. Students only know as much as they know, so answers before formal education on ethics may show that students know more, feel more comfortable about ethics and social impacts, and how they may argue to others about the importance of ethics. So, for the post survey lower agreement or students expressing that they are unsure should not be immediately perceived as formal education settings for ESI not working. The nuances of learning new things and recognizing there is more to understand could be an inflection point for students to want to learn more about ESI. During the analysis of the students' responses to the short answer questions, nuances such as these will be accounted for.

The interpretation of the students' responses could vary due to unintended bias by the researchers and subjectivity. The short nature of the survey was to encourage full attention throughout the surveying process, however other questions were removed to shorten the length. There could be further reflection and perspectives into the questions that were asked if the survey was given in another manner. Further study and perspectives should be sought to expand research in the field of engineering ESI education. Ultimately, the composition of the surveys was composed to increase engagement and be a supplement to the BE 392 class curriculum.

Chapter 6

Results and Discussion

Pre-Survey Results

In the following section, the analysis of the pre-survey will be outlined using the methodology from the adapted SEED survey, Formal curricular experiences, Co-curricular experiences, and Ethical development. Each subsection will begin with the questions from the survey which probed students' responses to areas of ESI influence and experience. For the pre-survey, prior formal curricular experience is a defining feature of the analysis between participants as well as major. A summary of the findings found from the pre-survey for the three areas of evaluation, formal curricular experiences, Co-curricular experiences, and Ethical development are condensed below. The overall results can be found in the sub-sections further in the section.

For Formal curricular experiences in the pre-survey, the 19 surveyed students indicated 14 total experiences prior to BE 392 in settings like introductory engineering courses and non-engineering courses (table 3). Pedagogies within these settings described by participants were guest lecturer and discussions with classmates. No students in the pre-survey signaled that they were in co-curricular activities, so the question on the survey was adjusted to clarify question three to get students experiences in the mid-survey. For ethical development, the students were asked to define ethics and social impacts and how they would argue the importance of ESI to another individual. Additionally, the comparison from the pre-survey and mid-survey will be used to

evaluate the ethical development of the participants. These results are outlined in the comparison section on page 90.

Formal curricular experiences

As described by the SEED survey, formal curricular experiences are measured by the setting such as introductory engineering course, pre-college program, out-of-class workshop, non-engineering course, and other settings. Also measured were the pedagogies used in these settings like presentation by a professor, presentation by individual speaking about their own experiences, guest speaker, discussion with classmates, movie or film, skit, role playing, in-class game, and online modules (Finelli et. al., 2012). Finally, the students' perception of importance of ESI instruction and satisfaction with quality of ESI instruction. Using the students' responses to the pre-surveyed, all of these were evaluated.

Question 3

Table 3: Quantity of Formal Curricular Experiences for all Surveyed (N=19)

	Pre-College Program	Introductory engineering course	Out-of-class workshop	Non-engineering course	Other	**Total**
Biological Engineers	1	6	0	1	0	**8**
Agricultural and Biorenewable Systems Management	0	2	0	4	0	**6**
Total	**1**	**8**	**0**	**5**	**0**	**14**

Source: Question Three Responses on Pre-Surveys

The settings for formal curricular experiences can be seen in Table 4. The number indicated in the separate sections denotes if a student described the setting below. Some students did not indicate that they had any formal ethics instruction, while others described multiple settings in which they received experiences. The most common formal curricular setting prior to BE 392 for biological engineers was introductory engineering courses, 75%. The most common pedagogy for the introductory engineering course was a guest speaker, 100% of that setting. These students had a guest lecturer in their BE 308 course for one week. This included a lecture on ethical frameworks, a case study on Henrietta Lacks and HeLa cells, group discussion, and reflection. The most common setting for ethics instruction prior to BE 392 for agricultural and biorenewable systems management students was in non-engineering courses, 67%. Some of the non-engineering courses listed by the agricultural and biorenewable systems management students were BA 241 and BA 242, SOC 119N, and ANSC 213. Sixty-three percent of students, combined biological engineers as well as agricultural and biorenewable systems management, had prior ethics instruction.

On the pre-surveys no students indicated any co-curricular activities in response to question three, so for the post-survey some clarification will be needed to probe for their involvements. Due to this no analysis for co-curricular experiences will be conducted for the pre-survey.

Table 4: Likert Questions on the Pre-Survey

Q 7: During my undergraduate studies I have learned enough about ethics to feel comfortable making decisions during my career.
Q 8: During my undergraduate studies I have learned enough about social impacts to feel comfortable making decisions with social implications during my career.
Q 9: During my undergraduate studies I have learned about the implications of my work on the environment.
Q 10: During my undergraduate studies I have learned about the implications of my work on the public.
Q 11: During my undergraduate studies I have tried to find peers that hold the same ethical values as me.
Q 12: During my undergraduate studies I have tried to find clubs that hold the same ethical values as me.
Q 13: During my undergraduate studies I have tried to find peers that hold the same societal impact values as me.
Q 14: During my undergraduate studies I have tried to find clubs that hold the same societal impact values as me.
Q 15: I am knowledgeable about philosophical ethics.
Q 16: I am knowledgeable about applied ethics.
Q 17: I am knowledgeable about societal impacts and social justice.
Q 18: I can identify ethical problems and the impacts of my work if asked.

Another aspect which probed for the dimension of formal curricular experiences were the ranked questions. All of the Likert scale questions can be found above in Table 4. Table 5 shows the counts for all the questions, seven through eighteen. The students are designated by their major, biological engineering in Table 6 and 7 or agricultural and biorenewable systems management Table 8 and 9 with their counts and percentages.

Table 5: Answers to the various probing questions for perception of importance of ethics instruction and satisfaction with quality of ethics instruction and student behavior on the pre-survey (N=19)

		Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18
Bio. Eng.	Strongly Agree	-	1	1	1	3	1	3	2	-	-	2	-
	Agree	6	4	4	3	3	3	3	3	2	3	2	4
	Neutral	-	-	1	1	1	2	1	1	3	3	2	1
	Disagree	-	1	-	1	-	1	-	1	1	-	-	1
	Strongly Disagree	1	1	1	1	-	-	-	-	1	1	1	1
ABSM	Strongly Agree	-	-	5	4	-	2	1	4	-	1	1	-
	Agree	6	6	7	6	10	5	7	4	3	4	5	5
	Neutral	4	3	-	2	2	5	4	3	3	4	5	6
	Disagree	2	3	-	-	-	-	-	1	5	2	1	-
	Strongly Disagree	-	-	-	-	-	-	-	-	1	1	-	1

Source: Ranked Question Responses on Pre-Surveys

Table 6: Percentage of Biological Engineering participants answered on pre-survey (N=7)

	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18
Strongly Agree	-	14%	14%	14%	43%	14%	43%	29%	-	-	29%	-
Agree	86%	57%	57%	43%	43%	43%	43%	43%	29%	43%	29%	57%
Neutral	-	-	14%	14%	14%	29%	14%	14%	43%	43%	29%	14%
Disagree	-	14%	-	14%	-	14%	-	14%	14%	-	-	14%
Strongly Disagree	14%	14%	14%	14%	-	-	-	-	14%	14%	14%	14%

Source: Ranked Question Responses on Pre-Surveys

For the pre-survey, 86% of biological engineers surveyed agree that they have learned enough about ethics to feel comfortable making decisions in their career. No students strongly agree. Only one student strongly disagreed that they learned enough about ethics during their

undergraduate so far (student 12). Student 12 is an outlier in this study as they rarely agreed with any of the ranked questions compared to their peers. This student did indicate that they had prior formal instruction on ethics. The questions that biological engineers agree with the most are question eleven and question thirteen. These questions probe students on who they surround themselves with, that the values of ethics and social impacts influence how they find peers in university. Biological engineering students indicated that they are not as knowledgeable on philosophical ethics, with over half answering either neutral (43%), disagree (14%), and strongly disagree (14%).

Table 7: How often Biological Engineers picked an answer to the Likert questions on pre-survey

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
16.7%	44.2%	19%	7%	9.3%

Source: Ranked Question Responses on Pre-Surveys

Across the ranked questions, the likelihood that biological engineers will answer the various ranks can be found in Table 6. Biological engineers are more likely to answer strongly agree or strongly disagree compared to their agricultural and biorenewable systems management counterparts (Table 8).

Table 8: Percentage of Agricultural and Biorenewable Systems Management answered on pre-survey (N=12)

	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18
Strongly Agree	-	-	42%	33%	-	17%	8%	33%	-	8%	8%	-
Agree	50%	50%	58%	50%	83%	42%	58%	33%	25%	33%	42%	42%
Neutral	33%	25%	-	17%	17%	42%	33%	25%	25%	33%	42%	50%
Disagree	17%	25%	-	-	-	-	-	8%	42%	17%	8%	-
Strongly Disagree	-	-	-	-	-	-	-	-	8%	8%	-	8%

Source: Ranked Question Responses on Pre-Surveys

Agricultural and biorenewable systems management students felt more comfortable than their biological engineer counterparts answering that they know that their work has implications on the environment. In their courseload they have a course on the life-cycle analysis of various products, which could answer this difference. More agricultural and biorenewable systems management students agreed that their habits of finding clubs are influenced by the ethics and values of the club than their biological engineering counterparts.

Table 9: How often Agricultural and Biorenewable Systems students answered the Likert questions on pre-survey

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
12.4%	47.2%	28.5%	9.8%	2%

Source: Ranked Question Responses on Pre-Surveys

Further graphs to show the trends of students' answers to the ranked questions in comparison to their prior formal ethics experience can be found in appendix A.

Another area in the survey which probed formal curricular experiences was question four and five. These were open-ended questions which asked the students to describe why they thought ethics and social impacts were important, or not.

Question 4

Figure 2: Frequency of words and paired words when explaining why ethics is, or is not, important on pre-survey (Fruchterman Reingold layout)

As a part of understanding formal curricular experiences of the undergraduate students, perception of the importance of ethics was measured. Students were asked to define ethics in a previous question, question one. Figure 2 is a Gephi visualization of the word frequency and word pairs most common when students answered question four, "Why is ethics important, or not important, to you?" The darker the color and more solid the line connecting two words, the more often students used a pair of words. The color of the node (light to dark) also indicates how frequently students used a word. Words that are a part of the visualization were used more than three times in the various responses from students.

There were only two word pairs when analyzing responses from question four. The strongest of the two is the connection between “ethics” and “important.” This indicates that the students used these words often together. “Important” (17 times) and “ethics” (20 times) were the most frequently used words when responding to this question. Other words that appear that also occurred in their responses to question four is “right,” “good,” “actions,” and “decisions.” It can be inferred that students believe that ethics is important because it is the “right” or “good” thing. And that “actions” and “decisions” influence ethics. Overall, students perceive ethics as important.

Question 5:

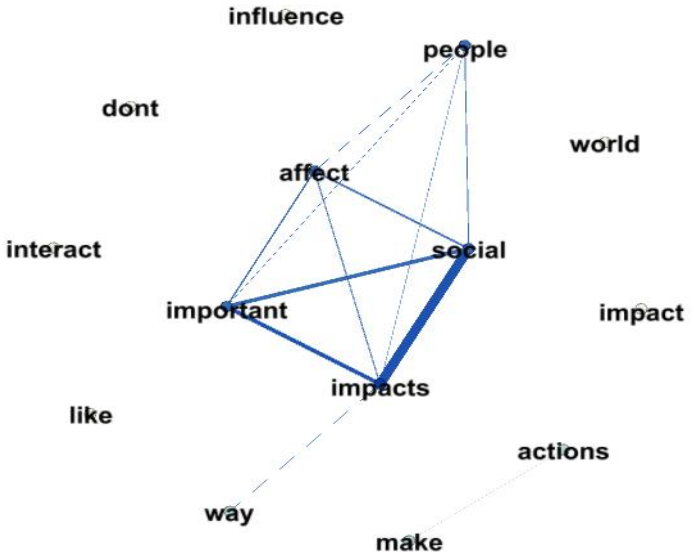


Figure 3: Frequency of words and paired words when explaining why social impacts are important to them on pre-survey (Fruchterman Reingold layout)

Students' perception of social impact importance was also probed in these surveys. They were asked to define social impacts in a previous question, question two. Figure 3 is a Gephi visualization of the word frequency and word pairs most common when students answered question five, "Why are important, or not important, to you?" The darker the color and more solid the line connecting two words, the more often students used a pair of words. The color of the node (light to dark) also indicates how frequently students used a word. Words that are a part of the visualization were used more than three times in the various responses from students.

There were 12 word pairs when analyzing responses from question four. The strongest is the connection between "social" and "impacts." This is due to students using the two words to begin their response to the question, like reiterating the question. This was found in a majority of students' responses. Two words have four word pairings or connections, "important" as well as "people." Throughout the responses, students used "important" 14 times and "people" nine times. It can be inferred that students believe that social impacts influence and affect people and the world. Overall, students perceive social impacts as important.

Students' full responses to both question four and five can be found in appendix A.

Ethical development

As described by the adaptations to the SEED survey, ethical development is measured by the students' knowledge of ESI by defining ethics and social impacts. Also, measured were if the student indicated any positive ethical behavior like, taking courses because of the community service component and participating in K-12 outreach or volunteer service projects.

The responses to these probing questions are as follows:

Question One:

1) “Ethics means different things to me depending on the situation. As an academic discipline, I think of ethics as the study of how people make decisions when those decisions might negatively affect someone. Particularly, ethics discusses the frameworks for how these decisions can be made. Normally when I think of ethics, though, I think of my own ethics, which is the fluid framework I use to make complicated decisions in a world where many decisions create harm. I don't think of this form of ethics using discipline specific language or a framework that can be represented in a flow chart. Rather, it a deep, non-verbal combination of rational and emotional understandings that inform the decisions I make and the heuristics I've developed to make these decisions easier.”

For student number one, they are a biological engineering student, they go on to signify that they believe ethics is fluid depending on the situation. They also define ethics in many ways, based on the academic discipline, impacts on people, and fluid frameworks.

2) “Ethics is about understanding and deciding what is right and wrong based on principles like fairness, honesty, and responsibility. It guides how people behave, make choices, and interact with others in a way that respects both individual and collective well-being.”

Student number two is in the agricultural and biorenewable systems management major. This student uses language that evokes an ethical understanding based on etiquette and interactions with society.

3) “Ethics to me means having good morals, and not being rude and ignorant towards other people.”

Student number three is in the agricultural and biorenewable systems management major. They define ethics on “good” morals, implying that there is a spectrum of morals that are good and or bad. Other students define ethics based on morality, but this student is the only one to indicate a “good or bad.” This “good” can be inferred to be “not being rude and ignorant” from their response.

4) “Ethics is the conscious framework that guides our decision making process.”

Student four is in the biological engineering major. They also raise that ethics is defined by frameworks and using them for decision-making.

5) “Making a choice that aligns with a cultures sense of rightness”

Student five is in the agricultural and biorenewable systems management major. They pose that culture is the deciding factor of ethical development and implementation.

6) “Ethics are standards we live by that we believe in. They are moral codes that an induvial will base most of their life and life actions upon.”

Student six is in the agricultural and biorenewable systems management major. They also define ethics based on moral codes and positions these as “believe[d]” in. This indicates that values may be a larger part of this student definition of ethics.

7) “To me ethics means doing the right thing but also making sure it doesn't impact other people.”

Student seven is in the agricultural and biorenewable systems management major. They indicate there is a “right and wrong.” They also signify that the right ethical thing does not negatively impact others.

8) “Ethics is one's morals and ideals or in other words what someone believes to be right and wrong.”

Student eight is also in the agricultural and biorenewable systems management major. They also indicate that there is a "right and wrong," ethics is based on values, and that people need to believe in the ethics of right and wrong.

9) "Ethics are moral principles on how people/businesses behave and make decisions."

Student nine is in the agricultural and biorenewable systems management major. This student is the only one that implies that businesses can have a set of ethical values to follow. They also pose that morals or moral principles inform ethics.

10) "Ethics to me means the study and application of doing the right thing."

Student ten is in the biological engineering major. They denote that ethics could be a field of study as well as an application to situations. They also signal the idea of "right and wrong."

11) "Ethics to me is the understand of what is societally described as right and wrong. It's a basic gauge of your sense of right and wrong in my opinion."

Student eleven is in the agricultural and biorenewable systems management major. They reference the idea that ethics may be based on societies' view of right and wrong. The use of "my opinion" is interesting because the student believes that their definition is different than others.

12) "Holding oneself or others to objective morals that are defined."

Student twelve is in the biological engineering major. They define ethics based on morals, but the use of objective might indicate that these are not based on personal values but define values by a greater group. They also reference holding others to morals or ethics.

13) "Ethics is a moral conduct of what actions are considered right and wrong. It serves to guide decision-making both personally and professionally."

Student thirteen is in the biological engineering major. They also pose that morals and the difference between right and wrong informs ethics. They are also the only student to bring in professional ethics into their definition.

14) “Ethics are the ideas and ways you interact with others and treat them.”

Student fourteen is in the agricultural and biorenewable systems management major. Their definition is highly influenced by the relationship and dynamics with other people. There is no indication of good and bad or right or wrong in their definition.

15) “doing the right thing”

Student fifteen is in the agricultural and biorenewable systems management major. Based on their response, ethics is defined by only doing the “right thing.” This definition could be seen as one dimensional, however, this does follow the idea that unethical would be doing the “wrong thing” in a situation.

16) “Ethics is knowing the difference between right and wrong and choosing to do what's right. It's about treating people fairly, being honest, and making good choices, even when no one's watching.”

Student sixteen is in the biological engineering major. Their response signifies a level of understanding of ethics needed to know the difference between right and wrong. They also pose the idea that ethics is a personal action “when no one’s watching.” The adjectives of fair and honest can be linked to various frameworks of ethics.

17) “Ethics is a framework for acting in the world according to a set of values to deal with issues that deal with human morality.”

Student seventeen is in the biological engineering major. Their response that ethics is a set of values to "deal with human morality" is an interesting way to outline ethical frameworks. That "human morality" is something to be delt with day to day or in ethical situations.

18) "Ethics in my words is what is considered to be the right thing."

Student eighteen is in the agricultural and biorenewable systems management major. Their response that ethics is "the right thing" is similar to student fifteen's response. That ethics is based on a the "right" or correct way.

19) "Doing what is right morally."

Student nineteen is in the agricultural and biorenewable systems management major. Again, their response is similar to other students that only define ethics as the "right" end of the spectrum of right and wrong. They also indicate that ethics is morally based.

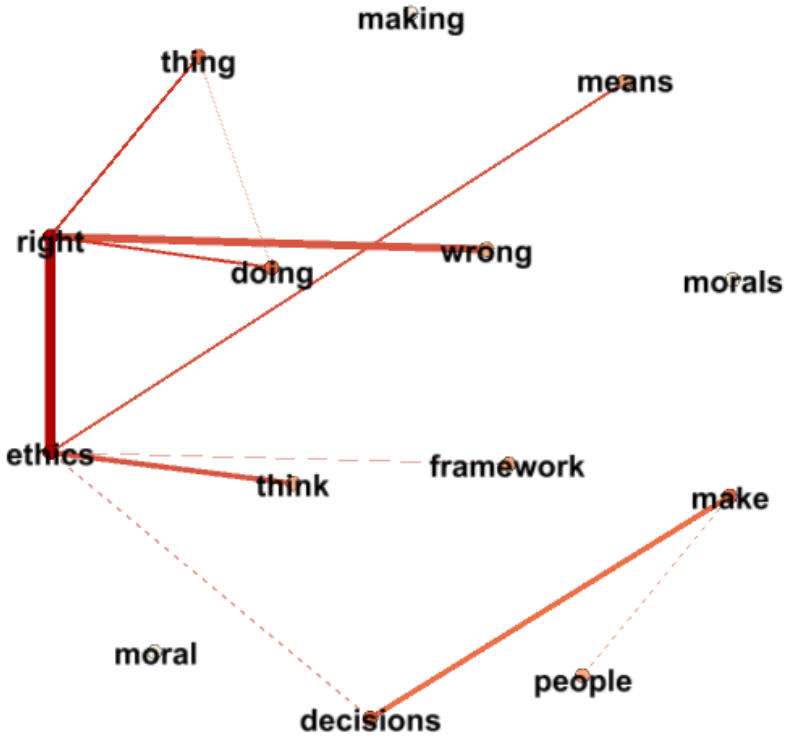


Figure 4: Frequency of words and paired words when defining ethics on pre-survey (Fruchterman Reingold layout)

Engineering ethics are the obligations an engineer holds to their profession, the public, clients, employers, and stakeholders. This definition is based on the network of language professional societies have used in their Codes of Ethics. Figure 4 is a Gephi visualization of the word frequency and word pairs most common when students answered question one, “In your own words, what does ethics mean?”. The strongest connection between word pairs is “ethics” and “right,” which suggests that in the students probed in this study use these two words in tandem to describe ethics. The second strongest connection is between the words “right” and “wrong.” Many of the students used these to describe their definition of ethics. Similarly, morals

were used to describe some of the student's definition of ethics. Moral and morals were separated due to the "s" at the end of moral, however, together they occurred 6 times in students' responses. Other words like morality could be included in this number as well, however, they were not repeated enough to bypass repetition features in the WORDij software.

The interconnectedness of this visualization implies that students defined ethics similarly to their peers. Many of the students' responses specified that there were right and wrong ways to be ethical. Morality is another indicator students used to describe their definition of ethics. Many students denoted that they got their understanding of ethics from parents or religious groups they are a part of, explaining the value and moral basis for their responses. Just below that in frequency, framework was another word used by students to define their view of ethics. The students that used framework and decision making were biological engineers, who have had some ethics experience from their guest lecturer in BE 308.

Question Two

1) "I think of social impacts as the way in which a decision/technology/other thing affects people in some way. I normally just think of how decisions affects humans when I think of "social" impact, though it could extend to non-human beings, too, depending on how broad your understanding of society is."

Student number one is a biological engineering student. Their response is quite expansive, including decisions and technology impacting humans and non-humans.

2) "Social impacts are the effects that actions, policies, or events have on people and communities. These impacts can be positive or negative and influence aspects like quality of life, health, education, culture, and relationships."

Student number two is in the agricultural and biorenewable systems management major. This student also has a longer list of things that impact society like actions, policies, and events. They also include in their response that they do not have to be only negative. They also list the aspects of society that can be affected as well.

3) "Social impacts are the ways that a community impacts itself or a group of peoples decision impact others."

Student number three is in the agricultural and biorenewable systems management major. Their response is less expansive then the precious students,' however, they do understand the influence decisions have on others and communities.

4) "Social impacts are the outcomes related to the decisions we make, and they pertain to the people, place, and things that we interact with."

Student four is in the biological engineering major. They indicated that decisions influence people, places, and "things" we may interact with.

5) "How people will treat you based on your choices."

Student five is in the agricultural and biorenewable systems management major. This answer is quite different than their peers' response. This student defined social impacts based purely on the self. They did not define it based on a person's choice or decision influencing outcomes, but on how other will perceive them based on their choices.

6) "Impacts that effect not just one person but the society as a whole. For example, policy changes in tax brackets effects the society as a whole and thus cause social impacts."

Student six is in the agricultural and biorenewable systems management major. They highlight a ripple effect that social impacts may have with an example in their definition. Their

example uses an economic policy that influences society, which shows that the student is more comfortable with defining this in their own words.

7) "Social impacts are decisions that are made that end up either positively or negatively impacting the social group targeted."

Student seven is in the agricultural and biorenewable systems management major. They highlight that social impacts are not only negative outcomes. A part of their definition indicates that there are social groups that can be targeted in social impacts.

8) "Events or actions that impact a society or group of people."

Student eight is in the agricultural and biorenewable systems management major. Their response is quite literal, but not incorrect. It would be interesting to see how they would further define the events or actions which they use in this definition.

9) "Impacts (good/bad) that people experience due to a decision or action that may come from businesses, policies, or the government."

Student nine is in the agricultural and biorenewable systems management major. They, like some of their peers, indicated there are good and bad impacts. Their definition focuses on larger entities influencing the social impacts, like businesses, policies, and the government and did not define it to an individual level.

10) "Social impacts are what we can do to impact society individually and as a whole."

Student ten is a biological engineering major. Their definition of social impacts is based on individual actions impacting society. They do not indicate "what we can do" quite is, however, with this phasing it can be inferred that this student is focusing on positive societal impacts.

11) “Social impacts would be anything that has consequences on society around us. For example, a derogatory comment about another race may not be hurtful to you but to the people around, they may not even identify with the race but might know people of the race or just genuinely be empathetic.”

Student eleven is in the agricultural and biorenewable systems management major. They use the word “consequences” in their definition implying negative impacts. They also provide an example to accompany their definition.

12) “Intended and unintended widespread consequences of decisions and actions that last long periods of time.”

Student twelve is in the biological engineering major. This student highlights that social impacts may not be intended, however this consequences are still due to the decision made. This student also used the word “consequences” implying negative impacts.

13) “Social impacts are the effects and results that actions have on the feelings and livelihood of others.”

Student thirteen is in the biological engineering major. This student poses that social impacts include feelings that may be experienced due to decisions or actions.

14) “Social impacts are ways that people or groups of people are affected based on a situation.”

Student fourteen is in the agricultural and biorenewable systems management major. This student indicates that social impacts impact individuals as well as communities. It would be interesting for the student to further define what they believe a situation would be in their response.

15) “things you do that affect others”

Student fifteen is in the agricultural and biorenewable systems management major. This response is quite short and vague. However, inferring some tings from this student, they indicate that in their words social impacts are on an individual level. From this individual level, decisions can affect larger groups of people.

16) "Social impacts are how things like new technology, policies, or big events affect people and communities."

Student sixteen is in the biological engineering major. This student poses that humans are not the only thing that can create social impacts. They highlight polices, events, and technology impacting people individual and groups.

17) "Decisions that affect people socially"

Student seventeen is in the biological engineering major. This response is quite literal. However, they highlight that social impacts come from decisions. It would be interesting for this student to further define "decisions" and "socially."

18) "Things or events that have significant impact on society and smaller social groups."

Student eighteen is in the agricultural and biorenewable systems management major. They specify in their response that social impacts have "significant impacts" on groups. They did not directly indicate choices or decisions impacting individuals.

19) "The way our actions and the actions of communities affect others."

Student nineteen is in the agricultural and biorenewable systems management major. This student highlights in their definition that social impacts can come from individuals as well as groups.

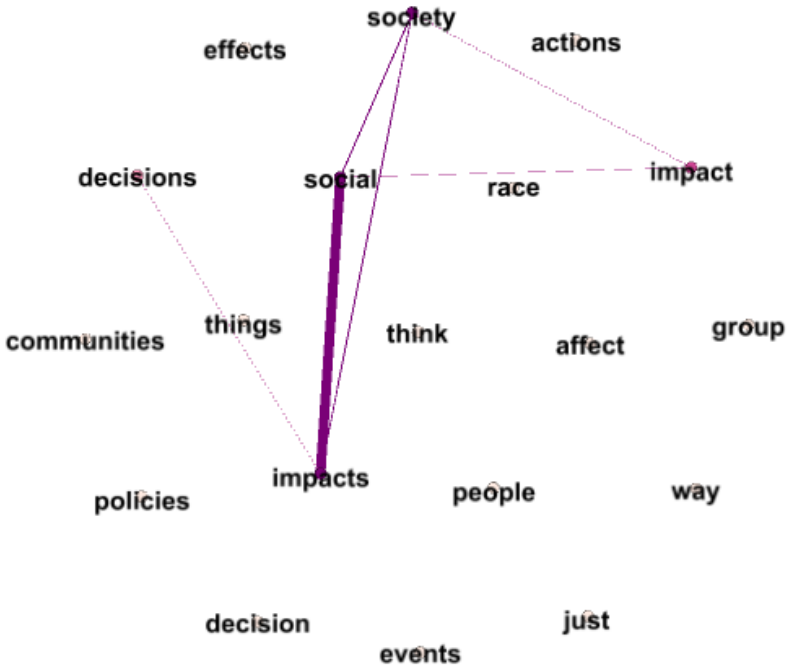


Figure 5: Frequency of words and paired words when defining social impacts on pre-survey (Fruchterman Reingold layout)

Engineering has many implications for the world around us. Decisions and actions conducted by engineers can create intentional, and unintentional, impacts to communities and individual people. These social impacts of engineering and our technologies can affect the public, environment, and our employers. This definition is based on the language used by Codes of Ethics as well as ABET's criterion for engineering and technology's impact on our world. Figure 5 is a Gephi visualization of the word frequency and word pairs most common when students answered question two, "In your own words, what does social impacts mean?". The most frequently used word pair when answering question two was "social" and "impacts." This is due to students using

the two words to begin their response to the question, like reiterating the question. This also would explain the strength of the connection between the two words in the visual. Like in the last question "impact" and "impacts" as well as "decision" and "decisions" were separated as words when running it through the WORDij software. However, "decisions" was paired with "impacts" in the responses.

The interconnectedness of this visualization was not to the degree of the first question about defining ethics. Students had mixed responses to question two. A wider breath of definitions were included by students. There were more self-focused definitions, while others exclusively looked outwards to society. Some of the students used examples in their responses to get the understanding across to the reader. These responses could be due to social impacts including a wide variety of implications, actions, and involved parties that can fall under the definition. Nineteen separate words were a part of the visualization compared to question one's 14. This indicates that students used more distinct words with higher frequency to define social impacts. Overall, students were less confident in defining social impacts themselves.

Question 6:

Table 10: Students' answer to question six of the open-ended questions "Do you actively consider ethical issues or social impacts during decision making? If so, where did you develop that skill?" on pre-survey

	Yes	Yes (not often/I wish more/passive)	No (Only SI)	Total
BE	4	2	0	6 (one blank answer)
ABSM	8	3	1	12

Source: Open-Ended Questions from Pre-Survey

Overall, students do think of ethics and or social impacts when making decisions. Two-thirds of the biological engineering students indicated that they do think of both ethics and social impacts when making decisions in their lives. One-third still did think of ESI, however on wished they thought more actively, or described it as a more passive experience. There was one student who did not respond to question six from the normal seven biological engineers. Similarly, two-thirds of agricultural and biorenewable systems management students thought of both in daily life and making decisions. One respondent answered that they only think of the social impacts when making decisions. No other students indicated that they do not think of ethics at all. While this is an anonymous survey, students may not have wanted to be perceived as not thinking about ESI in their daily life which could have skewed the responses. Many of the students indicated family, church groups, or work (like family business) influencing their ESI development. These are all influences prior to formal educational settings like high schools and university courses.

Question 19:

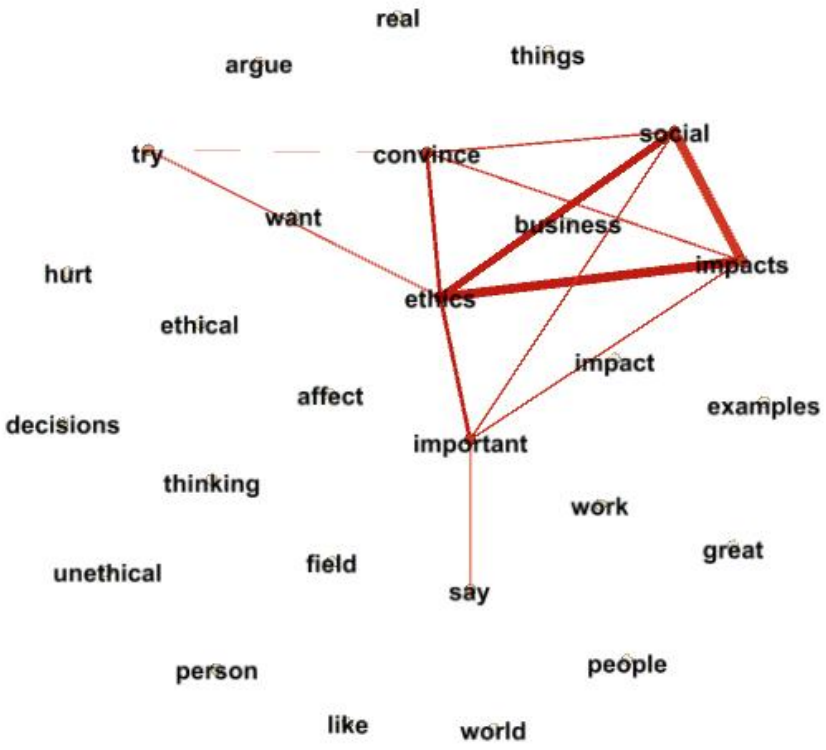


Figure 6: Frequency of words and word pairs when answering "If you had to convince someone that ethics and social impacts are or are not important, how would you do that? What argument would you use?" on pre-survey (Fruchterman Reingold layout)

An additional question that was asked was question 19. This was the last question on the survey, and an open-ended response. While not used as a direct measure for the methodology outlined in this thesis, the analyzed data does have some noteworthy outcomes. There are 27 distinct words with frequencies higher than three from the responses to question 19. There are similar words like "ethics" and "ethical" which were separated due their spelling. Words like "ethics," "social," and "impacts" were frequently used due to student restating the question. These three words also have the strongest connection of the 12 pairs present in the visual. "Ethics" also

has the highest number of pairings or connections at five. In the students' responses, many described that they would use examples or real-life scenarios to convince the other person of the importance of ESI. The word "convince" was used nine times compared to "argue" which was used three times. In their responses students described a feeling of not being able to sway someone completely if they already do not buy into ESI importance. Students used more feeling and emotion based tactics in their responses to question 19. In contrast, they specified morals, "right versus wrong," and "good and bad" as the reasoning for their own reasons of finding ESI important.

Students' full responses to questions six and 19 can be found in appendix A.

Mid-survey Results

In the following section, the analysis of the mid-survey is below. The methodology from the adapted SEED survey is used to evaluate the mid-survey in the sections Formal curricular experiences, Co-curricular experiences, and Ethical development. Each subsection will begin with the questions from the survey which probed students' responses to areas of ESI influence and experience. For the mid-survey, now that students have had formal curricular experience, the defining feature of the analysis between participants is there major. A summary of the findings from the mid-survey can be found, for the three areas of evaluation formal curricular experiences, Co-curricular experiences, and Ethical development, are condensed below. The overall findings can be found in the comparison section on page 90.

For Formal curricular experiences in the mid-survey, the 18 surveyed students surveyed the agricultural and biorenewable systems management students had higher levels of agreement to the Likert questions compared to their biological engineering counterparts. In the mid-survey, only

three students signaled that they were in co-curricular activities. Formal curricular experiences are still the majority of the listed responses in question three. Students either did not understand the question being asked or the question needs further clarification for the next time the surveys are used. For ethical development, the students were asked to define ethics and social impacts and how they would argue the importance of ESI to another individual. Additionally, the comparison from the pre-survey and mid-survey will be used to evaluate the ethical development of the participants. These results are outlined in the comparison section on page 90.

Formal curricular experiences

As described by the SEED survey, formal curricular experiences are measured by the setting such as introductory engineering course, pre-college program, out-of-class workshop, non-engineering course, and other settings. Also measured were the pedagogies used in these settings, like presentation by a professor, presentation by individual speaking about their own experiences, guest speaker, discussion with classmates, movie or film, skit, role playing, in-class game, and online modules (Finelli et. al., 2012). Finally, the students' perception of importance of ESI instruction and satisfaction with quality of ESI instruction will be evaluated. This will be done by analyzing the students' responses to the Likert questions. The knowledge of the BE 392 course instruction and the pedagogies used to teach students will be used to inform the analysis for this section.

Table 11: Likert Questions on the Mid-Survey

Q 7: During my undergraduate studies I have learned enough about ethics to feel comfortable making decisions during my career.
Q 8: During my undergraduate studies I have learned enough about social impacts to feel comfortable making decisions with social implications during my career.
Q 9: During my undergraduate studies I have learned about the implications of my work on the environment.
Q 10: During my undergraduate studies I have learned about the implications of my work on the public.
Q 11: During my undergraduate studies I have tried to find peers that hold the same ethical values as me.
Q 12: During my undergraduate studies I have tried to find clubs that hold the same ethical values as me.
Q 13: During my undergraduate studies I have tried to find peers that hold the same societal impact values as me.
Q 14: During my undergraduate studies I have tried to find clubs that hold the same societal impact values as me.
Q 15: I am knowledgeable about philosophical ethics.
Q 16: I am knowledgeable about applied ethics.
Q 17: I am knowledgeable about societal impacts and social justice.
Q 18: I can identify ethical problems and the impacts of my work if asked.
Q 20: After taking BE 392 my knowledge on ethics has increased.
Q 21: After taking BE 392 my knowledge on social impacts has increased.
Q 22: During BE 392 I have learned about the implications of my work on the environment.
Q 23: During BE 392 I have learned about the implications of my work on the public.

Another aspect which probed for the dimension of formal curricular experiences were the ranked questions. All of the Likert scale questions can be found above in Table 11 for reference. Table 12 shows the counts for all the questions, seven through eighteen. The students are designated by their major: biological engineering in Table 13 and 14 or agricultural and biorenewable systems management table 15 and 16 with their counts and percentages. The count for agricultural and biorenewable systems management students decreased by one, as a students

did not complete the survey by the due date. So, the total number of students in agricultural and biorenewable systems management is now 11 students.

Table 12: Answers to the various probing questions for perception of importance of ethics instruction and satisfaction with quality of ethics instruction and student behavior on the mid-survey (N=18)

		Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18
Bio. Eng.	Strongly Agree	1	1	2	1	1	-	1	-	-	-	1	-
	Agree	5	4	4	5	5	5	6	5	3	5	4	5
	Neutral	-	1	1	2	1	2	-	2	3	-	-	1
	Disagree	1	1	-	-	-	-	-	-	1	2	2	1
	Strongly Disagree	-	-	-	-	-	-	-	-	-	-	-	-
ABSM	Strongly Agree	6	7	7	3	3	5	3	5	-	1	1	-
	Agree	5	3	4	7	7	3	5	5	6	7	8	8
	Neutral	1	1	-	1	1	2	3	-	4	3	2	-
	Disagree	-	-	-	-	-	1	-	1	1	-	-	-
	Strongly Disagree	-	-	-	-	-	-	-	-	-	-	-	3

Source: Ranked Question Responses on Mid-Surveys

Table 13: Percentage of Biological Engineering participants answered on mid-survey (N=7)

	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18
Strongly Agree	14%	14%	29%	14%	14%	-	14%	-	-	-	14%	-
Agree	72%	57%	57%	72%	72%	72%	86%	72%	43%	72%	57%	72%
Neutral	-	14%	14%	29%	14%	29%	-	29%	43%	-	-	14%
Disagree	14%	14%	-	-	-	-	-	-	14%	29%	29%	14%
Strongly Disagree	-	-	-	-	-	-	-	-	-	-	-	-

Source: Ranked Question Responses on Mid-Surveys

*Not all questions add up to 100% due to rounding

Table 14: How often Biological Engineers picked an answer to the Likert questions on mid-survey

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
9.41%	67%	15.5%	9.5%	0%

Source: Ranked Question Responses on Mid-Surveys

For the mid-survey, 72% of biological engineers surveyed agree that they have learned enough about ethics to feel comfortable making decisions in their career, with 14% of students strongly agreeing. Fourteen percent of students disagree with question seven indicating that they have not learned enough to feel comfortable agreeing with this question. The questions that biological engineers agree with the most are question nine and question thirteen. Question nine asks students if they have learned about the implications of their work on the environment. Question thirteen probes students on who they surround themselves with and how social impacts influence how they find peers in university. Biological engineering students indicated that they are not as still not as knowledgeable on philosophical ethics, with over half answering either neutral (43%), disagree (14%).

Across the ranked questions, the likelihood that biological engineers will answer the various ranks can be found in Table 14. Biological engineers are less likely to answer strongly agree compared to their agricultural and biorenewable systems management counterparts (table 16).

Table 15: Percentage of Agricultural and Biorenewable Systems Management answered on mid-survey (N=11)

	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18
Strongly Agree	55%	64%	64%	27%	27%	45%	27%	45%	-	9%	9%	-
Agree	45%	27%	36%	64%	64%	27%	45%	45%	55%	64%	73%	73%
Neutral	9%	9%	-	9%	9%	18%	27%	-	36%	27%	18%	-
Disagree	-	-	-	-	-	9%	-	9%	9%	-	-	-
Strongly Disagree	-	-	-	-	-	-	-	-	-	-	-	27%

Source: Ranked Question Responses on Mid-Surveys
*Not all questions add up to 100% due to rounding

Table 16: How often Agricultural and Biorenewable Systems students answered the Likert questions on mid-survey

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
31%	51.5%	13.5%	2.25%	2.25%

Source: Ranked Question Responses on Mid-Surveys

Agricultural and biorenewable systems management students answered strongly agree more than their biological engineer counterparts when answering a majority of the Likert questions. These students also answered disagree a quarter of the amount of their biological engineering counterparts. However, one question of note is question eighteen. The same percentage of students agreed that they can identify ethical problems and the impacts of their work if asked, but 27% of agricultural and biorenewable systems management students strongly disagreed to this question. That is three out of the eleven students in agricultural and biorenewable systems management. This was the only time this group of students answered strongly disagree.

Further graphs to show the trends of students' answers to the ranked questions in comparison to their major can be found in appendix B.

Table 17: Answers to the additional probing questions for satisfaction of BE 392 instruction from mid-survey (N=18)

		Q20	Q21	Q22	Q23
Bio. Eng.	Strongly Agree	-	1	1	2
	Agree	5	4	4	3
	Neutral	2	2	1	1
	Disagree	-	-	1	1
	Strongly Disagree	-	-	-	-
ABSM	Strongly Agree	7	5	5	5
	Agree	3	4	6	6
	Neutral	1	1	-	-
	Disagree	-	-	-	-
	Strongly Disagree	-	-	-	-

Source: Ranked Question Responses on Mid-Surveys

In Table 17 the counts for the additional Likert questions added in the mid-survey can be found. Because students have now had formal instruction, the perception and satisfaction of the instruction will be evaluated.

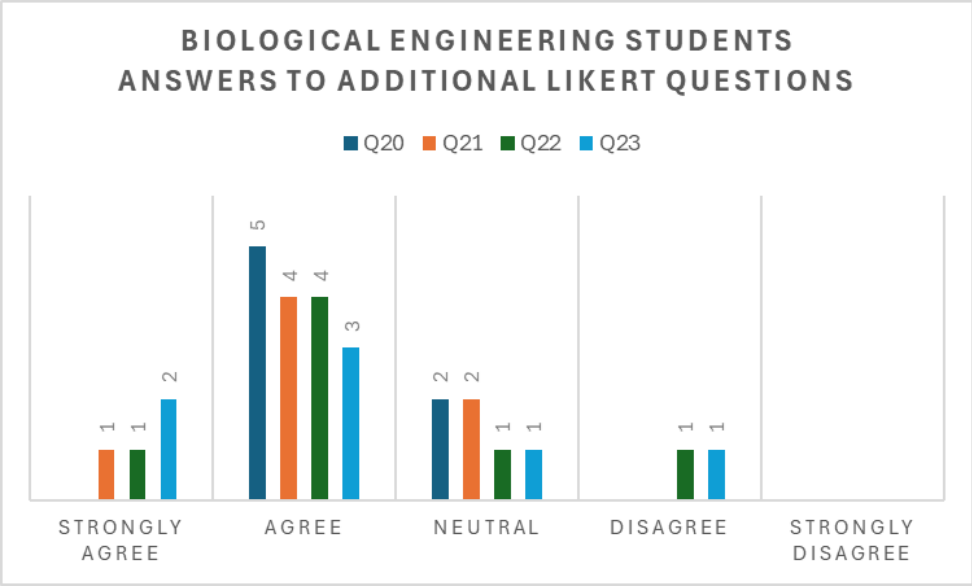


Figure 7: Counts of biological engineering students' responses to additional Likert questions on mid-survey.

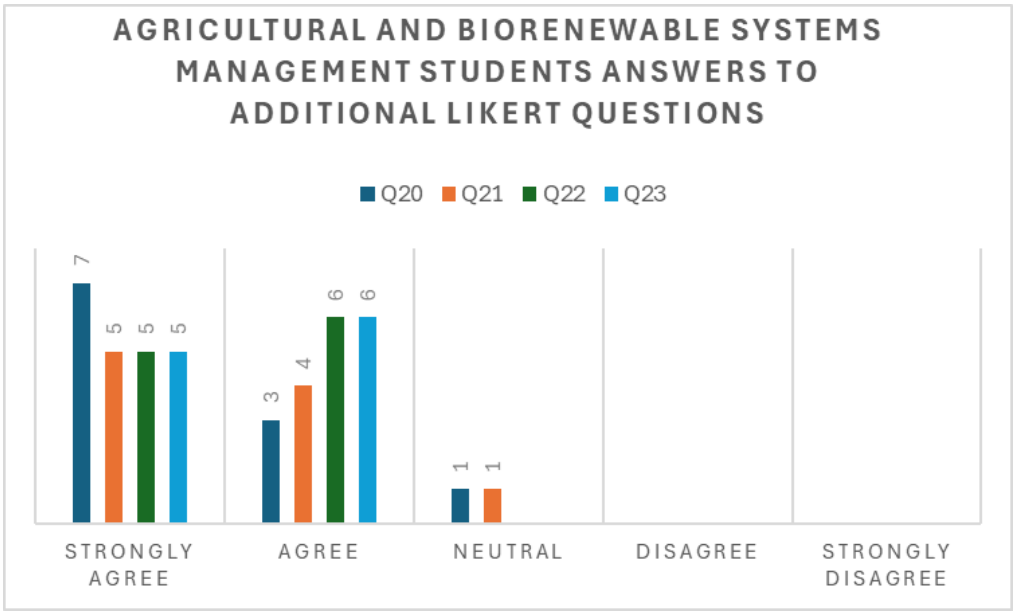


Figure 8:Counts of agricultural and biorenewable systems management students' responses to additional Likert questions on mid-survey.

Agricultural and biorenewable systems management students indicated stronger than their biological engineering peers that their knowledge on ethics and knowledge on social impacts has increased taking BE 392. They also agree more often that they have learned about the implications to their work on the environment and their work on the public than their biological engineering counterparts in the additional Likert questions. This is not to say that biological engineering students did not feel that they gained more knowledge having the BE 392 ESI instruction, just that they did not show as strong of feelings. More biological students felt neutral about all of the questions and some even disagreed to question twenty-two and twenty-three. So, agricultural and biorenewable systems management students felt more satisfied with the formal ethics instruction based on the Likert responses than their biological engineering peers.

Another area in the survey which probed formal curricular experiences was question four and five. These were open-ended questions which asked the students to describe why they thought ethics and social impacts were important, or not.

Question 4:

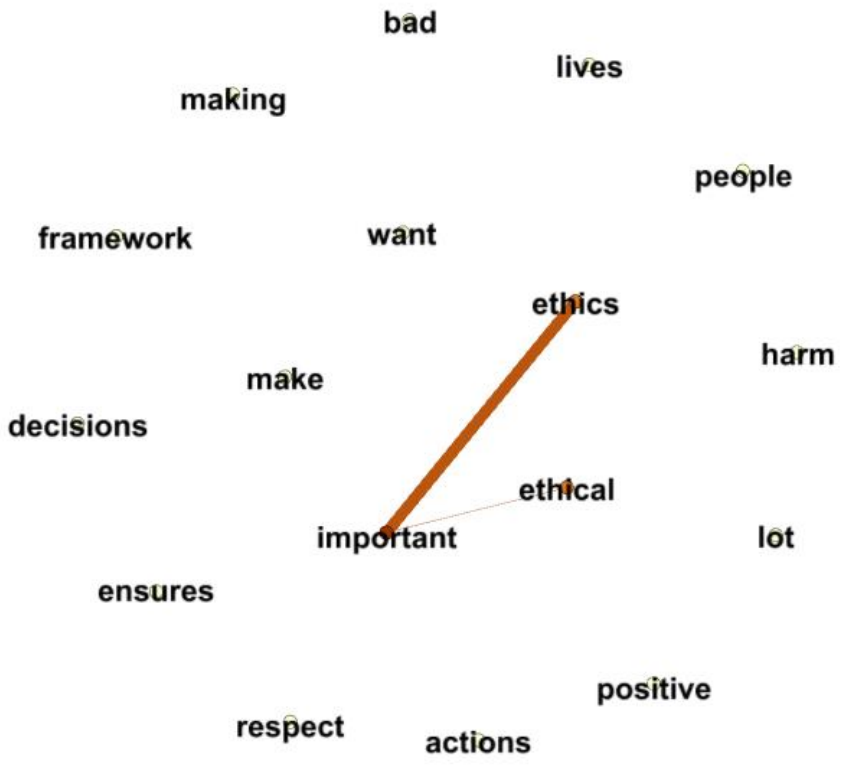


Figure 9: Frequency of words and paired words when explaining why ethics is, or is not, important on mid-survey (Fruchterman Reingold layout)

As a part of understanding formal curricular experiences of the undergraduate students, perception of the importance of ethics was measured. Students were asked to define ethics in a previous question, question one. Figure 9 is a Gephi visualization of the word frequency and word pairs most common when students answered the same question four from the pre-survey,

“Why is ethics important, or not important, to you?” How solid the line, ae well as the darker the color of a line connecting two words, the more often students used a pair of words. The color of the node (light to dark) also indicates how frequent students used a word. Words that are a part of the visualization were used more than three times in the various responses from students.

There were three word pairs, two of which were the same word pair with the words in a different order, when analyzing responses from question four. The strongest of the two is the connection between “ethics” and ”important.” This word pair was used 16 times in the response to question four. Students used these words often together. However, it should be noted that students restated the question often to being their responses. “Important” (21 times) and “ethics” (22 times) were the most frequently used words when responding to this question. Other words that appear that also occurred in their responses to question four is “people,” “positive,” “actions,” “decisions,” and “framework.” Overall, students perceive ethics as important.

Question 5:

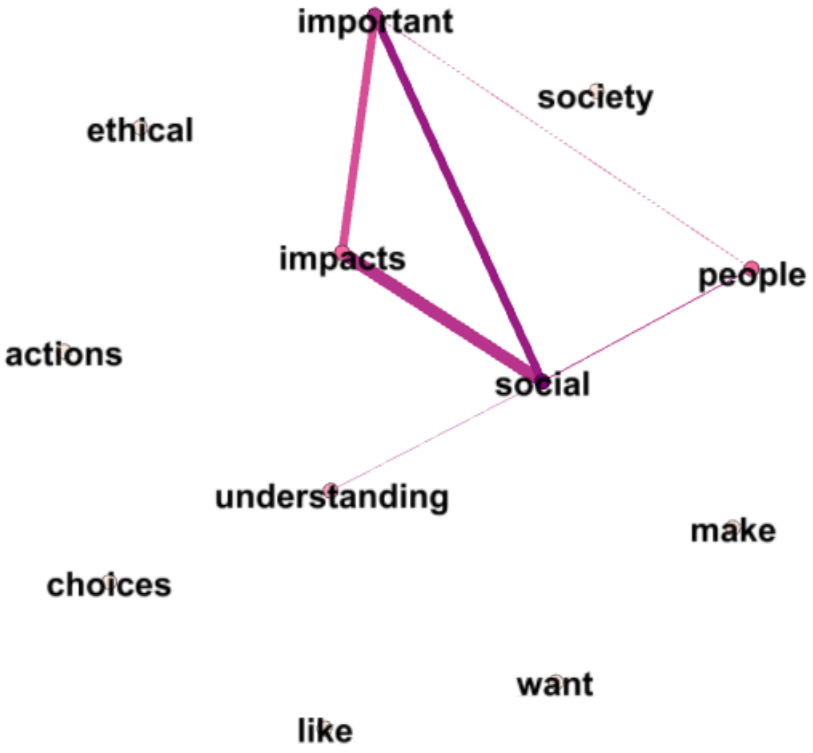


Figure 10: Frequency of words and paired words when explaining why social impacts are important to them on mid-survey (Fruchterman Reingold layout)

Students' perception of social impact importance was also probed in these surveys. They were asked to define social impacts in a previous question, question two. Figure 10 is a Gephi visualization of the word frequency and word pairs most common when students answered the same question five from the pre-survey, "Why are important, or not important, to you?" How solid the line, as well as the darker the color of a line connecting two words, the more often students used a pair of words. The color of the node (light to dark) also indicates how frequent students

used a word. Words that are a part of the visualization were used more than three times in the various responses from students.

There were 8 word pairs when analyzing responses from question four, with two of the pairs reordering the word order. The strongest is the connection between “social” and ”impacts.” This is due to students reiterating the question, therefore using the two words to begin their response. Reiterating the question was found in a majority of students’ responses. One word has four word pairings or connections and this was “social.” Throughout the responses students used “important” 18 times and “people” six times. Overall, students perceive social impacts as important.

Students’ full responses to both question four and five can be found in appendix B.

Co-Curricular experiences

Table 18: Quantity of Co-Curricular Experiences for all Surveyed (N=18)

		Biological Engineers	Agricultural and Biorenewable Systems Management	**Total**
Engineering Based	Engineering student organization focused on women	0	0	**0**
	Engineering student organization focused on students of color	0	0	**0**
	Engineering student organization based on major, discipline, or professional interests	0	0	**0**
	Engineering student organization focused on service	0	0	**0**
	Engineering design competition team	0	0	**0**
	Political organization or campaign, other than student government	0	0	**0**
	Any type of student government or council	0	0	**0**
	Environmental awareness or action group	0	0	**0**

Non-engineering based	Providing tutoring organized by the college or university	0	0	**0**
	Student judicial council or board	0	0	**0**
	Leadership program or academy	0	0	**0**
	ROTC (Reserve Officers Training Corp)	0	0	**0**
	Varsity athletic team	0	2	**2**
	Social fraternity or sorority	0	0	**0**
	On-campus religious organization	0	0	**0**
	Total	**0**	**2**	**2**

Source: Question Three Responses on Mid-Surveys

A majority of students, both biological engineers and agricultural and biorenewable systems management students still did not indicate co-curricular activities that they are a part of in question three. Formal curricular experiences were primarily still discussed in question three. There was an agricultural and biorenewable systems management student who responded, “Yes, in my clubs and organizations through school.” While this does indicate some involvement in co-curricular activities, it cannot be further analyzed as they did not say what these clubs were. This question on the surveys should be further clarified or simplified to ensure students recognize to list the clubs they participate in.

The surveyed students might not realize that many co-curriculars can influence ESI learning and development which could be why there were so little indication of what activities they are doing outside of their university courses. There is an American Society of Agricultural

and Biological Engineers (ASABE) student chapter on Penn State's campus however, no students indicated that they participate in this organization when responding to question three. It is encouraged that students engage more in their co-curricular activities within the agricultural and biological engineering department.

Ethical development

As described by the adaptations to the SEED survey, ethical development is measured by the students' knowledge of ESI by defining ethics and social impacts. Also, measured were if the student indicated any positive ethical behavior, like taking courses because of the community service component and participating in K-12 outreach or volunteer service projects.

The responses to these probing questions are as follows:

Question One:

1) Ethics are moral principles on how people/businesses behave and make decisions.

For the mid-survey, student one is an agricultural and biorenewable systems management student. This student defines ethics from the perspective of both individuals, people, as well as a larger group, businesses. They also denote moral principles as the basis of ethics.

2) Ethics are how we make difficult decisions that impact others.

For the mid-survey, student two is a biological engineering student. This student highlights in their definition that ethics involves decisions that may have consequences for others.

3) Ethics is about knowing what is right and wrong. It helps people be fair, honest, and kind in their daily lives. It can vary from culture to culture.

For the mid-survey, student three is an agricultural and biorenewable systems management student. Their definition is based off of the idea of “right and wrong.” They go on to highlight that ethics aids people in being fair, honest, and kind. The student includes that culture is an influence of ethics.

4) To me ethics means considering the well being of society and the things around you when completing a job or when solving a conflict.

For the mid-survey, student four is an agricultural and biorenewable systems management student. This student uses consequentialism and ethics of care ideas in their definition.

5) Ethics is about understanding and choosing between right and wrong, based on principles that guide our behavior and decisions. Ethics is about making choices that align with integrity and responsibility.

For the mid-survey, student five is an agricultural and biorenewable systems management student. Again, this is a student that uses the idea of “right and wrong.” They highlight principles and values like integrity and responsibility in their definition.

6) To me ethics means being able to understand why one decision is more "right" than another based on fairness. Deciding which decision will have the best outcome not only for you, but for the others involved.

For the mid-survey, student six is an agricultural and biorenewable systems management student. This student uses the value of fairness and the idea of consequentialism in their definition.

7) Ethics is the conscious framework that guides our decision making process.

For the mid-survey, student seven is a biological engineering student. This student highlights in their definition that ethics involves decision making and is a conscious effort.

8) Ethics to me is morals someone follows and applies to their life.

For the mid-survey, student eight is an agricultural and biorenewable systems management student. This student defines ethics as moral principles that should be followed.

9) I think ethics is knowing what the right thing is to do and doing it

For the mid-survey, student nine is an agricultural and biorenewable systems management student. This is a student also uses the idea of "right and wrong," but they indicate ethics to them is choosing the "right" choice.

10) Decision making parameters that stem from a need in society.

For the mid-survey, student ten is a biological engineering student. Decision making is the core of this student's definition of ethics. They indicate that ethics come from societies needs.

11) Personally, ethics mean having the capacity and knowledge to make the decision with the most positive outcome for the greatest amount of subjects. This comes with the dilemma of having to assess what a positive outcome is.

For the mid-survey, student eleven is an agricultural and biorenewable systems management student. This student underscores that in their definition of ethics a "positive"

outcome for the most people is the best outcome. They also add that assessing what a "positive" outcome happens to be is part of the ethical issue.

12) Ethics is a framework with which to address concerns where intuition is not immediately able to determine an outcome. It is used when a person is concerned with doing the right thing as defined by their gut but can't get that exact gut answer.

For the mid-survey, student twelve is a biological engineering student. This student describes ethics as a framework itself. This framework can guide individuals to an ethical outcome.

13) Doing what is morally applicable in the situation at hand.

For the mid-survey, student thirteen is an agricultural and biorenewable systems management student. The student uses morals to define ethics and implies that morals should be applied to situations.

14) To me, ethics is an understanding and explanation of what is considered morally right and morally wrong.

For the mid-survey, student fourteen is a biological engineering student. This student indicates that the understanding of "right and wrong" is informed my morality.

15) Ethics means doing what is right and beneficial to the overall community and greater good, outside of ones or a companies' interest.

For the mid-survey, student fifteen is a biological engineering student. This student uses utilitarianist ideas to define their ethics. They also highlight the difference between "right and wrong."

16) Ethics is using what you believe is doing the right thing and doing your best to apply that to your everyday life. This can use this at work, with family and friends, or just in general.

For the mid-survey, student sixteen is an agricultural and biorenewable systems management student. This student indicates that there are different settings in which ethics can be applied. They also note that using ethics is a conscious effort.

17) Ethics means the morals that people believe and choose to make decisions and actions based on.

For the mid-survey, student seventeen is an agricultural and biorenewable systems management student. The student defines ethics as moral principles that should be followed for decision-making and actions.

18) Standards to conduct yourself or a group in accordance with determined values; to think and act in a way that is morally sound.

For the mid-survey, student eighteen is a biological engineering student. This student uses morality and value in relation with others to define their ethics.

Figure 11: Frequency of words and paired words when defining ethics on mid-survey (Fruchterman Reingold layout)

As previously defined in the pre-survey section, engineering ethics is the obligations an engineer holds to their profession, the public, clients, employers, and stakeholders. This definition is based on the network of language professional societies have used in their Codes of Ethics. Figure 11 is a Gephi visualization of the word frequency and word pairs most common when students answered question one, “In your own words, what does ethics mean?”. The strongest connections between word pairs are “ethics” and “right” and “ethics” and “means” which suggests that in the students probed in this study use these words in tandem to describe ethics. Another

strong connection to highlight is between the words “right” and “wrong.” Many of the students used these to describe their definition of ethics. Similarly, morals or morality, decisions, and outcomes were used to describe some of the student’s definition of ethics. Many students denoted that they got their understanding of ethics from parents or religious groups they are a part of, explaining the value and moral basis for their responses. The higher level of interconnectedness of this visualization implies that students defined ethics similarly to their peers. Students used 14 distinct words in their responses for the mid-survey question one.

Question two:

1) Impacts (good/bad) that people experience due to a decision or action that may come from businesses, policies, or the government.

For the mid-survey, student one is an agricultural and biorenewable systems management student. This student implies that social impacts are consequences from actions conducted by larger entities and policy. They highlight that these impacts can be good or bad.

2) Social impacts are the ways in which a decision affects people or ecologies.

For the mid-survey, student two is a biological engineering student. This person also uses the outcome of decisions to define social impacts. They highlight that ecologies and the environment can be affected.

3) Social impacts refer to the effects that policies have on communities. They can be positive, like job creation, or negative, such as environmental harm.

For the mid-survey, student three is an agricultural and biorenewable systems management student. The indicated that policies create social impacts that can be good or bad.

4) Social impacts are the result of something that causes a change in the community in the area or effects a certain group of people.

For the mid-survey, student four is an agricultural and biorenewable systems management student. This student uses the consequences of "something," which is not defined, that effects a community.

5) Social impacts are the effects that actions, decisions, or policies have on people and communities. These impacts can shape how individuals and groups live, interact, and develop within society.

For the mid-survey, student five is an agricultural and biorenewable systems management student. This student highlights that there are various ways to impact society like actions, decisions, and policies. They also go on to explain that these impacts can influence life and communities' development.

6) To me social impacts are either beneficial or negative effects that come from new laws or ideas implemented on different societies, which can cause different kinds of responses from different people.

For the mid-survey, student six is an agricultural and biorenewable systems management student. Student six indicates that impacts from new ideas or laws can be good or bad. They also highlight that responses from communities can be different.

7) Social impacts are the outcomes related to the decisions we make, and they pertain to the people, place, and things that we interact with.

For the mid-survey, student seven is a biological engineering student. Student seven highlight in their definition that interactions people, places, and things have on decisions and outcomes.

8) Social impacts are actions or events that cause an impact on a societal group.

For the mid-survey, student eight is an agricultural and biorenewable systems management student. This student uses “impact” and “societal” in their definition of social impacts. They do indicate that they come from actions and or events.

9) it is a affect that come from an organizations decisions

For the mid-survey, student nine is an agricultural and biorenewable systems management student. Student nine implies that the affects of social impacts come directly from organizations.

10) Ways people are able to interact and positively impact those around them on a daily basis.

For the mid-survey, student ten is a biological engineering student. Student ten defines social impacts as the positive things that influence people. They emphasize interactions.

11) Social impacts are how society is affected by large scale decisions made.

For the mid-survey, student eleven is an agricultural and biorenewable systems management student. This student defines social impacts on the large scale only, identifying society and its influences from bigger decisions.

12) Social impacts are the way that decisions affect how people interact with each other in a dimension that isn't properly characterized by other forms of organization like profession

For the mid-survey, student twelve is a biological engineering student. Student twelve uses words like decision and interaction to describe social impacts, however, they say that it is characterized by something other than the pure definition of organizations and professions.

13) Actions of an individual or the public that have affected a community.

For the mid-survey, student thirteen is an agricultural and biorenewable systems management student. This student indicates in their definition that social impacts are both individual and community based. Both can influence action on communities.

14) Social impacts are the ways that actions or words affect the function or mindset of groups of people.

For the mid-survey, student fourteen is a biological engineering student. This student implies that words as well as actions influence people, their function, and mindset. This is the first student to indicate that words can create social impacts in their definition.

15) Social impacts are the results of change in society and how that change affects the communities. The often are results of movements, or are the start of movements depending on the issues at hand.

For the mid-survey, student fifteen is a biological engineering student. Student fifteen implies that changes from social movements affect communities.

16) Things like actions or events that have an impact on a community as a whole.

For the mid-survey, student sixteen is an agricultural and biorenewable systems management student. Student sixteen indicates in their definition that actions and events create social impacts for communities.

17) Social impacts are the effects people's actions create.

For the mid-survey, student seventeen is an agricultural and biorenewable systems management student. This student defines social impacts on an individual level. they describe that actions done by people create social impacts.

18) Consequences of actions or culture that have an implication for people within a society. Can be both good and bad, general and disproportionate.

For the mid-survey, student eighteen is a biological engineering student. This student's definition uses the idea of consequences are the basis of social impacts. They go on to describe that they can influence in good ways as well as bad ways with different levels of distribution across communities.

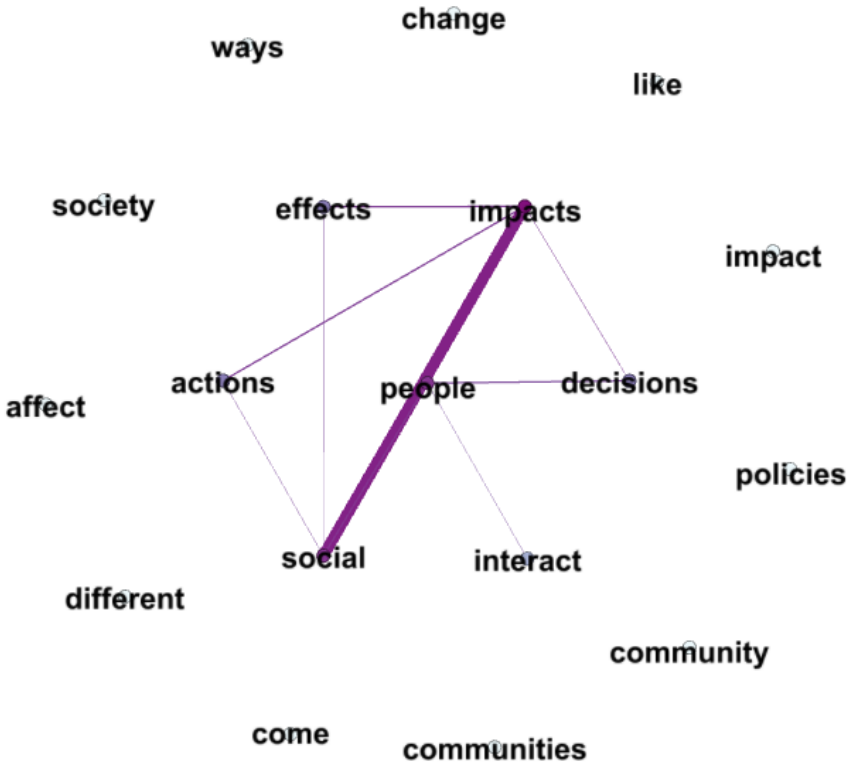


Figure 12: Frequency of words and paired words when defining social impacts on mid-survey (Fruchterman Reingold layout)

As previously identified in the pre-survey section, engineering has many implications for the world around us. Decisions and actions conducted by engineers can create intentional and unintentional impacts to communities and individual people. These social impacts of engineering and our technologies can affect the public, environment, and our employers. This definition is based on the language used by Codes of Ethics as well as ABET's criterion for engineering and technology's impact on our world. Figure 12 is a Gephi visualization of the word frequency and word pairs most common when students answered question two, "In your own words, what does social impacts mean?". The most frequently used word pair when answering question two was

"social" and "impacts." This is due to students reiterating the question. Reiterating the question would also explain the strength of the connection between the two words in the visual. Another strong word pair is between "people" and "impacts." Words that appeared the most often after "social" and "impacts" were "people" at ten times, "actions" at seven times, "effects" at five times, and "society" and "interact" at four times. It can be inferred that students' definitions that people impact or are impacted by these decisions, actions, or events.

The interconnectedness of this visualization is larger than the first question about defining ethics with ten word pairs to question one's seven pairs. Students had mixed responses to question two. A wider breath of definitions were included by students. There were more self-focused definitions, while others exclusively looked outwards to society. Students did not use examples in their responses to the mid-survey. To define social impacts 18 separate words were a part of the visualization compared to question one's 14. This indicates that students used more distinct words with higher frequency to define social impacts.

Question 6:

Table 19: Students' answer to question six of the open-ended questions "Do you actively consider ethical issues or social impacts during decision making? If so, where did you develop that skill?" on mid-survey

	Yes	Yes (passive)	No	Total
BE	6	0	1	7
ABSM	9	2	0	11

Source: Open-Ended Questions from Mid-Survey

Overall, students do think of ethics and or social impacts when making decisions. Six of the seven biological engineering students indicated that they do actively think of both ethics and

social impacts when making decisions in their lives. There was one student who indicated that they do not think of ethics, however, they are trying to improve this skill. Similarly, nine of eleven agricultural and biorenewable systems management students thought of both in daily life and making decisions. Two respondents answered that they are more passive using ethics and social impacts on decision-making. No other students indicated that they do not think of ethics at all. While this is an anonymous survey, students may not have wanted to be perceived as not thinking about ESI in their daily life which could have skewed the responses. Many of the students indicated family, church groups, or work (like family business) influencing their ESI development. These are all influences prior to formal educational settings like high schools and university courses.

Question 19:

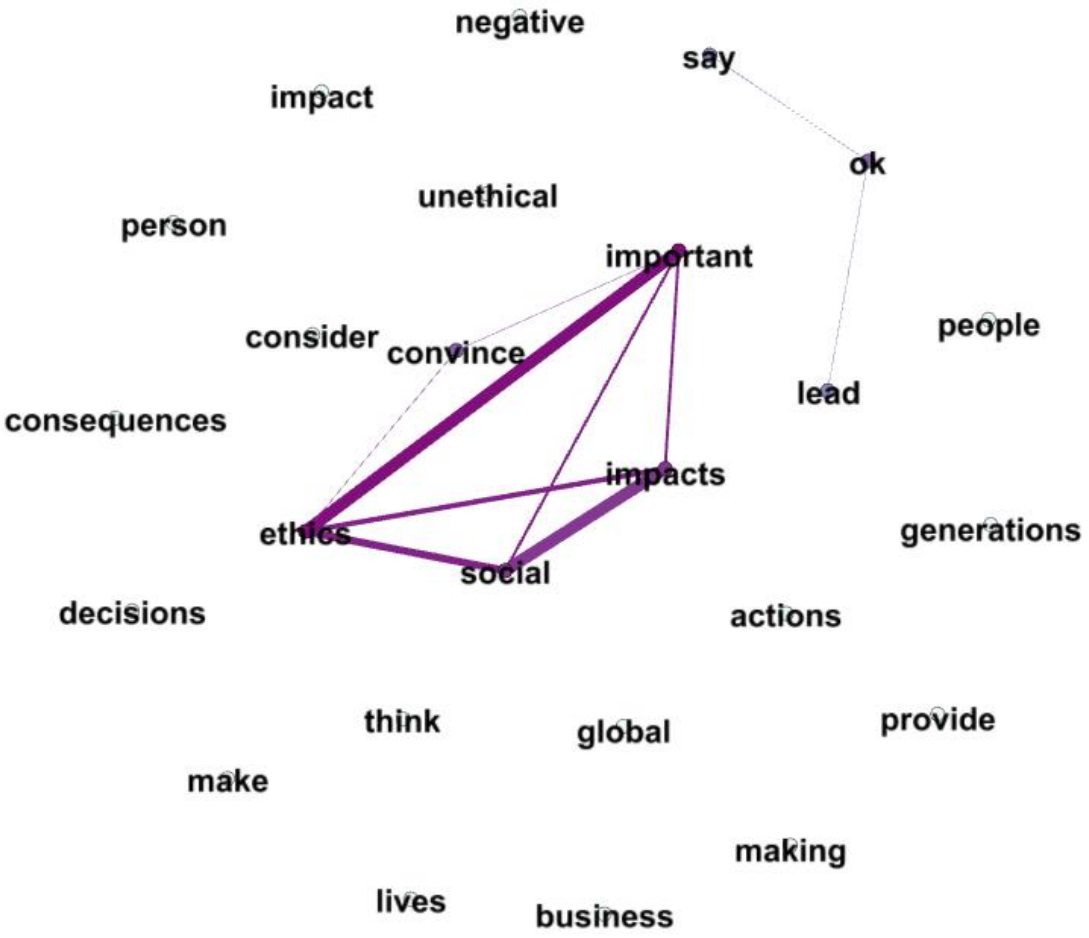


Figure 13: Frequency of words and word pairs when answering "If you had to convince someone that ethics and social impacts are or are not important, how would you do that? What argument would you use?" from mid-survey (Fruchterman Reingold layout)

An additional question that was asked was question 19. This was the last question on the survey and an open-ended response. While not used as a direct measure for the methodology outlined in this thesis, the analyzed data does have some noteworthy outcomes. There are 25 distinct words with frequencies higher than three from the responses to question 19. Words like "ethics," "social," and "impact" or "impacts" were frequently used due to student restating the

question. These three words, using “impacts” not “impact,” also have the strongest connection of the 11 pairs present in the visual. “Ethics” also has the highest number of pairings or connections at five. In the students’ responses, many described that they would use examples or real-life scenarios to convince the other person of the importance of ESI. The word “convince” was used four times compared to “led” which was used three times. In their responses to the mid-survey, some students described a feeling of not being able to sway someone completely if they already do not buy into ESI importance, some even indicated it was an inevitable “they do or they do not believe” situation. Compared to the pre-survey, students were not as quick to convince others, they wanted to state facts rather than use more feeling and emotion-based tactics in their responses to question 19. That is not to say some students did not describe these methods, just not in as high of a quantity.

Students’ full responses to questions six and 19 from the mid-survey can be found in Appendix B.

Comparisons Between Pre-survey Results and Mid-survey Results

This section will outline the differences between the responses on pre-survey and the mid-survey. To aid the comparison there will be summary tables that show the differences in word frequency and word pairs, Likert question responses, and the Wilcoxon Test for the Likert questions. These findings will inform if the formal curricular experience in BE 392 had significant impact on undergraduate students’ ethical development and signified comfortability using ESI when making decisions.

Word frequency and word pairs. There were changes to the words which appeared more frequently in the responses to the open-ended questions from the pre-survey to the mid-survey. However, the scale at which word frequency changed was by one to two word increases or decreases. Students' frequency of words stayed the same for question one, however, more word pairs were created in the responses on the mid-survey. Question two's word frequency went down from 19 words to 18 words but an increase in word pairs from six to 10. Students used more language in their responses to the mid-survey which implied increased knowledge about ethical frameworks and ethical theories like Consequentialism, Utilitarianism, and ethics of care. In both surveys, students used moral values and principles to describe ethics. For social impacts, students used less examples to describe their definition of social impacts on the mid-survey in comparison to the responses to the pre-survey. Definitions of both ESI topics were more personal than an overview of general definitions in both the pre-survey and mid-survey. Students' responses outlined personal definitions of ethics. For the importance of both ESI topics students, ethics word frequency went up in the mid-survey but word frequency for social impacts went down. The definitions outlined by students in the mid-survey encapsulated of their instruction from BE 392 and further widened to not just include the difference between "right and wrong." It can be inferred from the responses that students were more confident in these responses compared to the pre-survey.

Table 20: Totals for both participant groups on Likert questions on pre-survey (N=19)

Agreement	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18
Strongly Agree	0	1	6	5	3	3	4	6	0	1	3	0
Agree	12	10	11	9	13	8	10	7	5	7	7	9
Neutral	4	3	1	3	3	7	5	4	6	7	7	7
Disagree	2	4	0	1	0	1	0	2	6	2	1	1
Strongly Disagree	1	1	1	1	0	0	0	0	2	2	1	2

Source: Likert Questions from Pre-Survey

Table 20 is a summary of the total responses to the Likert questions on pre-survey. Both biological engineering students' responses were combined with agricultural and biorenewable systems management students.

Table 21: Totals for both participant groups on Likert questions on mid-survey (N=18)

Agreement	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18
Strongly Agree	7	8	9	4	4	5	4	5	0	1	2	0
Agree	10	7	8	11	12	8	11	10	9	12	12	13
Neutral	1	2	1	3	2	4	3	2	7	3	2	1
Disagree	1	1	0	0	0	1	0	1	2	2	2	1
Strongly Disagree	0	0	0	0	0	0	0	0	0	0	0	3

Source: Likert Questions from Mid-Survey

Table 21 is a summary of the total responses to the Likert questions on mid-survey. Both biological engineering students' responses were combined with agricultural and biorenewable systems management students. For the mid-survey there was one student who did not answer the Likert questions in agricultural and biorenewable systems management, so the total was 18 participants. For statistical tests, neutral answers for each of the questions were used for the missing student.

Table 22: Wilcoxon test comparison for each Likert question

Question Number	Wilcoxon Test Statistic	p-value	Reject Null Hypothesis [Y/N]
7	5.5	0.00319	Y
8	10	0.00986	Y
9	23	0.353	N
10	32.5	0.597	N
11	39	1	N
12	37	0.871	N
13	42	0.782	N
14	25.5	0.834	N
15	15	0.0266	Y
16	13.5	0.0696	N
17	42	0.467	N
18	28	0.647	N

Null Hypothesis is: Are the responses to the Likert questions from the mid-survey statistically different from the responses to the pre-survey.

Table 22 presents the results from the Wilcoxon test conducted on the Likert questions. This test was performed to see if the responses to the twelve ranked questions were different between the pre-survey and the mid-survey. The alpha used for this test was α=0.05, with a confidence level of 95 percent. With these parameters, the questions with significantly different responses were question seven, eight, and fifteen. Question seven was “Durning my undergraduate studies I have learned enough about ethics to feel comfortable making decisions during my career,” question eight was “During my undergraduate studies I have learned enough about social impacts to feel comfortable making decisions with social implications during my career,” and finally, question 15 was “I am knowledgeable about philosophical ethics.” All of these questions got higher levels of agreement in the mid-survey. On the pre-survey, students where the least confident with question 15 with many disagreements and students feeling neutral. However, agreement to this question went up in mid-survey but only for more agreement and students feeling neutral.

Another question to note is question 16. If the confidence level was lower at 90 percent, with an alpha of α=0.1, this question would have also rejected the null hypothesis. This question was “I am knowledgeable about applied ethics.” There was a higher level of agreement in the mid-survey compared to the pre-survey for this question.

All outputs from the python code that conducted the Wilcoxon test can be found in Appendix C.

Chapter 7

Concluding Remarks

Engineers have a substantial influence on society, innovation, and policy. New infrastructure is being created every day. Regulations for housing, the environment, and research are evolving with input by engineers. So, teaching the next generation of engineers' ethics and perception of their impact is paramount to how the world will function for decades to come. Seeking to understand how undergraduate students in an accredited engineering program learn ESI topics, are changed by this instruction, and how other prior experiences can impact their outcomes was the foundation of this study.

To answer the research question, "do undergraduate students' answers to self-reflection surveys indicate how much their formal curricular, co-curricular, and perceived importance of ESI impact their ESI development?" the findings are, yes, these influences do impact ethical development. Students' formal experience in BE 392 increased perceived importance of ethics after instruction, satisfaction with ethics instruction, and the findings from the comparison of comfortability from the pre-survey to the mid-survey, impacted their responses to questions evaluating ethical development and overall improved comfortability. In the self-assessment surveys given to students in the BE 392 course, students indicated higher comfortability in using ESI to make decisions after having formal instruction. When defining ESI, students used language reminiscent of ethics frameworks like Consequentialism, Utilitarianism, and ethics of care. Students also noted prior formal ESI experiences like guest lecturers in introductory engineering courses, ethics courses, and high school classes. Some students indicated sports teams for co-curricular experiences as well as family, work, and religious responsibilities that influenced their

ESI knowledge. Overall, formal ESI instruction in BE 392 had a positive impact on undergraduate biological engineering students and agricultural and biorenewable systems management students. While only three of the 12 Likert questions had significant differences in their responses, these results give hope to further ESI instruction for engineering students and improvement of undergraduate students ESI development.

Implications of Work

In the context of the Agricultural and Biological Engineering department at The Pennsylvania State University, the findings of this thesis should encourage the department to continue application of micro-insertions in BE 308 and the multiple week instruction in BE 392. The formal instruction in these cases have positive implications for students' comfortability in applying ESI to decision-making. The department should encourage the pursuit of co-curricular activities for biological engineers and agricultural and biorenewable systems management students and provide support for ESI in their professional clubs. On a university scale, engineering departments should ensure that there are sufficient micro-insertions in required engineering courses, as well as support for students that may want to take ESI courses outside of the academic timeline and requirements of their major.

The implications of this study on the continued research into engineering education and ESI education is that formal ethics instruction in a required engineering course does have merit on increased comfortability with using ESI in decision-making. While this study was conducted on a

smaller engineering department's students, these outcomes should inspire the continued research on undergraduates' self-reflection of ESI.

Future Work

The self-reflection assessments of undergraduate students in the Agricultural and Biological Engineering department at The Pennsylvania State University will be continued in the BE 392 course. Not only were the surveys used to conduct the study for this thesis, but they are being used by faculty in the Agricultural and Biological Engineering department to further improve the course and cater the instruction to the students taking the course. After a few years of implementation, trends can be studied within the department and the BE 392 course itself. It is my hope that another Schreyer Honors student in the Agricultural and Biological Engineering department gains an interest in engineering ethics to continue this work.

If this survey was conducted in the future, I would like to see questions about a time students had to solve an ethical issue in their life and how they handled it and students identifying ESI in example problems. This could be an addition to the adapted methodology of the surveys for the most influential experience. The identification questions would be an adding to the assessment of ethical development in the surveyed students. With these additions the surveys would cover a wider assessment of students' development than was able to be done in this version of the surveys.

Appendix A Pre-Survey

Survey Questions

Major:

1) In your own words, what does ethics mean?

2) In your own words, what are social impacts?

3) Have you been previously instructed about ethics? If so, what were the course titles, activities, or groups? (You may list.)

4) Why is ethics important, or not important, to you?

5) Why are social impacts important, or not important, to you?

6) Do you actively consider ethical issues or social impacts during decision making? If so, where did you develop that skill?

Please answer the questions below by circling the best answer.

7) During my undergraduate studies I have learned enough about ethics to feel comfortable making decisions during my career.

Strongly Disagree Disagree Neutral Agree Strongly Agree

8) During my undergraduate studies I have learned enough about social impacts to feel comfortable making decisions with social implications during my career.

Strongly Disagree Disagree Neutral Agree Strongly Agree

9) During my undergraduate studies I have learned about the implications of my work on the environment.

Strongly Disagree Disagree Neutral Agree Strongly Agree

10) During my undergraduate studies I have learned about the implications of my work on the public.

Strongly Disagree Disagree Neutral Agree Strongly Agree

11) During my undergraduate studies I have tried to find peers that hold the same ethical values as me.

Strongly Disagree Disagree Neutral Agree Strongly Agree

12) During my undergraduate studies I have tried to find clubs that hold the same ethical values as me.

Strongly Disagree Disagree Neutral Agree Strongly Agree

13) During my undergraduate studies I have tried to find peers that hold the same societal impact values as me.

Strongly Disagree Disagree Neutral Agree Strongly Agree

14) During my undergraduate studies I have tried to find clubs that hold the same societal impact values as me.

Strongly Disagree Disagree Neutral Agree Strongly Agree

15) I am knowledgeable about philosophical ethics.

Strongly Disagree Disagree Neutral Agree Strongly Agree

16) I am knowledgeable about applied ethics.

Strongly Disagree Disagree Neutral Agree Strongly Agree

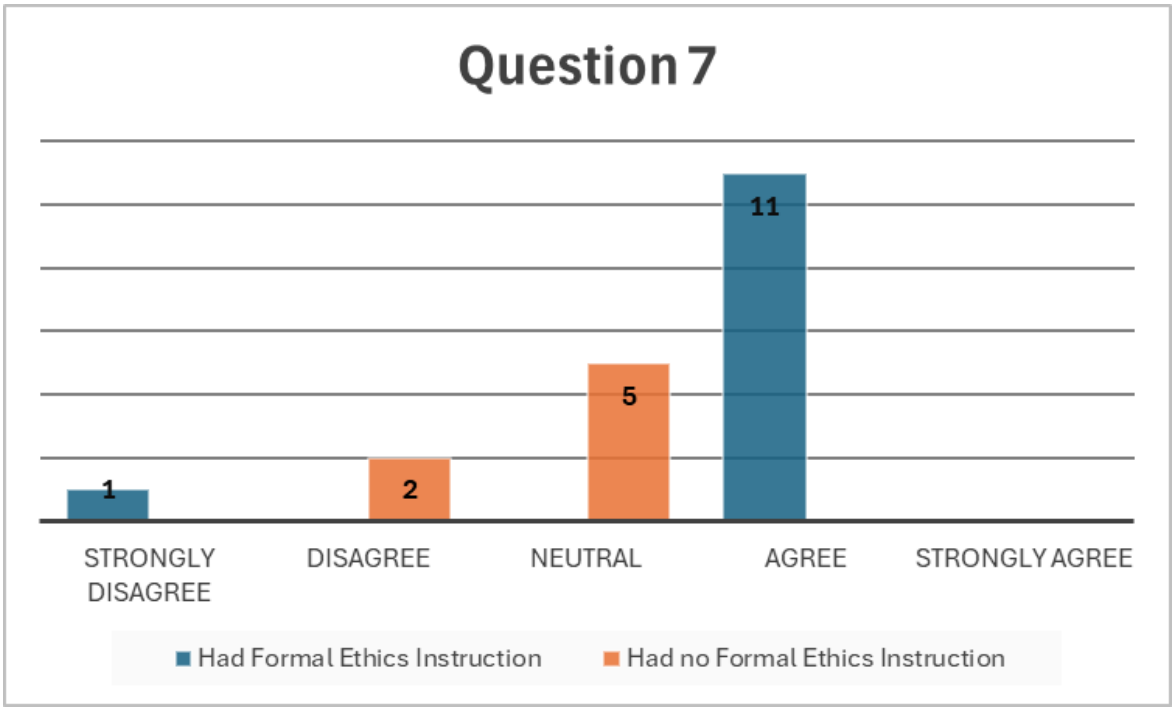
17) I am knowledgeable about societal impacts and social justice.

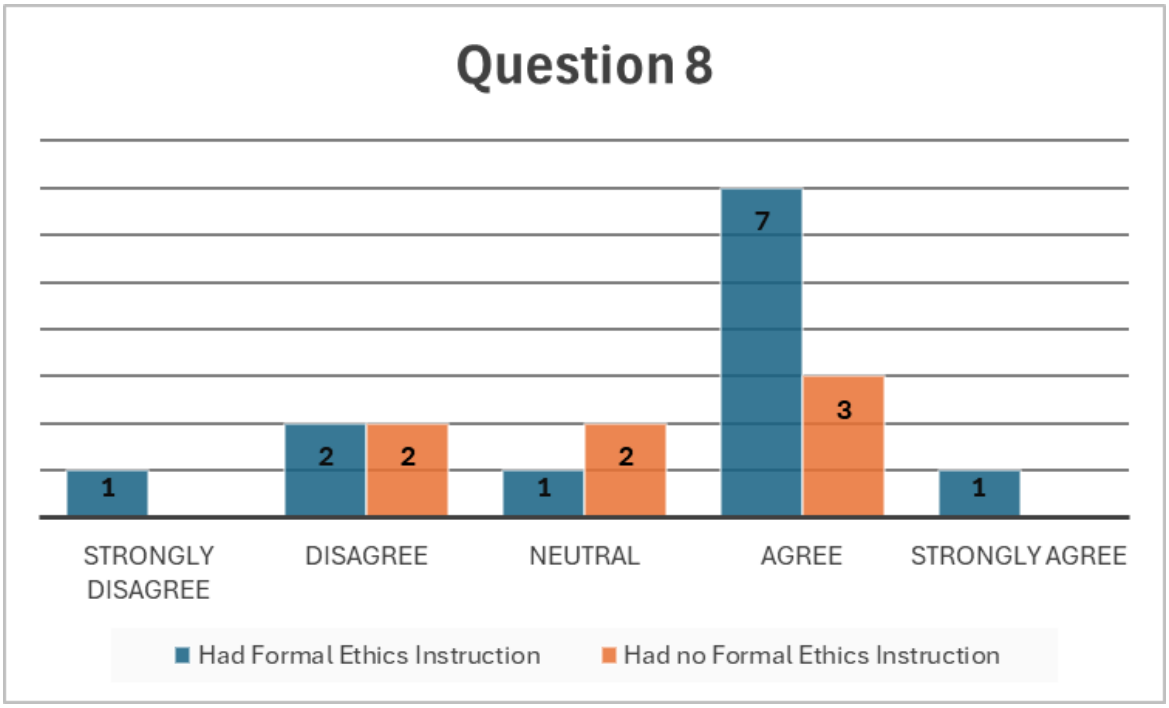
Strongly Disagree Disagree Neutral Agree Strongly Agree

18) I can identify ethical problems and the impacts of my work if asked.

Strongly Disagree Disagree Neutral Agree Strongly Agree

19) If you had to convince someone that ethics and social impacts are or are not important, how would you do that? What argument would you use?

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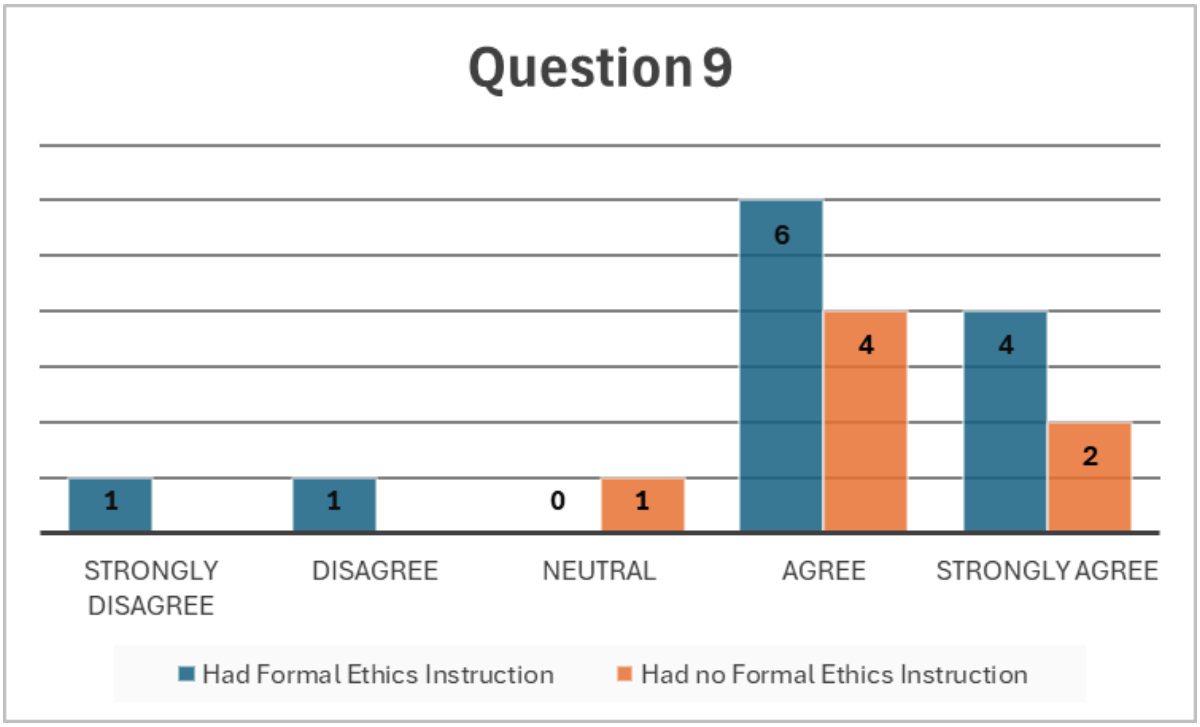
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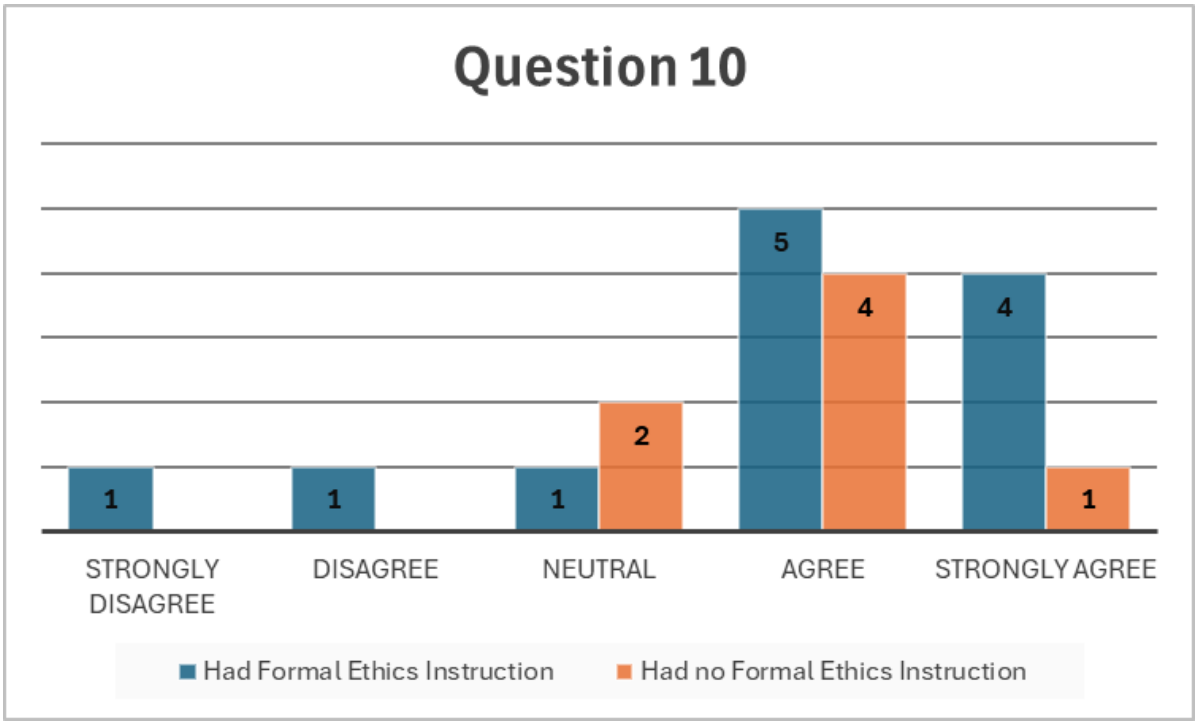
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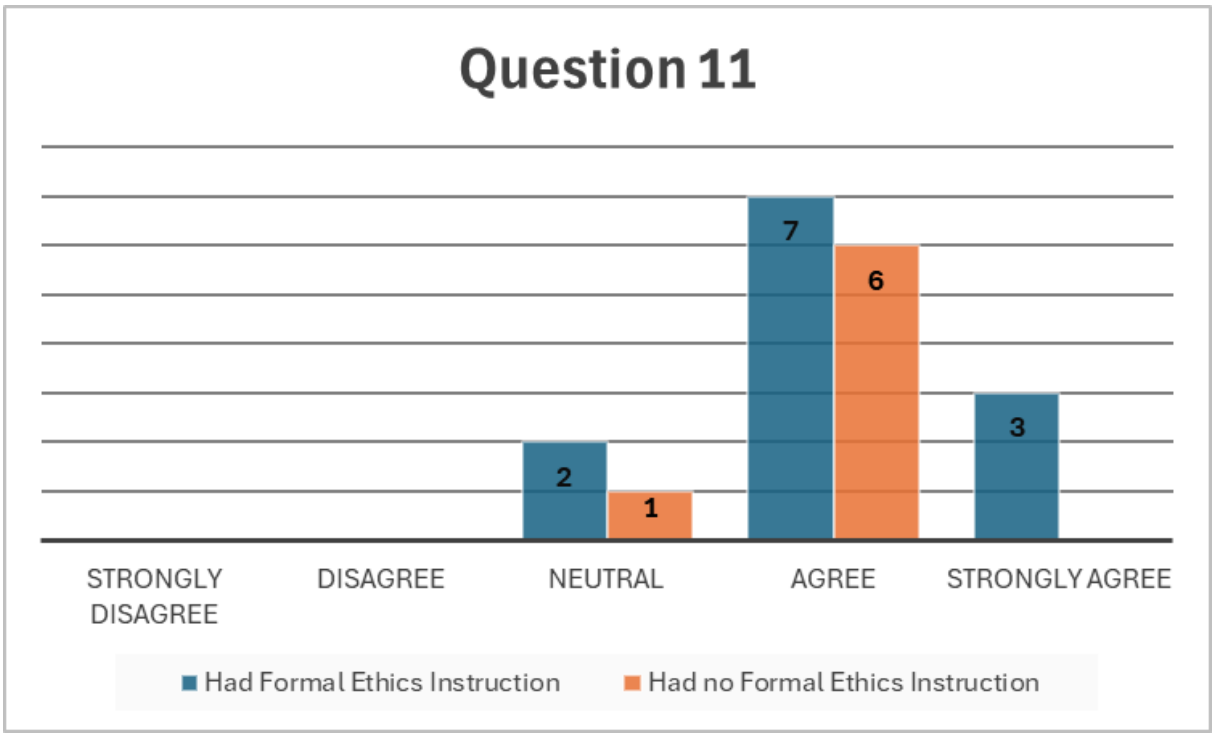
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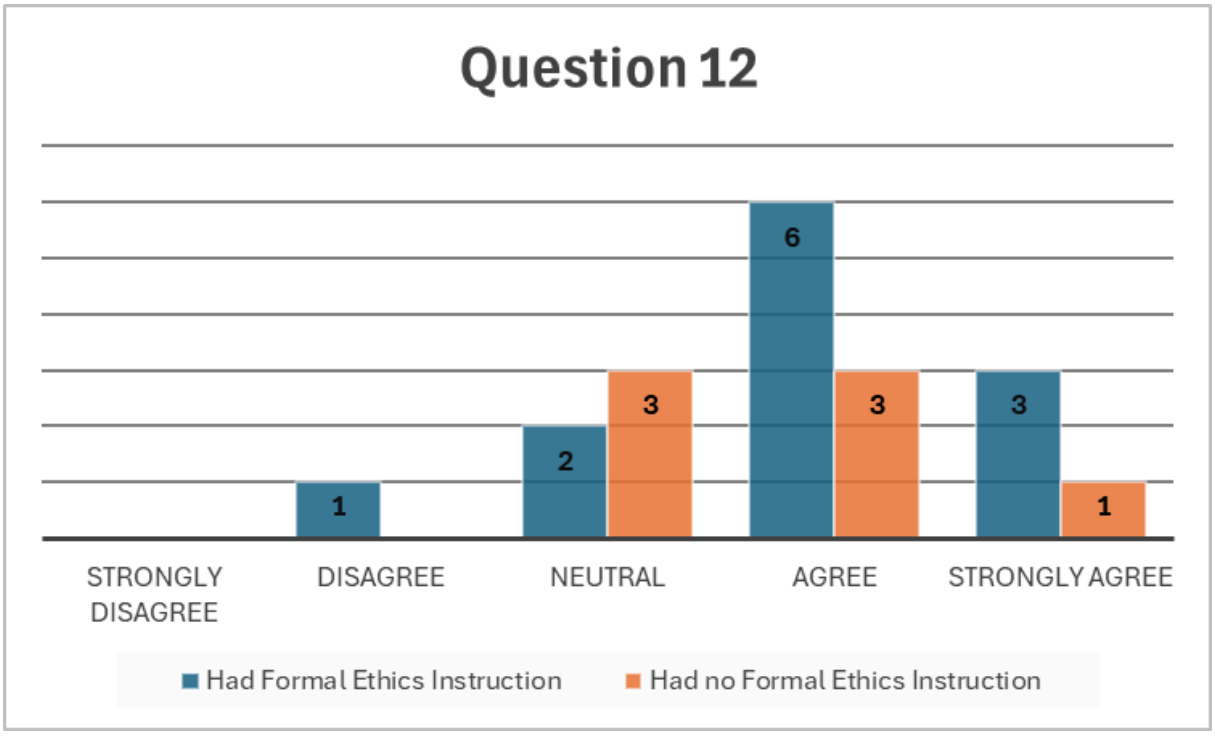
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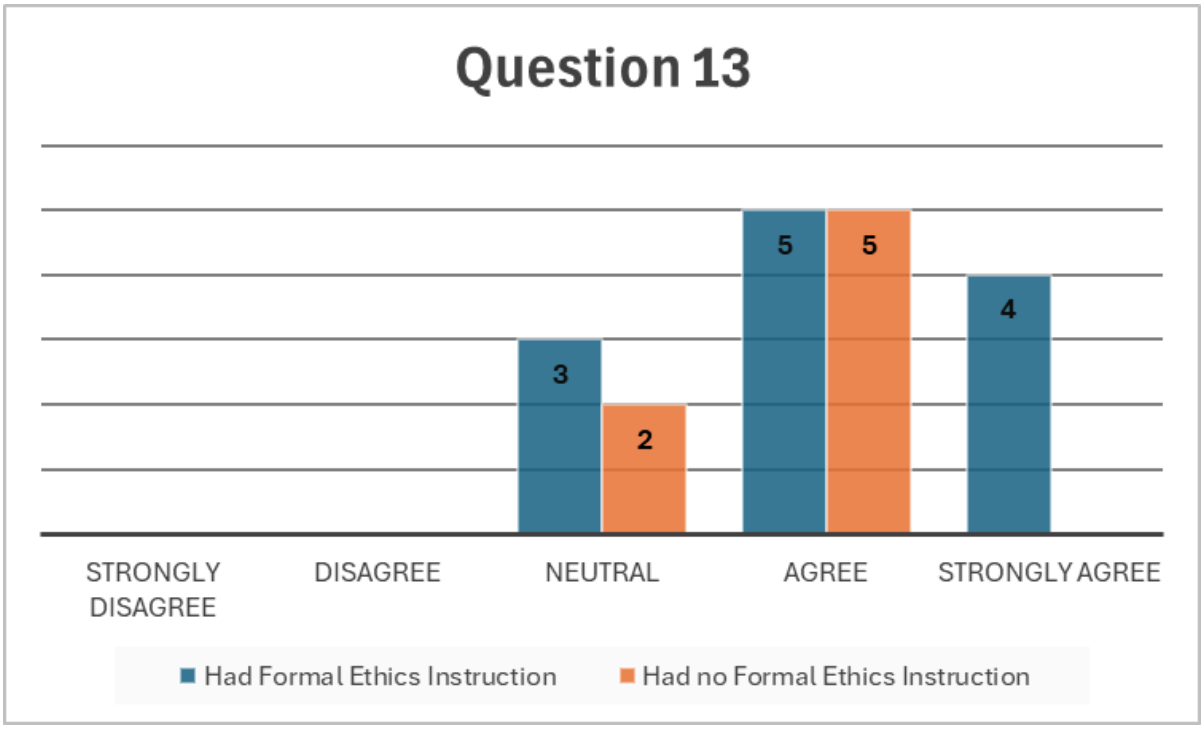
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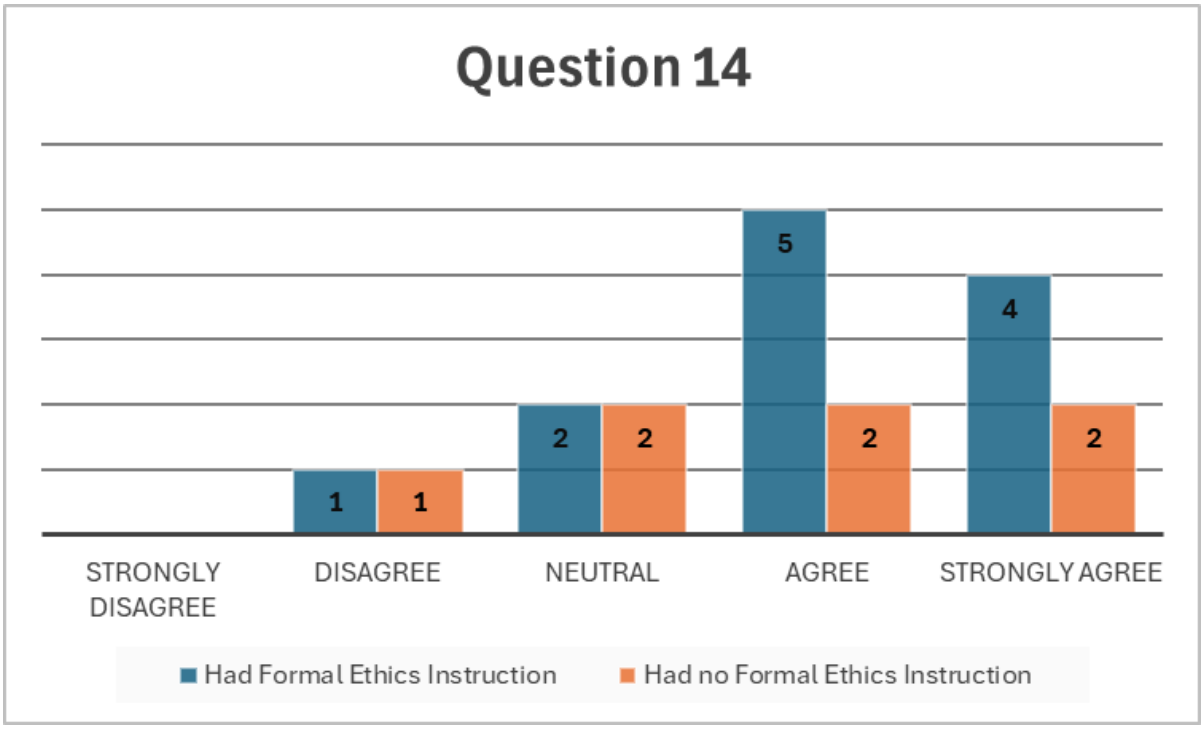
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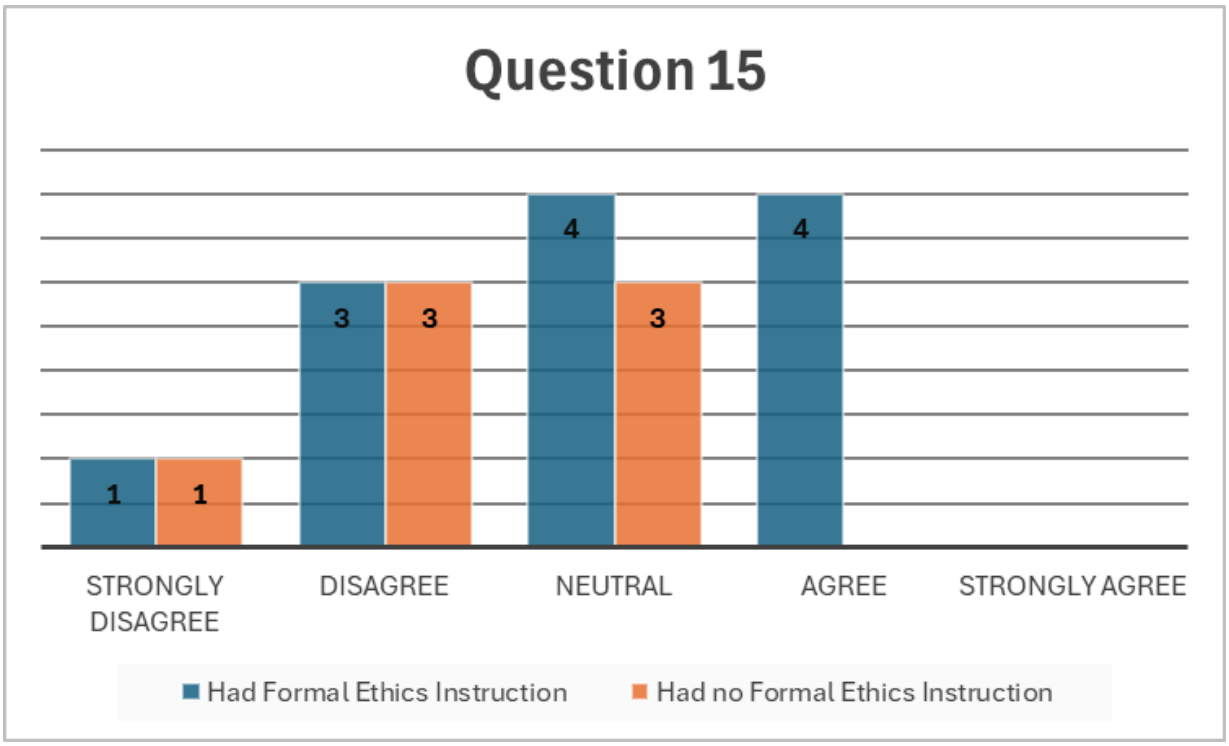
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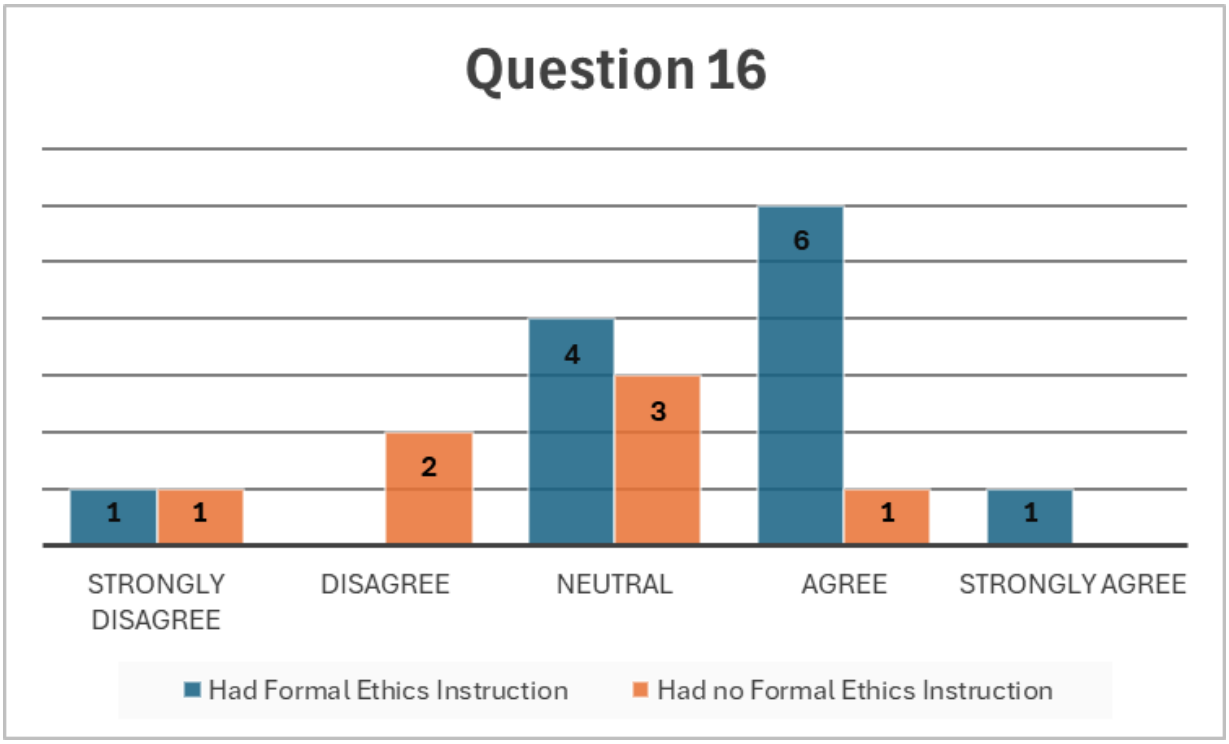
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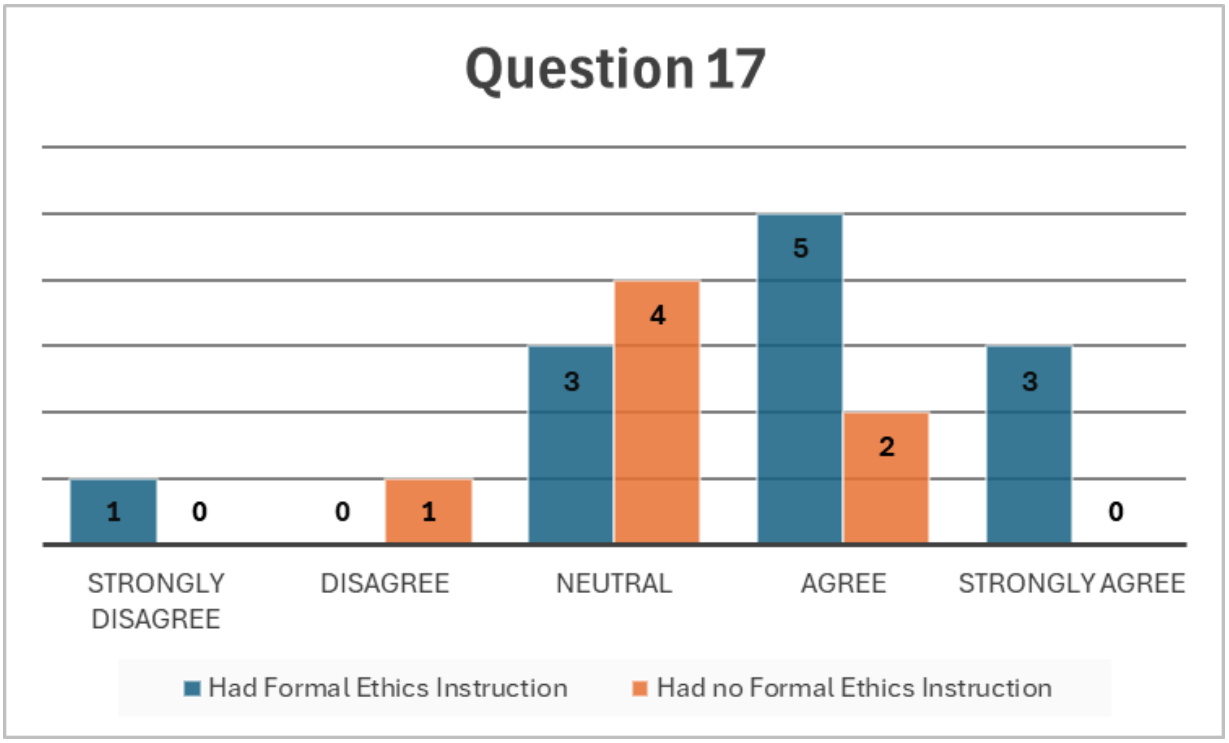
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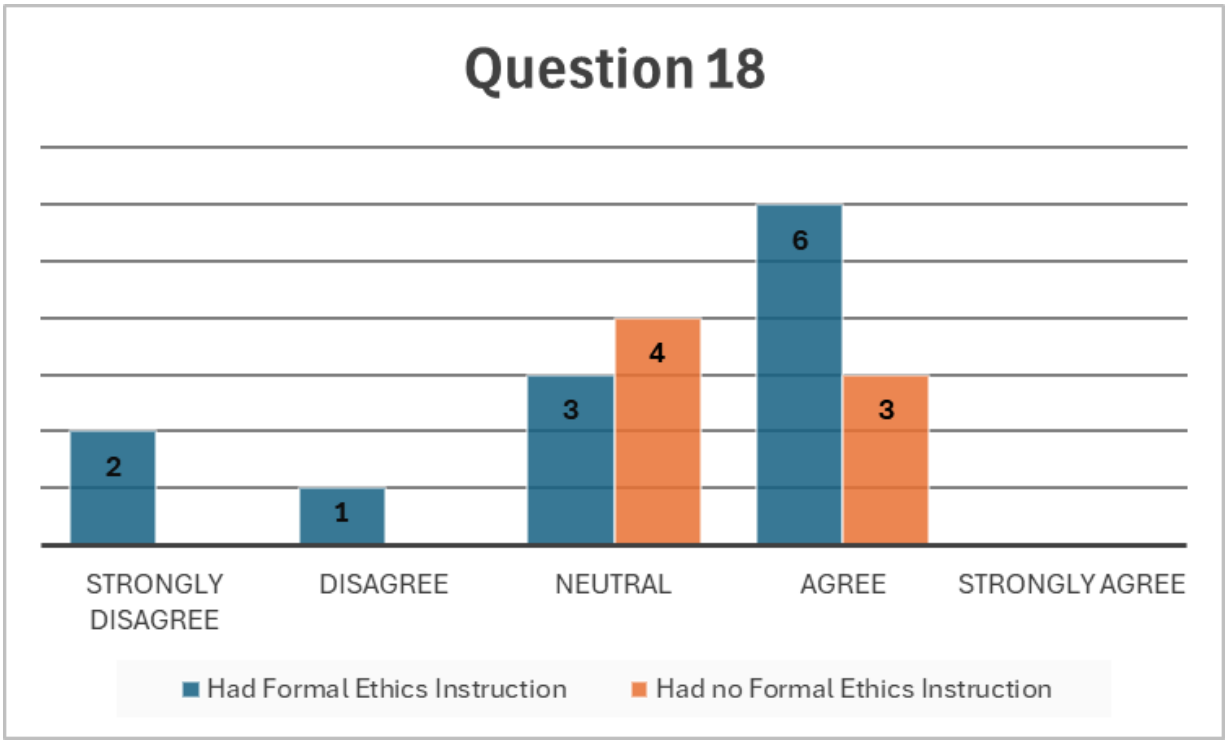


When probing the students of BE 392 what types of experiences they have participated in they said some of the following responses:

*The numbers corresponding with the responses are the same individual across the responses to the pre-survey.

Question Three

1) "Formally, I've only been instructed about ethics by Dr. Catchmark briefly in BE308. I'm sure others have explained some of what we did, so I won't go depth about it since I'm submitting this late."

For student number one, they are a biological engineering student, and it is noteworthy that they assumed that other students from the BE 308 course would explain the pedagogical instruction conducted in the week-long insertion. The additional context that they are submitting

the survey late could give some extra context to their responses. They do make sure to name the course they were instructed in as well as the guest lecturer.

2) "Yes, I have taken SOC 119N for a semester where we learned how people act and why they do. The class led me to learn more about different cultures and why people may act they way that they do."

Student number two is in the agricultural and biorenewable systems management major. SOC 199N Race, Ethnicity and Culture is described as focusing on "historical patterns and current status of racial, ethnic and cultural groups and issues locally, nationally, and internationally" (Penn State The College of Liberal Arts, 2021). It is a general education course that meets the requisites of humanities or social science. The specific learning objective of "Students will be able to more clearly explain how their identity reflects and shapes their life experiences as well as others in their racial and ethnic group(s)" the course highlights the intended outcome of increased understanding of social impacts (Penn State The College of Liberal Arts, 2021). This might indicate that this student will feel more comfortable with social impacts in their other responses.

3) "I haven't really had any ethics classes."

Student number three is in the agricultural and biorenewable systems management major. While this student has indicated that they have not had formal ethics courses they still have a definition and interpretation of both ethics and social impacts. They disagreed that they have learned enough about ethics so far in their undergraduate to feel comfortable making ethical decisions or decisions based on social impacts.

4) "We covered a small portion of ethics in BE 308 this past Fall, which included a case study exercise and some activities related to the on campus ethics institute."

Student four is in the biological engineering major and similar to the other students in the major they experienced the week-long guest lecture by Dr. Catchmark. They also indicate that during the week-long experience they learned about the Penn State's Rock Ethics Institute. This Institute focuses on research and leadership at Penn State, which has affiliated faculty, two of which are from the agricultural and biological engineering department, Dr. Catchmark and Dr. Costello. No other student who experienced the week-long guest lecture indicated they learned about the resource of the Rock Ethics Institute.

5) "no"

Student five is in the agricultural and biorenewable systems management major. While they indicated no formal instruction on ethics, they agreed often on the ranked questions. They answered that they felt neutral about their knowledge about ethics to feel comfortable making decisions based on ethics. But they agreed that they would feel comfortable making decisions based on social impacts.

6) "No not really."

Student six is in the agricultural and biorenewable systems management major. And similarly, they answered neutral for question seven and agreed to question eight.

7) "Yes I have, I took Ansc 213 where we talked about ethics in biotechnology and in an ANSC/ABSM class about ethics in Agriculture, but I can't remember the exact course title. We did group activities, we would have a reading during class and would get in groups to answer questions."

Student seven is in the agricultural and biorenewable systems management major. They named a class called ANSC 213 Introduction to Animal Biotechnology which discusses the technology, genetics, and technological applications of animal biotechnology (Penn State

College of Agricultural Science, 2024). While the other course could not be found, the addition of group discussion is a part of the pedagogies outlined by the SEED survey.

8) "I had a one-day lecture along with a lab on ethics in BE 308. We looked at ethics in engineering and in the lab, we looked at some examples and scenarios of ethics."

Student eight is also in the agricultural and biorenewable systems management major. They took the BE 308 course; therefore, they experienced the week-long guest lecture. They indicate that there was a 50-minute lecture as well as during the normal lab period. They also indicate that they followed the pedagogy of case studies and guest lecturer.

9) "Yes, BA 241 & 242."

Student nine is in the agricultural and biorenewable systems management major. BA 241 Legal Environment of Business and BA 242 Social and Ethical Environment of Business and a pair of classes that focus on the environment of business. BA 242 specifically focuses on business's impact on society (Penn State Smeal College of Business, n.d.). This student agreed to all of the ranked questions except for answering neutrally to questions 11 and 13 which are about finding peers that have the same ethical and social impacts values as themselves.

10) "I have has a lecturer come in to talk about engineering ethics and had some ethics in my sociology class."

Student ten is in the biological engineering major. They indicate a guest lecturer, which most likely is in BE 308. However, the sociology class could not be found. This student disagreed that they have learned enough about ethics to apply it in their career at this time. They did agree that they knew about social impacts to feel comfortable making decisions with them in mind.

11) “I have actually taken ethic in my freshman year, however, I don't remember the name of the course. I also had an ethics instructor teach two lectures and a lab last semester, l believe his name was Jefferey Catchmark.”

Student eleven is in the agricultural and biorenewable systems management major. The first-year course the student suggests could not be found, however they indicate they took BE 308’s guest lecture. They imply that the week-long ethics insertion was two 50-minute lectures and during a lab for the BE 308 course. This differs from student eight’s response to this question. This student agreed to question seven and strongly agreed to question eight.

12) “Yes, a guest lecture(s) by Dr. Jeffery Catchmark. We read a case study of Henrietta Lacks and had an open discussion about the ethical issues that were both apparent and unapparent and how that situation could've been better handled. (FA24 - BE 308)”

Student twelve is in the biological engineering major. Similarly, they indicate the guest lecture in BE 308 and mention the pedagogies used during the insertion. These are like case studies and group discussions. Interestingly, this student strongly disagreed to many of the ranked questions except 11, 12, 13, and 14 which they answered neutral.

13) “I have been instructed about ethics for around half a week or so. We talked about ethics and the different angles of thinking about ethics, which included an approach having to do with utilitarianism, an approach having to do with previously establish "laws" or "rules" regarding moral conduct, and an approach having to do with the values of different parties involved in morally questionable situations. We did an activity investigating the ethics behind HeLa cells in class.”

Student thirteen is in the biological engineering major. The assumption is that the instructed ethics is the BE 308 course. They indicate that the lectures discussed ethical

frameworks, discussions of stakeholders in ethics situations, and case studies as the pedagogies. They answered question seven with agree and answered neutral to question eight.

14) "I have not yet been educated on ethics."

Student fourteen is in the agricultural and biorenewable systems management major. They answered neutral to question seven and agreed to question eight.

15) " no"

Student fifteen is in the agricultural and biorenewable systems management major. They answered neutral to question seven and agreed to question eight.

16) "In BE 308 we have Dr.Catchmark come speak about engineering ethics."

Student sixteen is in the biological engineering major. They indicated they were a part of the micro-insertion in BE 308 with the guest lecturer.

17) "High School Ethics Class"

Student seventeen is in the biological engineering major. They are the only student who indicate that they had ethics instruction before university. They do not talk about the guest lecture from BE 308. This student only agreed or strongly agreed to all of the ranked questions.

18) "I have not."

Student eighteen is in the agricultural and biorenewable systems management major. They answered disagree to question seven and agreed to question eight.

19) "Not formally, no."

Student nineteen is in the agricultural and biorenewable systems management major. They answered agree to question seven and strongly agreed to question eight.

Question 4

1) “I find myself in a strange middle position where strong yet open ethics are very important to me, but I don't find mainstream ethics frameworks as satisfying ways of exploring how everyday people who have never heard of aristotle before make ethically complex emotional/rational decisions. So yes, acting ethically is important to me, but I'm a little skeptical of capital e Ethics as I've been taught it - its logics seem very consistent with traditional male-centered ways of thinking which doesn't sit with me well.”
2) “Ethics is important because it shapes how people make decisions and interact with others, ensuring fairness, trust, and accountability in society. It helps individuals and organizations navigate situations where right and wrong aren't always clear.”
3) “Ethics is important because without it some people would be treated very poorly I feel, and without ethics the work environment would probably be even more hostile.”
4) “As ag and bio engineers, the responsibilities we have are quite immense being that both people and the environment are affected by our decisions. We must choose to be ethical in our actions to protect the valuable resources we oversee and take care of. Most of the issues we are challenged with are a result of irrational and unethical actions from other industries over the last couple of centuries and seeing the impact that those choices have had really sets the nail in the coffin as to why being ethical in our field is important.”
5) “I feel like ethics is highly dependent on gender, age, and nationality. It is important to me because it creates a fair experience for everyone.Nov”

6) “Ethics are important to me, they are codes that I live by, they coincide with my religion. So, my ethics are very strongly connected to my own religious beliefs. They thus influence how I live my life and the type of actions I take in society.”
7) “Ethics are important to me because without ethics we would have a lot of decision makers making very poor decisions. These would end up negatively affecting people not only in specific social groups, but every person outside of that too.”
8) “It's important because what we can do with our work could affect others such as consumers for example.”
9) “Ethics is important to me because of my upbringing. Ethics is obviously different for everyone and it is important to realize that and respect their view on it even if you disagree.”
10) “Ethics is important to me because it's an added framework that helps me be the best person I can be.”
11) “Ethics is important to me because I generally would like to know how not to hurt people by actions that are second nature to me. I'd prefer to act in a just and fair way towards others. I am concerned about the possibility there are individuals that lack good intention have the means to inflict major negative social impacts.”
12) “For those that have authority and the means to influence the well-being of others, I wish they either hold themselves or others hold them to an ethical code of conduct."
13) “Ethics is important to me because it helps me make decisions that I feel good about in terms of helping others or being perceived as a good person.”

14) “Ethics is relevant to me because it is a topic that I believe is included in day to day work and interactions.”
15) “o think ethics are important because it hold us accountable”
16) “It helps build trust, respect, and fairness in everyday life. Without ethics, things could get pretty messy and there's lots of dishonesty, unfairness, and problems.”
17) “Ethics is important because the framework provided is a good starting point to address issues, even if individual people diverge when it comes time to make every decision.”
18) “It is important to me because I believe in doing the right thing, and I feel the world would be a better place if everyone did the right thing all the time.”
19) “The more things get worse and the more people do wrong, the more problems grow.”

Question 5:

1) “Social impacts are extremely important to me! I am constantly trying to broaden my understanding of those affected by "social impacts," instead of considering a the social impacts to an "average human."”
2) “Social impacts are important because they shape communities, influence people's well-being, and determine whether changes like new policies, technologies, or business decisions are beneficial or harmful.”
3) “Social impacts are important because its not just one person its a group of people.”
4) “Social impacts are the outward appearance of our ethical behaviors and decision making. They are vitally important in our considerations of choices and actions as they create a cycle in a way of how we should be approaching situations we encounter. Social impacts, like ethics, influence how we view and interact with the world around us.”

5) “Because they decide how easy your life will be (if you are liked or not)”
6) “Social impacts are important to me since they affect everyone, they also can also affect me.”
7) “Social impacts are important to me because bad impacts on social groups can affect a lot of people beyond the people who are involved.”
8) “Similar to the previous question, it is important because these could affect coworkers and other people around me.”
9) “Social impacts are important to me because they affect me and those around me and can often stem from one's ethical views.”
10) “Social impacts are also important to me because they remind me how I treat others has a major impact.”
11) “Social impacts frame the way the world works and entire groups of people’s lives can be altered just due to how others impact them with their thoughts and actions so it’s important for me to know how to remain strong when I’m the victim and how to support others being victimized by this. I also try not to take actions that’d result in negative social impacts for others but it’s admittedly difficult not to want the actor to feel what they’ve made their victims feel.”
12) “In any social impact, there is a likely chance that it will disproportionately harm a demographic of people (depending on the scenario).”
13) “Social impacts are important to me because I don't want others to suffer from the results of actions that I may make or even actions that I may not make.”
14) “Social impacts are relevant to me because they could influence your job and how teams work together.”

15) “you should try and make decision that don't negatively effect people”
16) “Social impacts are important because they shape the way people live, work, and interact. They help us understand the bigger picture.”
17) “Social impacts are important because the way people interact with each other shapes the way that decisions are made in this world.”
18) “They are important because they affect how the world works, and they are also very dependent in helping everybody get along with each other.”
19) “I don't like seeing people unhappy or harmed.”

Question 6:

1) “Yes! I tend to think about this most when I am consuming things, particularly food. I also try to do this when deciding where I spend my time (producing things), but I don't think about this quite as much.”
2) “Yes, I actively consider ethical issues and social impacts when analyzing situations or providing insights. This skill comes from studying ethical frameworks, social responsibility principles, and real-world case studies across various fields like business, environmental science, and leadership.”
3) “I like to think that I do but I could be wrong, I haven't really been taught about ethics I just have the idea that being ethical means not being a bad person for the most part.”
4) "Yes, without a doubt. Thinking back about the personality and leadership evaluations we took, this is where the ""thinking"" mannerism comes into play. It is important to put these items at the forefront to decision making as it helps you to be cautious and consistent in your approach to issues and the fashion in which you respond. I think, in a way, it was second nature as it had been somewhat instilled in me growing up. But as Ive

gotten older and gained more exposure and experience, with responsibilities having increased, it has become even more apparent to consider the ethics and impacts my decisions and responses can have on others."

5) “I consider social impacts but not ethical issues because my ethics dont fall outside of typical ethical opinions of americans. I developed this on my own.”
6) “I always try to consider ethics when making a decision. They are the codes I have chosen to live by, I also try to consider what kind of social impact a certain decision will have. I gained this skill while on my mission, seeing how everything I did was tied to service in church and how my public actions could be a representation of the church, so I had to be conscious I was acting in accordance with what I believed but also how others might view my actions”
7) “Naturally when I'm by myself I don't, but when im with others I think about how my decision would affect them and the other people around me.”
8) “I do add in some amount of ethics into my thoughts depending on the situation and I'd say that I learned this skill just from the way I was raised.”
9) “Not always, but often. I believe I developed these skills from how I was raised and my family's businesses.”
10) “I often do because I feel bad when I something I do directly or indirectly hurts others. I developed it from my mom's teachings.”
11) “I feel as though I do because in the past I was affected by others not thinking about how their actions negatively impact me and I wouldn't want others to feel that way.”

12) "To the best of my capabilities. From my own previous experiences, and people telling me about their previous experiences of how a seemingly distant decision personally affected their life."
13) "Ethical issues and social impacts have been more of a passive, automatic way of thinking when making decisions. A lot of the thinking I do have related to it comes from my own experiences with my family, friends, and even coworkers and what they consider to be right and wrong; or how have they been personally impacted by different actions of others."
14) "Yes, from day-to-day life and understanding how people want to be treated and how they react to things."
15) "I consider what my choices do to others and i think you develop that skill by caring"
16) Did not answer.
17) "I do consider ethics and social impacts during decision making. I developed this skill through middle and high school, where I went to a small progressive school that was very focused on advocacy and social justice."
18) "Sometimes, but not always. I'm not sure where or when I stared doing this. I just think about some of the things that could happen if I do or say something."
19) "I do my best to and I feel like it is natural, because my parents taught me to be that way."

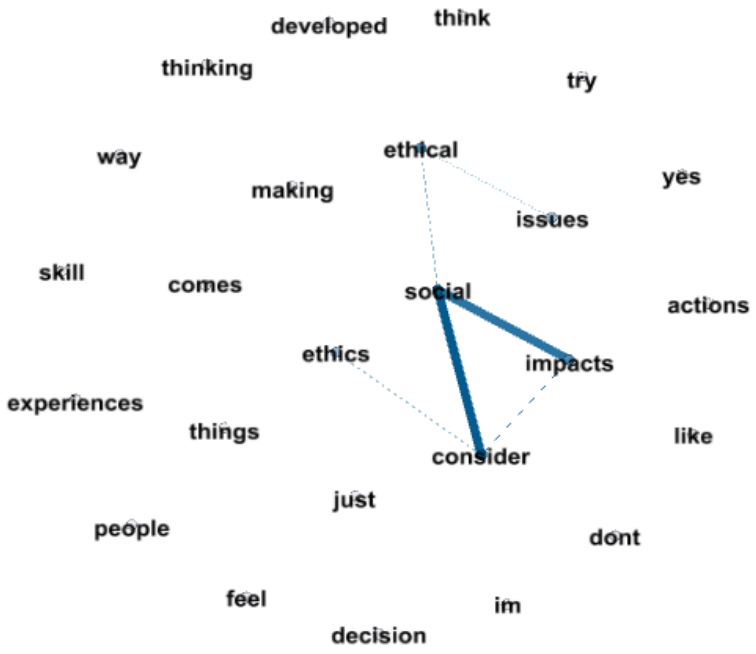


Figure 14: Frequency of words and word pairs when answering ”Do you actively consider ethical issues or social impacts during decision making? If so, where did you develop that skill?” (Fruchterman Reingold layout)

Question 19:

1) “If I had to, I would try to convince them that ethics/social impacts are important, but I wouldn't use an argument. Instead, I would get to know the person and listen to their stories. I would try to understand how they see ethics and societal impacts, and I would then try to outline how they already cared about ethics and social impacts, even if they thought about it in different terms.”
2) “If I had to convince someone that ethics and social impacts are important, I'd focus on real-world consequences. My argument would be that ethical decisions and social

considerations directly affect trust, sustainability, and long-term success in any field whether business, science, or personal relationships."

3) "I would use examples of things that have been socially impacted and remind them that without ethics and social impacts these examples probably wouldn't exist."
4) "From the engineer's standpoint, we have a great impact on the world around us based on the decisions we make. Great consequences can stem from clouded judgement or tempting scenarios. And being in the field of ag and bio, a lot of our work is relevant to the natural environment and the global population. If we are unethical in our processes while working on projects in or for either impact group, a devastating reaction could occur in the wake of our decisions. We must consider the authority and impact abilities we possess with our work as we strive to improve the industry, world, and field of ag and bio engineering."
5) "I would convince them by saying they would not like if they were treated unethically."
6) "I would argue that as humans we should always act in accordance with what we want and how we should focus only on ourselves. By being selfish we are always going to act without thinking about society and we might take actions and embrace behaviors that are unethical."
7) "Im not sure how I would do that because I believe every decision that's made has some type of ethical value. I could say that their decisions only affect them, the outcomes of that action would come back to bite them only."
8) "I would convince someone that ethics and social impacts are important by doing a similar activity as I did in my BE 308 ethics lab by providing examples and practice problems on identifying these things."

9) “I would argue that ethics impact everyone and anyone. However, as I said before, they vary from person to person. One may view ethics as necessary, and one may disregard the concept of ethics completely. Especially within a business model, ethics plays a huge role in how that business is run and how consumers view your business.”
10) “I would argue that thinking too much about actions can cause inaction or lead quickly into radicalization.”
11) “Real life examples of how what seems like it, help our country possible economically or otherwise (not really sure because I disagree with a majority if it) can actually marginalize millions of people and make their lives expeditiously worse.”
12) “ARE IMPORTANT: Would you not be as moved or outraged if someone close to you was harmed by an unethical action or social impact the same way as a stranger was? What would you do, say? NOT IMPORTANT: So long it doesn't hurt you, why care?”
13) “If I had to convince someone that ethics and social impacts are important, I would tell them to look at the state of the world and how the unethical decisions of others have made negative impacts on the current state of our society. I would ask them to think about the times that they have hurt others with their decisions and convince them that thinking about decisions from an ethical framework can help avoid tricky situations.”
14) “I do not have enough information or knowledge to come up with a claim at this time, either to defend or oppose the idea. I want to learn more about it to form a concise opinion and knowledge base.”
15) “I guess I would try to convince people that other people are not ethical. but that still not a great reason.”

16) “Ethics and social impacts matter because they affect real people. Without ethics, there's no trust. Ignoring social impacts can cause harm, but considering them leads to better choices for everyone.”

17) “I would try to convince someone that ethics are important by talking about the personal connections they may have and how non-ethical decisions would negatively affect them and the people around them. Things like healthcare, the price of groceries....”

18) “I would convince them they are important by showing different scenarios of what could happen if they are disregarded. For example, if the mistreatment of a certain race was going unchecked in a workplace, it would not only hurt the people being discriminated against, but also the company that is doing it, because people will realize they are not good to work for.”

19) “I would say they are important. I would say that it is important to treat others well, because eventually you'll want the same for yourself.”

Appendix B Mid-Survey

Survey Questions

Mid-Survey

Do not write your name on any portion of this questionnaire. Complete short answer questions in sentence form and only list if specified. Please answer all the questions to the best of your knowledge. There are no wrong answers.

Year:

Major:

1) In your own words, what does ethics mean?

2) In your own words, what are social impacts?

3) Have you been previously instructed about ethics? If so, what were the course titles, co-curricular activities (e.g., clubs, volunteering) or community groups? (You may list.)

4) Why is ethics important, or not important, to you?

5) Why are social impacts important, or not important, to you?

6) Do you actively consider ethical issues or social impacts during decision making? If so, where did you develop that skill?

Please answer the questions below by circling the best answer.

7) During my undergraduate studies I have learned enough about ethics to feel comfortable making decisions during my career.

Strongly Disagree Disagree Neutral Agree Strongly Agree

8) During my undergraduate studies I have learned enough about social impacts to feel comfortable making decisions with social implications during my career.

Strongly Disagree Disagree Neutral Agree Strongly Agree

9) During my undergraduate studies I have learned about the implications of my work on the environment.

Strongly Disagree Disagree Neutral Agree Strongly Agree

10) During my undergraduate studies I have learned about the implications of my work on the public.

Strongly Disagree Disagree Neutral Agree Strongly Agree

11) During my undergraduate studies I have tried to find peers that hold the same ethical values as me.

Strongly Disagree Disagree Neutral Agree Strongly Agree

12) During my undergraduate studies I have tried to find clubs that hold the same ethical values as me.

Strongly Disagree Disagree Neutral Agree Strongly Agree

13) During my undergraduate studies I have tried to find peers that hold the same societal impact values as me.

Strongly Disagree Disagree Neutral Agree Strongly Agree

14) During my undergraduate studies I have tried to find clubs that hold the same societal impact values as me.

Strongly Disagree Disagree Neutral Agree Strongly Agree

15) I am knowledgeable about philosophical ethics.

Strongly Disagree Disagree Neutral Agree Strongly Agree

16) I am knowledgeable about applied ethics.

17) I am knowledgeable about societal impacts and social justice.

Strongly Disagree Disagree Neutral Agree Strongly Agree

18) I can identify ethical problems and the impacts of my work if asked.

Strongly Disagree Disagree Neutral Agree Strongly Agree

Mid-Ethics Instruction Questions:

Please answer the questions below by circling the best answer.

1) After taking BE 392 my knowledge on ethics has increased.

Strongly Disagree Disagree Neutral Agree Strongly Agree

2) After taking BE 392 my knowledge on social impacts has increased.

Strongly Disagree Disagree Neutral Agree Strongly Agree

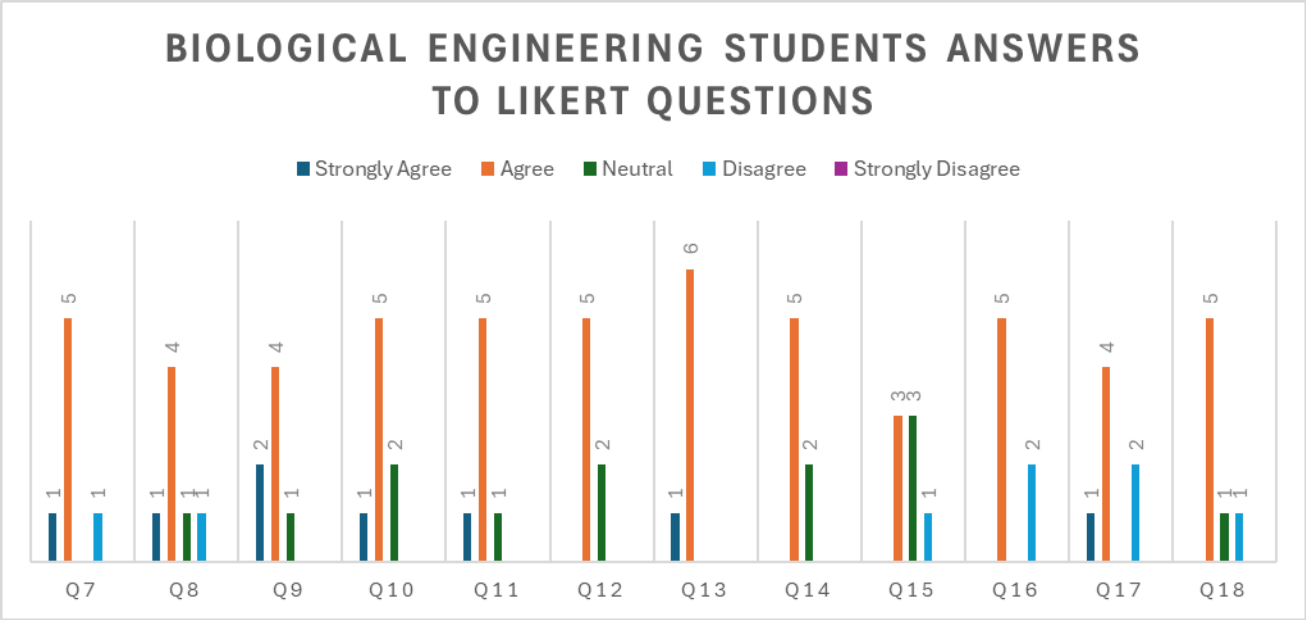
3) During BE 392 I have learned about the implications of my work on the environment.

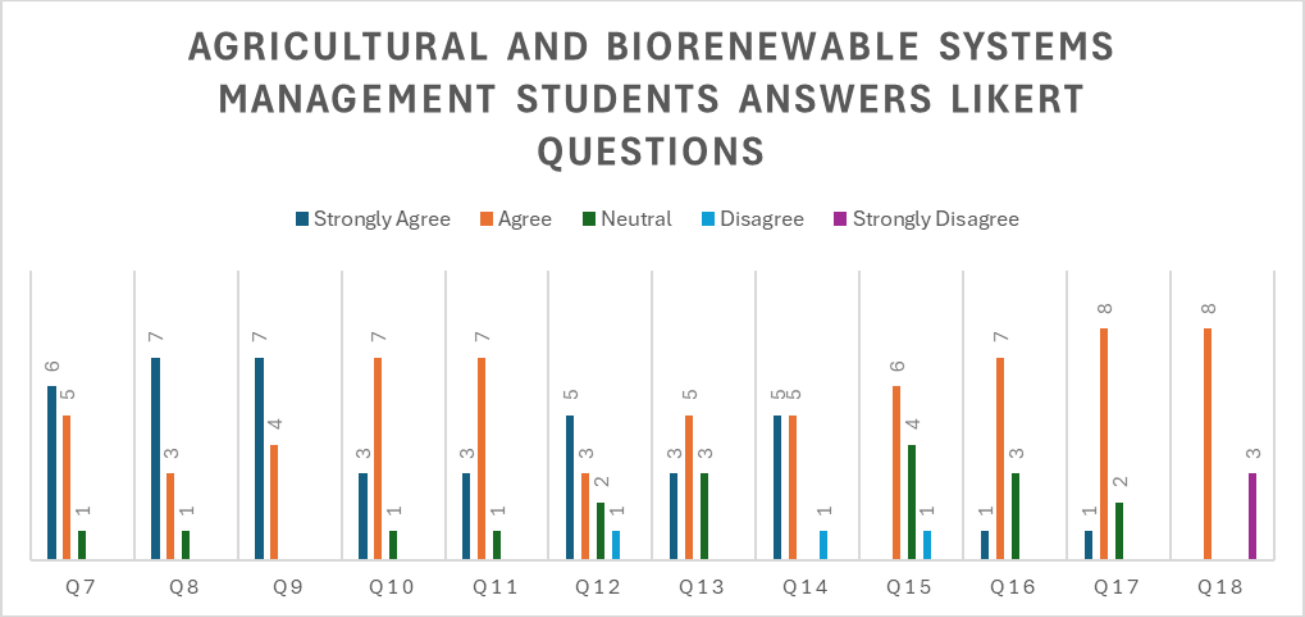
Strongly Disagree Disagree Neutral Agree Strongly Agree

4) During BE 392 I have learned about the implications of my work on the public.

Strongly Disagree Disagree Neutral Agree Strongly Agree

5)If you had to convince someone that ethics and social impacts are or are not important, how would you do that? What argument would you use?





*Student Numbers are not the same as Pre-survey individuals.

Question 4:

1) (ABSM) Ethics is important to me because of my upbringing. Ethics is obviously different for everyone and it is important to realize that and respect their view on it even if you disagree.
2) (BE) Ethics is important for me to navigate a world where many seemingly innocuous decisions cause indirect harm. One visible way I embody my ethics is by being vegan, which is a framework for minimizing harm in food consumption. Being vegan by itself doesn't necessarily minimize harm, though, so I've developed many other frameworks for what food I get and how I get it. Aristotelian ethics are not important to me because that framework doesn't seem to be inclusive of everyday people - particularly marginalized people - who also make complex ethical decisions without ever considering Aristotle or his ways of thinking. They are valuable insofar as understanding them allows me to critique them, but I don't find them important to me at all. There are better ethical frameworks.
3) (ABSM) Because bad ethics can breed hurt people on both ends.
4) (ABSM) Ethics is important because without ethics I feel like a lot of problems would be fixed with a quick fix that can actually be very detrimental to the community and surrounding areas.
5) (ABSM) Ethics is important because it helps guide fair and responsible decision-making in both personal and professional life. It builds trust, promotes respect, and ensures that actions consider the well-being of others.
6) (ABSM) Ethics are important to me because it prevents you from making decisions that are not only bad for you but also bad for other people. It lets others know you have

a moral consciousness, and you're not going to do anything that could possibly harm them or get them in trouble.

7) (BE) As ag and bio engineers, the responsibilities we have are quite immense being that both people and the environment are affected by our decisions. We must choose to be ethical in our actions to protect the valuable resources we oversee and take care of. Most of the issues we are challenged with are a result of irrational and unethical actions from other industries over the last couple of centuries and seeing the impact that those choices have had really sets the nail in the coffin as to why being ethical in our field is important.
8) (ABSM) It's important to me because ethics help to make up a person's character and one's ethics can also impact others around them.
9) (ABSM) ethics is important to me because if you are an unethical person is saying a lot about you character
10) (BE) It is important because it has become an intrinsic part of who I am and how I interact with the world.
11) (ABSM) Ethics is important to me because I want to make technological advancements to help both human/animal life and our planet at the same time. Often times with such large missions, something important is on the table to be compromised. Therefore, being well informed on how to get out of causing harm to one thing and still making progress towards your mission is important.
12) (BE) Ethics is important because it is a guide rail when a decision is too complex to make without a framework that has some basic categories of "right" and "wrong".

human civilization is predicated on the idea that people share overlapping ethics structures and will generally agree with each other on ethical decisions (like whether you can kill people, etc)

13) (ABSM) It ensures that people are given the respect they deserve and that interactions are positive.
14) (BE) Ethics is important to me because it determines how you perceive yourself. It dictates positive or negative values you see in yourself, or positive or negative values that you see in others.
15) (BE) Ethics is important to me because the results of being ethical, or not being ethical in some cases directly impacts people's lives. As an engineer specifically a lot of our choices and decisions have the ability to change people's lives and by adhering to a code of ethics that ensures that we are changing lives for the better and no one community is hurt by new advancements.
16) (ABSM) Ethics is important to me because in the work environment it ensures everybody is happy and friendly with each other.
17) (ABSM) Ethics is important because it is about morals, which I believe I have, and act according to them.
18) (BE) Ethics are important to me because I want to be as cognizant and accountable for my actions and decisions both as a professional and a person. I am aware that to some degree, I have an influence on the general public, but even more so, the people that I care about directly around me. I want to conduct myself morally and ethically to do no harm, and bring about the most positive influence to people.

Question 5:

1) (ABSM) Social impacts are important to me because they affect me and those around me and can often stem from one's ethical views.
2) (BE) My understanding of social impacts comes mostly from listening to indigenous and black thinkers. Learning about structural (and interpersonal racism) as a white person has helped me understand how any framework for understanding social impacts that treats society as homogenous is not only inadequate but perpetuates the violence of racism by not acknowledging it. Learning about colonialism and indigenous land relations has reshaped my understanding of the social to include everyone in our ecology - plants, animals, water, air. Instead of thinking about social impacts, I tend to think about being in good relations. So as a summary, social impacts are important to me, but not if they aren't intentional about the definition of "social" to accurately represent those impacted.
3) (ABSM) They are important because they protect me as well as other people.
4) (ABSM) Social impacts are important because they shape the well-being of individuals, communities, and society as a whole. Whether it's the environmental consequences of energy choices, the economic effects of industry, or the ethical responsibilities of businesses, considering social impacts leads to more responsible and sustainable outcomes
5) No answer.

6) (ABSM) Social impacts are important to me because I feel as though it gives you the chance to both hear and see how different people are being affected by something you want to place in their society. You're able to discover different ways to help begin more of a beneficial effect than a negative one to said society.
7) (BE) Social impacts are the outward appearance of our ethical behaviors and decision making. They are vitally important in our considerations of choices and actions as they create a cycle in a way of how we should be approaching situations we encounter. Social impacts, like ethics, influence how we view and interact with the world around us.
8) (ABSM) Social impacts are important to me because it helps me to be self aware of myself and my actions.
9) (ABSM) there important because they choices you make have impacts on others
10) (BE) They are importantly to me because I want to be able to make someone else feel positive.
11) (ABSM) Socail impacts are important to not be so self absorbed in my opinion. If you actually think about how your decisions affect others, you'll be less likely to make them to
12) (BE) Social impacts are important because even though social interaction is one of the more "squishy" domains as compared to more quantifiable data like profits or effectiveness or the like, it is what shapes us and our personalities and how we choose to continue to interact with the world. I want people to experience positive social impacts that stem from good ethical decisionmaking

13) (ABSM) They are important because humans thrive on social interaction so it is important to be aware of the impacts associated with those interactions.
14) (BE) Social impacts are important to me because groups of people are important for the well being for every individual.
15) (BE) Social impacts are important to me because it is how a community and people respond to ethics and social issues. Social impacts is how the community reacts to people's work and changes and can serve as a gage for how your work is going.
16) (ABSM) I would say social impacts are not as important to me as they are to some others. I grew up in a pretty quiet place with not a lot going on, so I never really saw them in action. However, they are important to help connect communities with each other.
17) (ABSM) Social impacts are important because they are the result of people's actions and could effect me.
18) (BE) From both case studies in history, as well as witnessing current changes in society in my own lifetime. It is apparent that people, myself included, can be harmed or helped by social impacts.

Question 6:

1) (ABSM) Often, I believe I developed these skills from how I was raised and my family's businesses.
2) (BE) Yes, but I tend to rely more on intuition and empathy than rationality when considering ethical issues or social impacts. I've developed that skill through listening to the stories of people different than me and critically examining what's involved in

the production of goods. I've also learned by counterexample, finding examples of bad ethics and what went wrong. So though I rely on intuition and empathy (the rational justification usual comes afterward to explain what I'm feeling to others), I've intentionally cultivated this emotional understanding to form an (ever evolving) ethical framework.

It's important to note that this type of active consideration is at odds with a science/engineering education, which overvalues intuitive and empathic understandings of how the world works. I've definitely learned this intuitive/empathetic ethics through classes (like African American literature, Native American history, and classes about farming), but they have not been engineering classes. The exception was a chemistry of sustainability class taught by Mary Beth Williams who is now the acting dean of the college of science. There, I was encouraged to explore environmental impacts related the chemistry we were doing, and we were assigned films and readings that cultivated an empathetic understanding of how chemistry affects ecologies.

For the following multiple choice questions, I've answered based on what I've learned about ethics during my time at PSU, but I would say almost all of this learning (with the exception of learning about structural racism) took place on my own time, and was sometimes actively discouraged by my professor/classes.

3) (ABSM) Yes, I feel like women naturally have more pressure to develop this skill. I also am very empathetic because I remember and am aware of what it feels like to be left out and isolated.
4) (ABSM) I do consider ethical issues and social impacts when making decisions but I have only actively started thinking about it after taking BE 392, although I haven't done a lot of work I do think about the impacts of what I am doing.
5) (ABSM) I've encountered ethical and social impact considerations in coursework and projects. Analyzing biofuels, EVs vs. ICEVs, and material life cycles all involve ethical questions about sustainability, resource use, and societal effects.
6) (ABSM) I believe I more actively consider social impacts over ethical issues during decision making. I developed the skill working at my job in Maryland, I think about how my area not being clean could possibly affect another employee using the same area after me. I also like to ask a lot of questions at work just to make sure my actions won't affect the actions of another employee.
7) (BE) Yes, without a doubt. Thinking back about the personality and leadership evaluations we took, this is where the "thinking" mannerism comes into play. It is important to put these items at the forefront to decision making as it helps you to be cautious and consistent in your approach to issues and the fashion in which you respond.

I think, in a way, it was second nature as it had been somewhat instilled in me growing up. But as Ive gotten older and gained more exposure and experience, with

responsibilities having increased, it has become even more apparent to consider the ethics and impacts my decisions and responses can have on others.

8) (ABSM) Always in every decision that could impact either of them. This was taught to me as a child.
9) (ABSM) all the time i think they develop by how you were brought up and how you would like to be treated
10) (ABSM) I do try to induce ethical and social impacts and have since my family taught me the impact I could have on my environment.
11) (ABSM) I do to the slightest extent, I think about how my daily interactions and conversations affected the other party, therefore, I'd say that's social impacts. I developed this skill just from observing people that aren't aware of how their actions and words have affected others in the past.
12) (BE) I do. It started with an early religious emphasis on ethics, and then more formal instruction in high school and college
13) (ABSM) I do and it has been through my interactions and decisions I have had to make in student leadership roles.
14) (BE) I do consider it sometimes during decision making, and I'd say I developed that skill from being told that I've been wrong or being told that something I did is bad. Therefore, it makes me consider the ethical issues and social impacts associated with my decisions in the future.
15) (BE) I think most times I do factor in ethics and social impacts and not so much because I am trying to but because I was raised to think about how your actions affect

other people and that is something that I have continued to do my whole life which has bled into my professional life as an engineer.

16) (ABSM) Not really. I would say when I make a decision I just think about which decision would be the best for me and the people around me.

17) (ABSM) I think more about it than in the past due to my learning of the topics in 392.

18) (BE) No, it is something that I wish to improve for myself; I think it is a conscious practice that needs to be done with the assistance of others. Questions and comments of why and how need to be asked by people that will honestly (and sometimes brutally) challenge the thinking of others to eliminate as many unknown/unintended consequences as possible.

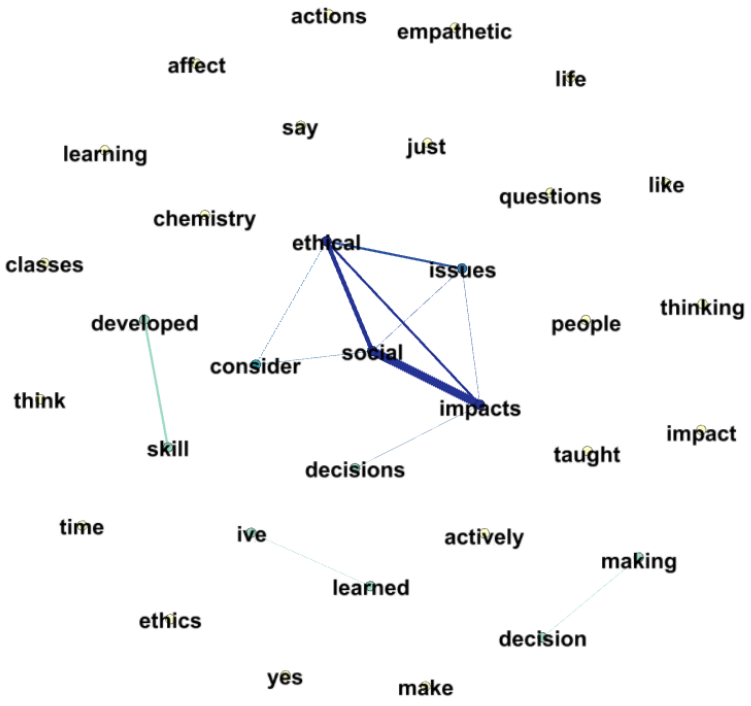


Figure 15: Question 6

Question 19:

1) (ABSM) I would argue that ethics impact everyone and anyone. However, as I said before, they vary from person to person. One may view ethics as necessary, and one may disregard the concept of ethics completely. Especially within a business model, ethics plays a huge role in how that business is run and how consumers view your business.
2) (BE) I'm so sorry I don't have time to do this! I remember answering this before, though, and I think that answer holds up to what I would say now. Basically showing someone how they already consider ethics and social impacts in their day to day decisions.
3) (ABSM) I would simply say: "ok, what if you were on the receiving end of unethical behavior?" In my opinion, most people face injustice but are unable to identify it with a lack of ethics.
4) (ABSM) No answer.
5) (ABSM) Ethics and social impacts are important because decisions that ignore them often lead to harmful consequences for individuals, businesses, and society. Ethical behavior builds trust, ensures fairness, and promotes long-term success, while unethical choices can result in scandals, legal issues, and public backlash. Social impacts matter because actions affecting communities such as environmental policies, business practices, or technological advancements can either improve lives or create long-term harm.
6) (ABSM) I would convince someone that ethics and social impacts are important because without ethics regulations, ideas, and research would lack the fairness of

making sure all people involved won't be negatively affected. Social impacts are important because it gives the people who are creating new regulations, ideas, and research, different feedback to consider before finishing their project and sending it out to others.

7) (BE) From the engineer's standpoint, we have a great impact on the world around us based on the decisions we make. Great consequences can stem from clouded judgement or tempting scenarios. And being in the field of ag and bio, a lot of our work is relevant to the natural environment and the global population. If we are unethical in our processes while working on projects in or for either impact group, a devastating reaction could occur in the wake of our decisions. We must consider the authority and impact abilities we possess with our work as we strive to improve the industry, world, and field of ag and bio engineering.
8) (ABSM) If I had to convince someone these topics are important or should be important to them I would provide examples of when these values were disregarded and had a negative outcome and maybe even provide some kind of activity of sorts.
9) (ABSM) i feel like it something you either think is important or not and if they don't agree that's fine
10) (BE) They aren't important because one does not need them in order to be a good member of society.
11) (ABSM) I would ask if they support people making decisions that will negatively affect their lives without considering the consequences of their actions.

12) (BE) I would try to talk about basic decisions that some extreme groups say are ok/not ok, and that the mindsets that lead to those also lead to the ethics we need... actually this makes no sense and I'm really tired so sorry
13) (ABSM) I would say that ethics are important because negative occurrences and actions grow larger and more consistent after each successive occurrence, so it is best to make positive choices as much as possible.
14) (BE) I would tell them to think about big decisions that involved ethics and considered social impacts, especially in the political realm or with big companies like NASA. I would provide examples of how thinking about these subjects was important or how being ignorant of these subjects had negative effects.
15) (BE) I would convince people that ethics and social impacts are important by explaining to them how ethics affects their lives and how they benefit from it, and then how other people in their community would as well. I would use the argument that if it weren't for ethics, people health and safety would not be the first thing considered when it comes to new technological advances. Communities are safer as a whole because of ethics.
16) (ABSM) I would convince them that they are important. I would show them a reality where ethics weren't cared for, and how angry everybody would be. If everybody just did and said what they want, people would hate each other.
17) (ABSM) I would argue that each person is associated with themselves. Therefore, the actions you make should roll off the other person's back, not making them have any feelings towards your actions and the consequences.

18) (BE) In the argument of global warming and climate change, I often refer to the phrase "not your fault, but it is your problem." Individually, my generation has done little to put ourselves in this position of global warming; the decisions made by generations before us have forced this upon us. We are victims of social impacts from the past. Further, what we do now, take action or remain passive in the fight against climate change, we will impose a social impact for the generations to come; those generations will be our children and grandchildren to put it into perspective.

Appendix C Software

Python code to clean data

C: > Users > McKenna-Dell > Downloads > ThesisClean.py > main

```python
import pandas as pd
import re

# Function to clean text
def clean_text(text):
    text = str(text).lower()  # Convert to string and lowercase
    text = re.sub(r'[^\w\s]', '', text)  # Remove punctuation
    return text

# Load the CSV file with specified encoding
def load_csv(file_path, encoding='utf-8'):
    try:
        data = pd.read_csv(file_path, encoding=encoding, encoding_errors='ignore')
        return data
    except Exception as e:
        print(f"Failed to load CSV: {e}")
        return None

# Save cleaned text to a text file
def save_to_text_file(cleaned_data, output_file):
    try:
        with open(output_file, 'w', encoding='utf-8') as f:
            f.write(cleaned_data)
        print(f"Cleaned text saved to {output_file}")
    except Exception as e:
        print(f"Failed to save text file: {e}")

# Main function
def main():
    file_path = r"C:\Users\McKenna-Dell\Downloads\MidSurvey\Mid-Survey.csv"  # Replace with your CSV file path
    column_name = "96396973"  # Replace with your column name
    encoding = 'Windows-1252'  # Replace with the correct encoding
    output_file = r"C:\Users\McKenna-Dell\Downloads\MidSurvey\cleaned_textQ19.txt"  # Output text file path
```

```python

    data = load_csv(file_path, encoding)
    if data is not None:
        # Check and print column names
        print(data.columns)

        # Strip spaces from column names
        data.columns = data.columns.str.strip()

        # Verify that the column '1' exists
        if column_name in data.columns:
            # Extract the column and apply the cleaning function
            cleaned_data = data[column_name].apply(clean_text)

            # Join all the cleaned text into a single string
            cleaned_text = ' '.join(cleaned_data)

            # Save the cleaned text to a text file
            save_to_text_file(cleaned_text, output_file)
        else:
            print(f"Column '{column_name}' not found in the DataFrame")

if __name__ == "__main__":
    main()
```

Wilcoxon Test Python Code

```python
import numpy as np
from scipy.stats import wilcoxon

# Strongly Agree    2
# Agree 1
# Neutral   0
# Disagree  -1
# Strongly Disagree -2

# Question Data
data1 = [-2,0,0,1,1,1,0,1,1,1,-2,-1,1,0,1,0,1,0,0]
data2 = [1,1,1,1,1,-2,1,1,-2,1,-2,1,1,1,0,1,1,-1,0]

# Perform the Wilcoxon signed-rank test
stat, p_value = wilcoxon(data1, data2)
print(f'Question 18')
print(f'Wilcoxon test statistic: {stat}')
print(f'p-value: {p_value}')

# Interpret the result
alpha = 0.05
if p_value < alpha:
    print('Reject the null hypothesis: There is a significant difference between the two samples.')
else:
    print('Fail to reject the null hypothesis: There is no significant difference between the two samples.')
```

Sample WORDij Logs Pre-Survey:

Text file name: C:\Users\McKenna-Dell\Downloads\SurveyCSV\Q1.txt

Configuration:

Drop list file name: C:\Users\McKenna-Dell\Downloads\WORDij30 for 64-bit Windows\stop-words-collection-2011.11.21\stop-words\stop-words-english5.txt

Include list file name: none

Character filter file name: none

Select list file name: none

Drop words less frequent than: 3

Drop word pairs less frequent than: 3

Preserve wordpair order: yes

Include numbers as words: no

Link until sentence end: yes

Link steps: 3

Linkage Strength Method: CONSTANT

Remove punctuation inside words: yes

Compound words: combine

Using Porter stemming algorithm: no

Using Chinese filter: no

Replace English contracted forms: no

Replace 's ending by is word: no

The program processed the file in 0.000359888 minutes.

Sample WORDij Log Mid-Survey:

Text file name: C:\Users\McKenna-Dell\Downloads\SurveyCSV\Q19.txt

Configuration:

Drop list file name: C:\Users\McKenna-Dell\Downloads\WORDij30 for 64-bit Windows\stop-words-collection-2011.11.21\stop-words\stop-words-english5.txt

Include list file name: none

Character filter file name: none

Select list file name: none

Drop words less frequent than: 3

Drop word pairs less frequent than: 3

Preserve wordpair order: yes

Include numbers as words: no

Link until sentence end: yes

Link steps: 3

Linkage Strength Method: CONSTANT

Remove punctuation inside words: yes

Compound words: combine

Using Porter stemming algorithm: no

Using Chinese filter: no

Replace English contracted forms: no

Replace 's ending by is word: no

The program processed the file in 0.000523858 minutes.

Outputs from Wilcoxon Python code

```
Question 7
Wilcoxon test statistic: 5.5
p-value: 0.0031896997062168704
Reject the null hypothesis: There is a significant difference between the two samples.
```

```
Question 8
Wilcoxon test statistic: 10.0
p-value: 0.009864624387284948
Reject the null hypothesis: There is a significant difference between the two samples.
```

```
Question 9
Wilcoxon test statistic: 23.0
p-value: 0.35290082341101536
Fail to reject the null hypothesis: There is no significant difference between the two samples.
```

```
Question 10
Wilcoxon test statistic: 32.5
p-value: 0.5974376336493683
Fail to reject the null hypothesis: There is no significant difference between the two samples.
```

```
Question 11
Wilcoxon test statistic: 39.0
p-value: 1.0
Fail to reject the null hypothesis: There is no significant difference between the two samples.
```

```
Question 12
Wilcoxon test statistic: 37.0
p-value: 0.8710263119498705
Fail to reject the null hypothesis: There is no significant difference between the two samples.
```

```
Question 13
Wilcoxon test statistic: 42.0
p-value: 0.7815112949987133
Fail to reject the null hypothesis: There is no significant difference between the two samples.
```

```
Question 14
Wilcoxon test statistic: 25.5
p-value: 0.8344945476326624
Fail to reject the null hypothesis: There is no significant difference between the two samples.
```

```
Question 15
Wilcoxon test statistic: 15.0
p-value: 0.026617440024176844
Reject the null hypothesis: There is a significant difference between the two samples.
```

```
Question 16
Wilcoxon test statistic: 13.5
p-value: 0.06960936453952438
Fail to reject the null hypothesis: There is no significant difference between the two samples.
```

```
Question 17
Wilcoxon test statistic: 42.0
p-value: 0.46685427082272546
Fail to reject the null hypothesis: There is no significant difference between the two samples.
```

```
Question 18
Wilcoxon test statistic: 28.0
p-value: 0.6467015473042993
Fail to reject the null hypothesis: There is no significant difference between the two samples.
```

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