Work in Progress: Navigating Undergraduates' Perspectives on Macroethical Dilemmas in Aerospace Engineering

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Abstract

This work-in-progress study aims to qualitatively examine undergraduate students' understanding of ethical dilemmas in aerospace engineering. Macroethics is particularly relevant within the aerospace industry as engineers are often asked to grapple with multi-faceted issues such as sustainable aviation, space colonization, or the military industrial complex. Macroethical education, the teaching of collective social responsibility within the engineering profession and societal decisions about technology, is traditionally left out of undergraduate engineering curricula. This lack of macroethics material leaves students underprepared to address the broader impacts of their discipline on society. Including macroethical content in the classroom helps novice engineers better understand the real implications of their work on humanity. Previous literature has explored how specific pedagogical interventions impact students' decision-making, but few studies delve into undergraduate students' awareness and perceptions of the issues themselves. Thus, it is essential to examine how students' perceptions of macroethical dilemmas are evolving in order for instructors to effectively meet the needs of their students.

This study addresses the need to better understand student awareness of macroethical issues by extending upon previous research to qualitatively analyze responses from an iteration of a macroethical perceptions survey (n = 81) administered to undergraduate aerospace engineers at a large, Midwestern, predominantly white, research-intensive, public university. Our prior work has been used to develop and iterate upon a mixed-methods survey that seeks to understand students' perceptions of ethical issues within the aerospace discipline. In the most recent version of our survey instrument, thirty-one Likert-scale questions asked about students' feelings towards *the current state* of aerospace engineering and their *ideal state* of the aerospace field. Within this survey, eight Likert-scale prompts are followed by open-ended questions asking students to explain their answers in-depth. For instance, if students agreed or strongly agreed with the statement *'It is important to me to use my career as an aerospace engineer to make a positive difference in the world.'*, a follow-up item asked students to explain what positive differences they would like to make in the world.

Student responses were analyzed using a combination of a deductive and inductive thematic analyses. Researchers first applied an a priori coding scheme onto responses that was initially developed using constructivist grounded theory, then used inductive analysis to account for new themes that naturally emerged within the data. The analysis delved deeper into students' moral engagement towards ethical issues, their perceptions of who is affected by these dilemmas, and how they have seen these dilemmas addressed in both academic and professional settings. Preliminary results from the study identified that students have a wide spectrum of *awareness* of relevant issues and express varying levels of *acceptance* about the state of aerospace engineering.While some students exhibited signs of *inattentiveness,* or limited ability to consider

viewpoints beyond their own, others demonstrated abilities to *see multiple perspectives* and critically *analyze* systems of power that influence how macroethical issues are addressed. Similarly, students also demonstrated varying degrees of acceptance, some demonstrating signs of *apathy* or moral disengagement regarding the field of aerospace engineering, others indicating signs of *conflict,* or a heightened state of stress about opposing ideals and values, and a final group of students indicating a desire to *challenge* or reform the existing culture of the discipline. These emergent themes will be used to inform teaching practices concerning engineering ethics education, refine future iterations of macroethics lesson content and survey instruments, and further incentivize the integration of macroethical content throughout aerospace engineering curricula.

Introduction

Aerospace engineering is a dynamic field often considered to be at the forefront of technological innovation. While aerospace has played a pivotal role in shaping societal progress, these advancements have also raised ethical concerns that engineers must consider as they navigate the discipline. These broader ethical dilemmas (e.g Environmental impact, weaponization of space, and unequal access to aerospace technology) are multifaceted issues that require critical thinking skills to make informed decisions [1], [2]. Despite the growing need to address these ethical considerations in education, current practices in undergraduate aerospace engineering programs often leave students ill-prepared to properly navigate the complex ethical landscape of the field [3], [4].

The Accreditation Board for Engineering and Technology (ABET) mandates that ethics be included in undergraduate engineering curricula, emphasizing that graduates should be able to "recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts" [5]. While this requirement seemingly demonstrates the importance of integrating ethics education into engineering curricula, the lack of specificity as to how, where, or the type of ethics instruction required often results in significant variations across institutional or even departmental contexts [3], [6], [7]. Engineering ethics encompasses both *microethics*, which focuses on individual engineers' decision-making, and *macroethic*s, which addresses the "collective social responsibility within the engineering profession and societal decisions about technology" [8]. While microethics education is often incorporated into engineering curricula, macroethical education has historically been lacking, hindering students' critical consciousness [9] about ethical issues that extend beyond individual decisions . The absence of structured macroethics education not only impedes students' ability to productively engage with their peers about ethical dilemmas, but also obstructs their understanding of diverse perspectives in engineering, essential for co-constructing knowledge on ethical issues [10]. Compounding this challenge are the dominant demographics present within aerospace engineering—white, cis-gendered, middle- and upper-class, male students—whose majority privilege shapes perceptions of macroethical issues in the field [2]. Macroethics education has

the potential to serve as a catalyst for reforming engineering education, shifting towards a field that innovates and creates while also being grounded in principles of justice.

To date, engineering ethics education has been studied through a variety of methods and approaches [7], [8], [11], but few have considered student-centered approaches to enhance the engineering curricula [1]. Jimerson et al. developed a survey instrument to assess engineering students' perceptions of ethical issues to better inform educational practices[12], which prompted further studies to analyze student attitudes toward relevant macroethical issues in engineering [13].

Prior iterations of our research have looked to develop macroethical content for undergraduate aerospace engineering courses and develop survey instruments to capture student perspectives of prevalent ethical issues in the field [14], [15]. In our previous work investigating qualitative student data, we identified that students have varying levels of awareness of macroethical issues, with some students expressing forms of acceptance about the state of the aerospace industry and others displaying signs of resistance [15]. In this study, we seek to further explore the awareness levels of undergraduate students by inquiring about how they feel about their macroethics education in aerospace engineering. Moreover, we want to better understand how students choose to accept or resist the current state of the aerospace discipline, specifically examining how and/or why students engage with macroethical issues in the field. We also hope to learn more about the contexts that students discuss these issues in and who is considered in these conversations. As a result, this study seeks to continue exploring students' understanding of macroethics and its role within aerospace engineering education and practice by asking the following research question: *What are students' perceptions and awareness of macroethical issues in aerospace engineering?*

Methods

Within this work-in-progress study, we report on qualitative data from the most recent iteration and administration of our macroethics survey of undergraduate aerospace engineering students (n = 81). This survey was implemented within a Fall 2023 sophomore-level aerospace engineering course at a large, Midwestern, predominantly white, research-intensive, public university. The course serves as an introduction to aerospace engineering, providing an overview of flight technologies, aeronautics, and astronautics. Macroethical material was embedded throughout the course content, but the survey was administered early into the semester in order to gauge the macroethical perceptions that students were bringing into the course. This particular course was chosen as the sample for our study due to several members of our research team making up the class instructional team.

This survey iteration contained a new assortment of Likert-scale items developed by a team with varying levels of experience within the aerospace discipline. This team comprised 2 undergraduate engineering students, 5 graduate engineering students, 2 engineering education

faculty with aerospace backgrounds, and 3 practicing aerospace engineers. This research team used their host of experiences in engineering and education, along with initial findings from an exploratory factor analysis[16], to draft questions inquiring about students' macroethical education, their perceptions of the aerospace field, and their hopes for the future of the industry. The finalized survey instrument contained thirteen Likert-scale questions that asked students about their *ideal state* of the aerospace engineering field and twenty-eight that asked about their perceptions of the *current state* of the discipline, with example survey items featured below in Table 1.

Table 1. Likert-Scale Example Items

***Current State* of Aerospace (n=28)**	***Ideal State* of Aerospace (n=13)**
"I have talked with people about my feelings about how aerospace engineering technology is used."	"I would like to learn more about how aerospace engineering impacts people and the world around us."
"I think I'll be able to find a job in aerospace engineering that aligns with my values."	"I would like my aerospace engineering professors to create opportunities in engineering classes to discuss the societal impacts of aerospace engineering."

In the survey students were asked to rate to what degree they agreed with a variety of statements regarding macroethics, and eight of these prompts contained qualitative follow-up questions asking students to explain their answer. While two of these prompts were asked to all respondents, the remaining six questions only appeared if a student responded in a particular way to the question. A list of the analyzed qualitative follow-up survey items are provided in Appendix A along with their corresponding Likert-scale questions.

The analysis of student open-response data was led by the first author and used a combination of deductive and inductive thematic analyses. Responses to each follow-up item were read through and analyzed by the first, second, fourth, and fifth authors. In the initial coding stage, the first and second author separately analyzed qualitative data applying an a priori coding scheme developed in prior research [15]. This coding scheme categorized perspectives of *student awareness,* with researchers memoing throughout the coding process in order to capture thoughts, ideas, or questions that were raised from the data. The researchers then took an additional pass through the data, this time inductively analyzing students' responses to account for any themes that naturally emerged from the data set. After these introductory passes, the first and second author met to review the coding process and discuss similarities or differences in their interpretations of student responses. The two researchers then developed a refined codebook based on findings from the thematic analyses and conducted another iteration of analysis. In this secondary round, the fourth and fifth authors were added to the analysis team, and researchers were asked to apply the refined codebook to deductively analyze the student response data. We report on data from this secondary round of analysis below, but authors intend

to continue iteratively analyzing the data until we feel that our coding schemes accurately reflect the entirety of student responses.

Findings

From the data, we were able to expand upon previous work to further define types of student awareness perspectives of macroethical issues in the aerospace industry as well as deeper understanding of the level of acceptance students have about the state of the discipline. Furthermore, students also identified a variety of community members (friends, family, academic peers, faculty, etc.) who they discuss macroethics with and in what contexts they take place.

Student Awareness

Themes relating to a spectrum of student *awareness*, or their in-depth understanding and analytical capabilities, of macroethical issues in aerospace engineering naturally emerged from the data. This spectrum highlights varying considerations of other perspectives and higher-order thinking skills in regard to ethical dilemmas. Initial rounds of analyses brought forth three differing themes, *inattentive, sees both sides,* and *analytical,* which are described in Table 2.

Table 2. Themes of Student Awareness of Macroethical Dilemmas

Theme	**Definition**	**Example Excerpt**
Inattentive	Limited or lower-order thinking, not considering other perspectives on issue, no analysis occurring	"[The field of aerospace engineering] pretty much aligns with how I'd like it."
Sees Multiple Perspectives	Ability to recognize various perspectives on issue, early signs of critical thinking with limited analysis	"I think while there are some benefits to it, each aerospace industry also has its drawbacks, and the potential to hurt more people than they help"
Analytical	Able to critically evaluate aspects of ethical issues or higher-level consideration of differing perspectives of issue	"… believe strongly that you will be hard-pressed to find something created on the scale that this field operates on which does not have a negative impact, especially with the current practices of the economic system, consumer ideology, and monetization mindset which permeates the globe."

The importance of student awareness of broader macroethical issues in engineering cannot be overstated. While *inattentive* forms of awareness are not inherently wrong, they present both a unique challenge and opportunity for engineering instructors. The difficulty lies in how to provide material to students that prompts critical consciousness development as well as the ability to recognize or value other perspectives on ethical issues. However, by integrating macroethics material into existing aerospace curricula, educators have the opportunity to reshape ethics education and potentially fill in these gaps in awareness. Students that use *analytical*

characteristics or attempt to *see multiple perspectives* demonstrate higher-order thinking and self-reasoning abilities in relation to engineering. In an industry where decisions have potentially drastic consequences, awareness of ethical dilemmas could be considered a tool for ethical engineering, enabling students to engage in the complexities of the industry with a nuanced understanding on the political, societal, environmental, or global implications of aerospace innovation.

Student Acceptance

Within student data, themes also emerged that depicted varying degrees of *acceptance,* or willingness to agree with the culture of the aerospace engineering community. This theme attempts to encapsulate how students react to or choose to engage (or not engage) with macroethical issues in the field of engineering, with certain students demonstrating signs of *apathy, conflict,* or a desire to *challenge* the culture of aerospace engineering.

Table 3. Themes of Student Acceptance of Macroethical Dilemmas

Theme	**Definition**	**Example Excerpt**
Apathy	Feelings of indifference regard state of aerospace, sense of moral disengagement present	"[conversations about macroethics are] usually not super extensive, I just mention how I'll end up working for a company and building death machines."
Conflict	Mixed emotions and distress regarding contrasting feelings about the state of aerospace	"I am an Arab Muslim from Syria. A huge issue I have is that when I do get hired at a company I love, there's a huge ethical issue rooted deeply in me. I have personally seen F18s bomb cities which I call home. I have seen American tanks destroy cities I call home. That leads me to believe that if I do help out by getting hired at any of these defense companies, I am directly contributing to the killing and destruction of my home and my people."
Challenges	Questioning the state of aerospace, desire to improve or change the field	"I want to try to incorporate sustainability and diversity. As a queer woman both of those things are really important to me. I want to help groups of people who need aerospace resources but may not have access to them."

In order to change how macroethical dilemmas in aerospace are addressed by the community, students need to see their potential to create a positive impact, which will establish a desire for them to want to effect change. As future leaders in aerospace, these students possess the ability to influence cultural norms, but often are discouraged due to their lack of agency or perceptions of social progress in the discipline. This impacts students' *acceptance* of the current state of the aerospace industry; and the amount of overwhelm students may experience about the culture of

aerospace can influence how they choose to act within the broader engineering community. Feelings of *apathy* are commonplace in engineering [17], [18], with students and practitioners alike disengaging when their work misaligns with their moral values [19], [20]. In contrast, engineers experiencing *conflict* are often at a heightened state of stress or worry about negative aspects of the field. These feelings of conflict are typically internalized by students, as they often go against the dominant ideology of the aerospace engineering community. There are, however, examples of students' wanting to *challenge* these narratives, expressing desires for the field to be reformed in order to address these macroethical issues. Students have a wide perspective on how to address the state of aerospace and who should ultimately be responsible for taking action.

Conclusion

This investigation aimed to gain a better understanding of undergraduate perspectives of macroethics in aerospace engineering in order to inform the development of macroethics material for the classroom. By expanding upon our previous explorations of student perceptions of macroethics, we were able to establish a deeper understanding of students' awareness and acceptance of ethical issues that permeate the aerospace industry. Based on these findings, we plan to continue analyzing and refining the themes that emerged from participant data in future work. We then intend to investigate what student behaviors, community norms, and other subjective factors influence students' ability to morally disengage or act unethically in aerospace communities. These findings offer significant implications for engineering educators who are interested in creating a more inclusive, adaptive, and effective learning environment for students. By understanding that students enter the classroom with an extremely wide range of perspectives, awareness, and experiences engaging with ethical issues, faculty have the opportunity to address these differences by adapting curricula and tailoring instruction to address these concerns. Reforming how we discuss macroethics in the classroom allows educators to have the ability to positively impact student motivation, critical thinking abilities, and effective communication within engineering spaces. This research paper highlights the need for macroethics education integration into engineering curricula. By encouraging students and faculty alike to challenge the status quo of the aerospace community, we can reevaluate and reform the discipline's ethical foundations. Furthermore, through the investigation of students' perceptions of macroethical issues, we have the potential to transform ethics education within aerospace engineering, fostering heightened ethical awareness and social responsibility amongst the upcoming generation of aerospace engineers.

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Appendix

A. Survey Instrument Questions

1. Please indicate how much you agree with the following statements about the **current** state of aerospace engineering and your *experiences* in an aerospace engineering program (*Likert-scale from strongly disagree to strongly agree*).

    a. When discussing macroethical issues in my classes, there have been a variety of viewpoints present.
    b. Aerospace engineering is a “technical” space where “social” or “political” issues such as inequality are irrelevant to engineers’ work.
    c. It is a priority for me as an aerospace engineer to help the United States develop better weapons than other nations.
    d. I have talked with my aerospace engineering professors out-of-class regarding concerns about the societal impacts of aerospace engineering.
    e. I have talked with people about my feelings about how aerospace engineering technology is used.
        i. **Follow-Up: Who do you talk to about these issues?** *(if agree or strongly agree)*

2. Please indicate how much you agree with the following statements about the **current** state of aerospace engineering and your *experiences* in an aerospace engineering program (*Likert-scale from strongly disagree to strongly agree*).

a. I have often had the opportunity to bring up macroethical issues in my aerospace engineering classes.
b. Aerospace engineering helps a greater number of people in society than it harms.
c. Aerospace engineers do not have to consider the societal impacts of new technology they develop in their engineering work.
d. In my engineering coursework thus far there has not been a substantial emphasis on macroethics in aerospace engineering.
e. Aerospace companies do work that benefits all of humanity
    i. **Follow-Up: What aerospace work benefits all of humanity?** *(if agree or strongly agree)*
    ii. **Follow-Up: What aerospace work does not benefit all of humanity?** *(if disagree or strongly disagree)*

3. Please indicate how much you agree with the following statements about the **current** state of aerospace engineering and your *experiences* in an aerospace engineering program (*Likert-scale from strongly disagree to strongly agree*).
    a. There is a conflict between my personal values and the job opportunities available in the aerospace engineering industry.
    b. The ethical curriculum I have received in my aerospace engineering courses so far has prepared me to engage in respectful and challenging dialogues with my peers.
    c. My aerospace engineering professors include discussion of complex societal issues in our class time.
    d. In today's world, an engineer has no responsibility for how the technology that they develop is ultimately used.
    e. I am concerned that I will have to take an aerospace engineering job that does not align with my values.
        i. **Follow-Up: What factors might influence someone to take an aerospace engineering position that doesn't align with their values?**

4. Please indicate how much you agree with the following statements about the **current** state of aerospace engineering and your *experiences* in an aerospace engineering program (*Likert-scale from strongly disagree to strongly agree*).
    a. I think I'll be able to find a job in aerospace engineering that aligns with my values.
    b. My aerospace engineering professors tend to avoid conversation topics that could be controversial.
    c. I feel comfortable having a different view than my aerospace engineering professor on macroethical issues.
    d. It is difficult to navigate how aerospace engineering impacts different groups of people and society as a whole.

e. I know of aerospace companies that I wouldn't consider working for because their practices are unethical.
    i. **Follow-Up: What are the practices of the companies that you consider to be unethical?** *(if disagree or strongly disagree)*

5. Please indicate how much you agree with the following statements about the **current** state of aerospace engineering and your *experiences* in an aerospace engineering program (*Likert-scale from strongly disagree to strongly agree*).
    a. My aerospace courses have prepared me to consider the societal impacts of technology I will work on.
    b. Aerospace engineers today are expected to do the tasks assigned to them without worrying about the macroethics of why they're being asked to do the tasks.
    c. My aerospace professors have established a classroom space where I feel comfortable bringing up my viewpoint about macroethical issues.
    d. It is easy to be an ethical engineer in the aerospace industry.
    e. Aerospace engineering is a “technical” space where “social” or “political” issues such as inequality are irrelevant to engineers’ work.
    f. My aerospace engineering professors seem to be aware of the social implications of the field
    g. My professors know the right way to think about these macroethical issues.
    h. I have been offered the opportunity to talk with other students about how aerospace engineering technology is used.
        i. **Follow-Up: What was the context of these conversations? In what setting did you have these conversations?** *(if agree or strongly agree)*

6. Please indicate how much you agree with the following statements about the **ideal** state of aerospace engineering and your *experiences* in an aerospace engineering program (*Likert-scale from strongly disagree to strongly agree*).
    a. I would like to have the opportunity to talk to my aerospace engineering professors out-of-class regarding concerns about the societal impacts of aerospace engineering
    b. An engineering professor’s job should also include teaching applicable ethics in addition to teaching the technical content.
    c. I would like to learn more about how aerospace engineering impacts people and the world around us.
    d. I wish there was more emphasis on macroethics in aerospace engineering in my engineering coursework.
    e. Aerospace engineering work should be used to help the people across the world who have the least amount of social power

    i. **Follow-Up: In what ways does the current state of aerospace engineering align and misalign with the way you'd like it be?**

7. Please indicate how much you agree with the following statements about the **ideal** state of aerospace engineering and your *experiences* in an aerospace engineering program (*Likert-scale from strongly disagree to strongly agree*).
    a. In an ideal world, aerospace engineers should be able to do the tasks assigned to them without worrying about the macroethical implications of the work.
    b. I wish my aerospace engineering professors would include more discussion of complex societal issues in our class time.
    c. When aerospace engineering technology is used to cause harm, the engineers who created that technology should hold some responsibility.
    d. I would like my aerospace engineering professors to create opportunities in engineering classes to discuss the societal impacts of aerospace engineering.
    e. It is important to me to use my career as an aerospace engineer to make a positive difference in the world.
        i. **Follow-Up: What is that "positive difference in the world" you would hope to make?***(if agree or strongly agree)*

8. Please indicate how much you agree with the following statements about the **ideal** state of aerospace engineering and your *experiences* in an aerospace engineering program (*Likert-scale from strongly disagree to strongly agree*).
    a. I think it is important to talk about how aerospace engineering technology is used.
    b. Engineers should be concerned with the impact of their work, not just the technical details of the engineering work.
    c. I'd like to be told the right way to address macroethical issues by people who know the best solutions.
        i. **Follow-Up: Who do you think knows the best solutions?***(if agree or strongly agree)*