Developing Critically-Conscious Aerospace Engineers through Macroethics Curricula: Year 3 (IUSE)

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Introduction

ABET Student Outcome 4 requires that an undergraduate engineering program gives their students "an ability 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" [1]. This outcome was created from three separate outcomes pre-2019, which focused separately on (f) an understanding of professional and ethical responsibility; (h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context; and (j) a knowledge of contemporary issues [2].

Student Outcome 4 is much more powerful than the pre-2019 outcomes because it suggests that "ethics" encompasses the economic, environmental, and social impacts of engineering. However, is this focus on *macroethics* being enacted in engineering classrooms that claim to achieve Student Outcome 4? In our experience as engineering students, faculty, and education researchers, it is usually not. Engineering education typically focuses on *microethics*, or individual relations within the engineering profession [3]. These frequently consist of accident case studies focusing on individual professionalism, integrity, and technical due diligence. While discussions about microethics are necessary, at best they paint an incomplete picture of the ethical responsibility of engineers. At worst, they reinforce the pervasive myth that engineering is apolitical [4], which flings open the door for the accidental *or purposeful* design and use of engineering technology for harm to people and planet.

Our design-based IUSE research project addresses this area of concern in engineering education, called *macroethics*, specifically centered on the discipline of aerospace engineering. Our focus on aerospace engineering comes from the Co-PIs' former and current connections to the discipline, and the need to address unique macroethical challenges in aerospace engineering. For example, one prominent issue is the deep connections between aerospace engineering and the military-industrial complex. Aerospace engineering students are very aware of the fact that many of the jobs available to them are militaristic to some degree, and their perspectives on the issue are varied [5].

Our project is undertaking integrated research and curriculum development to better understand students' perceptions of macroethical issues in aerospace engineering, and to develop curriculum specifically for engineering science courses that helps students to build their ethical awareness. Specifically, we ask two research questions and one curriculum assessment question:

> **RQ1)** What are undergraduate students' current awareness and perceptions of macroethical issues in aerospace engineering?
>
> **RQ2)** In what ways do students feel their education is or is not preparing them to address macroethical issues?
>
> **RQ3)** How does the macroethical curriculum impact students' perceptions and awareness of macroethical issues and their desire to engage with the macroethical implications of their future work?

In this paper, we discuss recent results from both our research and curriculum thrusts, and we conclude with a reflection on future work as a part of this IUSE grant and beyond.

Research on Students' Perceptions of Aerospace Macroethics

In 2025, we conducted eight interviews with undergraduate aerospace students and two follow-up focus groups to investigate students' perceptions of macroethical issues in aerospace engineering. These data collection events were conducted at a large, predominately white, research-intensive university in the Midwestern United States. The data collection and the subsequent analysis were grounded in the Theory of Planned Behavior [6]. This psychological theory hypothesizes how one's intentions and behaviors are influenced by one's attitudes, cultural norms, and perceived behavioral control. We are currently analyzing this data inductively using methods from grounded theory. While the formalized coding scheme is still under development, in this paper we present a handful of high-level themes starting to appear in the data.

The interview protocol discussed a number of macroethical aspects of students' future careers. But, one of the most prominent and salient topics is the presence of the military-industrial complex in aerospace engineering. Some students indicated a strong desire to work on military technologies and contribute to the defense industry, while others forcibly rejected this type of career. It is interesting to note that regardless of their views on defense work and its prevalence in aerospace, a majority of students identified feeling a lack of control over their career choices. As this was not an explicit question within the interview or focus group protocols, it was interesting to see this singular theme arise repeatedly across interviews from students with all different backgrounds. Given the tumultuous job market and uncertain political climate in the U.S. today, this feeling of restriction in career opportunities may be attributed to external circumstances particular to the time the data were collected (the Winter 2025 semester). However, it is important to note that only two of the eight total participants explicitly mentioned the current job market instability as driving their career decisions. Rather, students repeatedly highlighted their current position as students with little job experience, describing feeling that they lack control over their careers due to limited prior job experience, financial stressors, or both.

Many students identified feeling that they needed to take any career opportunity they could find, regardless of its alignment with their personal values, at this initial stage of their career and expressed hope that future career seniority would allow them more flexibility in aligning their job with their personal interests and values. One student who did not express any trepidation over career control had recently accepted a full-time position at a company they had previously interned for, and felt aligned well with their values. Another student shared that, while they had limited prior job experience, they felt strongly aligned with their values and anticipated relying heavily on those values to navigate their career trajectory. A majority of students also expressed that they were invested in finding a job which they felt made a difference in the world. When asked to further elucidate their perspectives, students responded with a wide array of answers including industry and academic research, space exploration, aircraft development and defense work. Many, but not all, students identified a long-running interest in the aerospace field in general.

Research on Students' Perceptions of Public Welfare and Campus Militarism

Another result of this project has been the development of a sub-project using a longitudinal mixed-methods survey intended to further the characterization of ethical disengagement among students, particularly with respect to the military-industrial complex and its presence on campus. Each year, the survey will collect data on the importance engineering and computer science students place on public welfare and what would constitute a successful career in engineering. We will also provide open-ended prompts on issues pertaining to the military-industrial complex, such as asking students how the campus presence of military contractors may have influenced their goals and to what extent engineers hired by military contractors are responsible for the applications of their product. With the current discussion-leading data on student ethical disengagement coming from a study polling wealthy, predominantly white schools (MIT, UMass Amherst, Smith College, and Olin College) [7], we are explicitly surveying students from five campuses within the California State University system. This is the largest university system in the nation, and demographically is better representative of the U.S. college student population in terms of social class and racial/ethnic background. As the project annually collects data over the course of four years, we will be able to compare how welfare and career perceptions trend between our institutions of interest and previously studied, more affluent institutions. Presently, we have collected data from two of five of our target campuses in the first year of data collection.

Aerospace Macroethics Curriculum Development and Implementation

In 2025, we repeated macroethics lessons in four courses at the University of Michigan-Ann Arbor (U-M) and the University of Colorado Boulder (CU), courses in which we had delivered lessons in previous years. These courses included sophomore aerospace vehicle design, junior orbital mechanics, and both aircraft and spacecraft senior design courses. The senior design lessons focused on the military-industrial complex and the junior lesson focused on the Federal Communications Commission (FCC)'s space debris regulations (as described in [8]). In the sophomore course, we gave students the choice to join one of four different dialogues on the military-industrial complex, commercial spaceflight, aviation regulations, and space debris regulations.

Additionally, we worked with Prof. Kaela Martin to implement lessons in her space mechanics and spacecraft senior design courses at Embry-Riddle Aeronautical University, Prescott (ERAU). We delivered the military-industrial complex lesson to one section of the senior design course and the FCC space debris regulation to two sections of the space mechanics course. For each lesson, Prof. Martin helped to tailor the content to her class's context and duration. This was particularly challenging because we only had 50 minutes for each space debris lesson, 30 minutes less than we had previously had for this lesson. Prof. Martin also played an active role in facilitation of the lessons, consistent with the grant's goal of building instructor agency in leading classroom discussions on macroethics. Post-class survey results show that all of the lessons conducted in Fall 2025, both at ERAU and U-M, were well-received by students, as shown in Figure 1.

Despite these positive results, we did experience some challenges with the first space debris lesson. We gave students a social perspective on the FCC's space debris regulations (exemplified by the public comment given by the Universal Church of Christ, a progressive Christian denomination

concerned with environmental justice) and asked them to compare this perspective to the perspective of satellite operators. This led to students critiquing the social perspective for not including rigorous "scientific evidence" in their argument in favor of space debris regulations. We believe some students left the lesson devaluing and dismissing social perspectives, which is the exact opposite as what we intended. So, for the second offering of the space debris lesson, we changed the discussion question to "What does this social perspective add to the perspectives of the satellite operators?" This framing had a positive effect on the dialogue, as it encouraged students to understand and seek out the value social perspectives bring to engineering, rather than dismiss them as unimportant and irrelevant to the engineering discipline.

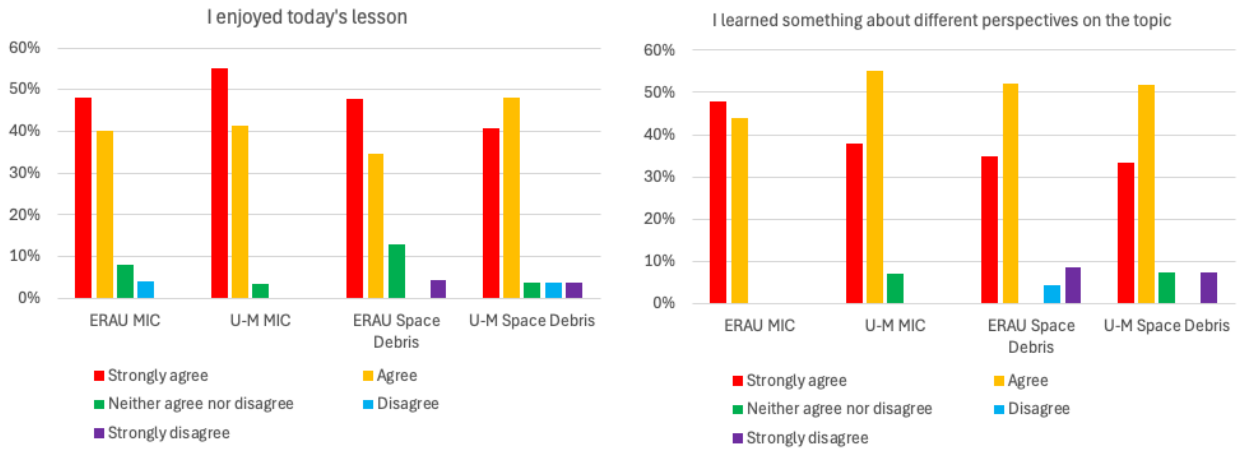

Figure 1. Post-lesson survey results for the military-industrial complex (MIC) and space debris dialogues at Embry-Riddle Aeronautical University, Prescott (ERAU) and the University of Michigan-Ann Arbor (U-M).

In the Summer of 2025, members of the research team engaged in a conjecture mapping exercise. A conjecture map is a design-based research methodology for identifying theoretically salient features of an educational intervention and mapping out how these work together to produce desired outcomes [9]. The goal of this conjecture mapping exercise is to draw out the important aspects of our macroethics lessons and to identify theoretical conjectures about how the tools used in the lesson ("embodiments") are used by students ("mediating processes") to achieve certain outcomes. After continuing to revise our conjecture map through discussions as a research team and with instructors, these theoretical conjectures will serve as the foundation for future targeted investigations into the efficacy of our macroethics lessons.

Our preliminary conjecture map (Figure 2) contains eleven embodiments, nine mediating processes, and three outcomes of the lesson. The most salient feature of this conjecture map is the three outcomes we want students to develop through the lesson: dialogue skills to productively discuss difficult and personal topics; an awareness of the ways in which seemingly apolitical technical decisions have ethical dimensions; and the moral resilience to have confidence in their beliefs, know why they have these beliefs, and be able to change their beliefs in the future. We design our macroethics lessons around these three goals, rather than lecturing or advocating for a particular position on an issue. Our lessons currently address the first two outcomes well, and we have

identified that we need to engage experts in other fields in order to develop lessons that truly help students develop moral resilience and practice ethical decision-making strategies.

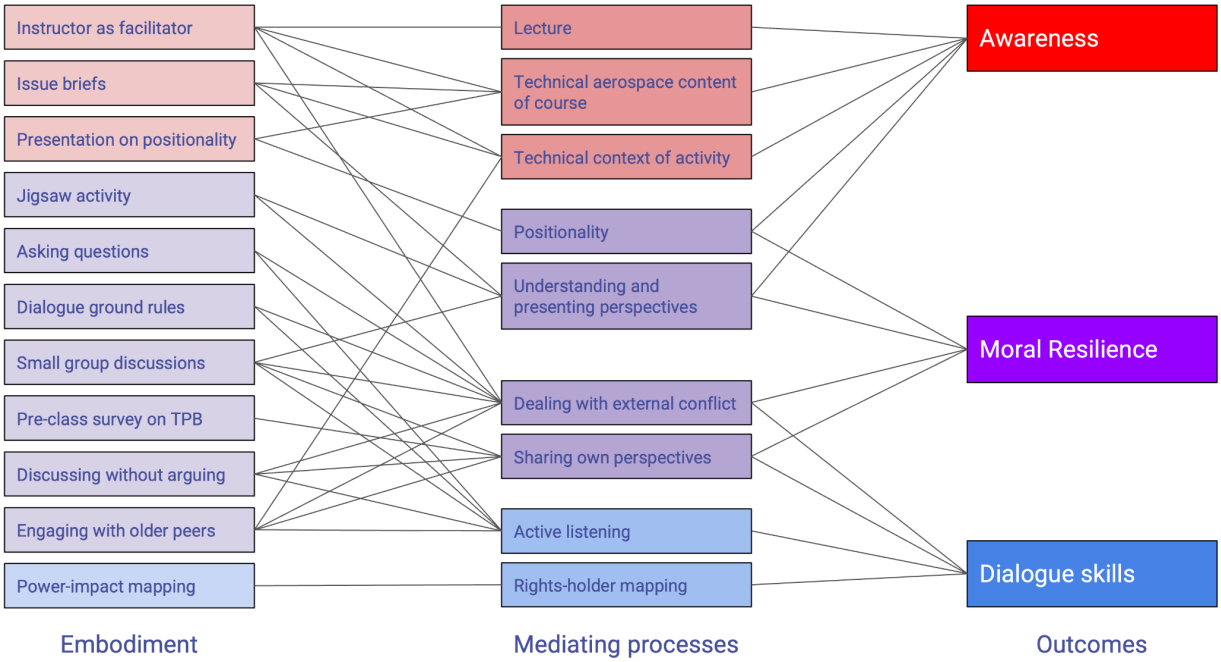

Figure 2. Draft conjecture map of the macroethics lessons

Future Work

In the final year of the grant, we intend to run macroethics lessons at our previous implementation sites of University of Michigan-Ann Arbor; California State University, Los Angeles; and Embry-Riddle Aeronautical University, Prescott. We are also currently coordinating with an additional institution to potentially expand to in the coming semester. While conducting the lessons, we are also specifically collecting data from senior students in aero- and astro-specific capstone design courses. This is an emergent focus of our project due to a preliminary finding of significant differences in macroethical perceptions between aerospace engineering students interested in aircraft and those interested in spacecraft. We will perform qualitative analysis of this data, and we intend to design a workshop to share our findings with aerospace engineering faculty members at the American Institute for Aeronautics & Astronautics SciTech Forum in 2027. We are also preparing multiple conference and journal publications related to the grant, on the topics of our macroethics lessons, our Likert-scale survey of students' macroethical perceptions, and on the aforementioned finding regarding differences between aero- and astro-focused aerospace students. Finally, the grant team is meeting with potential research collaborators outside of our current team to decide on the next steps needed to pursue the goals of the project beyond the lifetime of the grant, particularly recognizing the need to bring in historians, sociologists, ethicists, and other interdisciplinary scholars who hold critical expertise beyond our own.

Acknowledgements

This material is based upon work supported by the National Science Foundation under Grants No. 2236148 and No. 2236227. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

References

[1] ABET, "Criteria for Accrediting Engineering Programs, 2025 - 2026," ABET. Accessed: Oct. 18, 2025. [Online]. Available: https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2025-2026/

[2] "The Proposed Revisions To Criteria for Mapping Criteria 3 and 5," ABET, Inc., Oct. 2017. [Online]. Available: https://www.abet.org/wp-content/uploads/2018/03/C3_C5_mapping_SEC_1-13-2018.pdf

[3] J. R. Herkert, "Ways of thinking about and teaching ethical problem solving: Microethics and macroethics in engineering," *SCI ENG ETHICS*, vol. 11, no. 3, pp. 373–385, Sep. 2005, doi: 10.1007/s11948-005-0006-3.

[4] E. A. Cech, "The (Mis)Framing of Social Justice: Why Ideologies of Depoliticization and Meritocracy Hinder Engineers' Ability to Think About Social Injustices," in *Engineering Education for Social Justice*, vol. 10, J. Lucena, Ed., in Philosophy of Engineering and Technology, vol. 10. , Dordrecht: Springer Netherlands, 2013, pp. 67–84. doi: 10.1007/978-94-007-6350-0_4.

[5] E. A. Strehl, M. Ennis, A. W. Johnson, and C. L. Bowen, "Work in Progress: Undergraduate Student Perceptions of Macroethical Issues in Aerospace Engineering," presented at the 2023 ASEE Annual Conference & Exposition, Jun. 2023.

[6] I. Ajzen, "The Theory of Planned Behavior," *Organizational Behavior and Human Decision Processes*, vol. 50, pp. 179–211, 1991.

[7] E. A. Cech, "Culture of Disengagement in Engineering Education?," *Science, Technology, & Human Values*, vol. 39, no. 1, pp. 42–72, Jan. 2014, doi: 10.1177/0162243913504305.

[8] A. Johnson and C. Bowen, "Developing Critically-Conscious Aerospace Engineers through Macroethics Curricula: Year 2 (IUSE)," in *2025 ASEE Annual Conference & Exposition Proceedings*, Montreal, QC: American Society for Engineering Education, Jun. 2025.

[9] W. Sandoval, "Conjecture Mapping: An Approach to Systematic Educational Design Research," *Journal of the Learning Sciences*, vol. 23, no. 1, pp. 18–36, Jan. 2014, doi: 10.1080/10508406.2013.778204.