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Developing Critically-Conscious Aerospace Engineers through Macroethics Curricula: Year 2 (IUSE)

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Introduction

In engineering education, we often present our field as one that makes the word a better place through the application of technological advancements. While this is an easy goal to present, the reality of how engineering affects the world—for better and for worse—is much more complicated. How does the engineering profession weigh technology that benefits the Global North at the expense of the Global South? Or technology that benefits shareholders at the expense of labor? Or technology that provides small benefits to many at the great expense of fewer people (or vice versa)?

Numerous standards guiding engineering education and the practice of engineering suggest that students should be cognizant of and prepared to act upon these issues concerning *macroethics*—the social responsibility of the engineering profession [1]. For example, ABET Student Outcome 2 notes that students must develop an understanding of engineering design including "consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors." [2]. Additionally, the American Institute for Aeronautics and Astronautics' Code of Ethics says that engineers are expected to "hold paramount the safety, health, and welfare of the public in the performance of their duties" [3]. These statements leave great latitude to the curriculum and the instructor in interpreting who counts as the "public." Furthermore, these statements just identify the end result; they do not help instructors, students, nor engineers to identify strategies by which they can analyze impacts of and on sociotechnical systems.

Our design-based research project, supported by the NSF Improving Undergraduate STEM Education (IUSE) program, addresses these pivotal gaps within aerospace engineering undergraduate education by conducting research and developing lessons that support the development of aerospace engineering students' *critical consciousness* [4]. A concept first put forth by Brazilian literacy proponent Paulo Freire, critical consciousness describes the ability to critically analyze and act against systemic oppression from a social justice lens. Our aim is to help engineering students to develop the ability to not only consider the benefits of aerospace technology to the Global North or corporate shareholders, but to people and groups who have been oppressed and minoritized in society.

This orientation is not one typically taken in engineering education; rather, the culture of engineering typically embraces the myth of apoliticization and actively distances the field from issues of social justice [5]. For example, in aerospace engineering we often uphold examples of military technology such as fighter jets or missiles without ever discussing the harm these weapons cause to people, particularly those who are globally minoritized. Or, we talk about the technology needed to mine asteroids and the Moon without considering the legal, environmental, and spiritual implications of these efforts. In our experience teaching undergraduate students at multiple universities, we have learned that a number of engineering students personally reject this apolitical orientation [6], [7]. They understand how engineering can uphold oppression, and

they long to discuss critical issues with their peers and their instructors. In aerospace engineering, the discipline on which this research focuses, we have seen students personally wrestle with concerns about their future engineering careers, such as not wanting to develop weapons or work for companies with exploitative labor practices [8], [9].

Our project consists of two thrusts—in research and in curriculum development—designed to push back against the dominant apolitical culture and narrative of aerospace engineering. We do this out of a desire to reframe aerospace engineering education into an endeavor that centers the needs of the marginalized rather than the powerful. As Dr. Martin Luther King, Jr. wrote in his Letter from Birmingham Jail, "There can be no deep disappointment where there is not deep love" [10, Para. 31]. Our project comes from a true passion for aerospace engineering, which requires us to demand more of aerospace engineering education.

To act on this, our project centers two research questions addressing students' current and developing perceptions of macroethical issues in aerospace engineering: RQ1) What are undergraduate students' current awareness and perceptions of macroethical issues in aerospace engineering? and RQ2) In what ways do students feel their education is or is not preparing them to address macroethical issues? In our curriculum thrust, we are developing macroethics lessons that can be integrated *into* (as opposed to compartmentalized outside of) "technical" aerospace engineering science courses to emphasize the sociotechnical nature of engineering. In the curriculum thrust, we also address our third research question: 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 the past year, we have made progress on addressing RQ1 and RQ2 through parallel quantitative and qualitative methods. We have also continued the development of our macroethics lessons. In this paper, we describe the past year of progress and outline future work on this project.

Quantitative Research

In the past year, we have continued our development of a mixed-methods survey on students' perceptions of the macroethics of the aerospace field and their macroethical education. The quantitative component of the survey contains 28 Likert-scale items, which asked students the degree (on a scale of 1-5) to which they agree or disagree with statements designed to investigate their perceptions of the current state of aerospace engineering and aerospace engineering education and an additional 13 items about their idealized vision for it. As part of the survey development process, we began analysis of preliminary results from 98 students at a large, public, research university in the Midwestern U.S. We are conducting factor analyses of this data to identify the degree to which they conform to five conceptual factors identified in the pilot version of the survey [11]:

1) A belief in the criticality of the relationship between aerospace engineering and society
2) The ease or difficulty of being an ethical aerospace engineer
3) The connection between technological determinism and aerospace career paths
4) An emphasis on macroethics in aerospace engineering coursework via discussions
5) The ability of faculty to facilitate conversations on the macroethics of aerospace.

We have also begun to analyze the quantitative results of the survey at the conceptual level. The preliminary results offer insights into how students morally grapple with macroethical issues in aerospace, such as warfare and social marginalization. Unfortunately, the results show significant misalignment with social justice-oriented priorities (e.g., support of American nationalism, embrace of the myth of apoliticization). The results support the development of our macroethics curriculum through a better understanding of "where our students are" as well as demonstrate the need for the efforts of this project.

Qualitative Research

Macroethical concerns are particularly salient in aerospace engineering students' thoughts about their future careers. To address RQ1 with a specific focus on careers, we have designed an interpretivist protocol based on the Theory of Planned Behavior [12]. This theory hypothesizes that one's intentions and behaviors (e.g., students' career aspirations and intentions) are influenced by one's attitudes (e.g., their attitudes toward the macroethical implications of certain careers), cultural norms (e.g., their perceptions about the way others value certain careers), and perceived behavioral control (e.g., their beliefs about their ability to obtain a job that aligns with their values).

We have recruited undergraduate aerospace engineering students at the University of Michigan to participate in this research. We first investigate students' attitudes through individual interviews. These interviews start with general questions about attitudes, asking students which career pathways they are and are not interested in. We then ask about specific career types, asking students about their desire (or lack thereof) to 1) work for a small aerospace startup vs. a large, well-established aerospace company; 2) work for a company that has defense contracts; and 3) work for a defense contractor on aerospace projects that are not military-focused. We also ask how important workplace conditions and employee treatment are when selecting a company. Finally, we ask students what ethical dilemmas and macroethical concerns they feel they might encounter in their future work, and how they feel their aerospace engineering education influenced their attitudes towards these potential dilemmas and concerns.

Students then participate in a focus group of 6-10 students in similar academic year ranges and/or similar personal attitudes. These focus groups center on cultural norms and perceived behavioral control. With respect to cultural norms, we ask about aerospace career pathways that are valued and undervalued by their department, as well as the perceptions of the students' family, friends, and non-aerospace peers' attitudes about careers in aerospace. With respect to perceived behavior control, we ask about students' internal beliefs in their ability to succeed in an aerospace career, the control they feel they have in obtaining the aerospace career they want, and the difficulty they perceive in finding an aerospace job that aligns with their values.

Curriculum Development

Lastly, we have continued to develop and implement our aerospace macroethics lessons. In the past year, we revised existing lessons and delivered them in an sophomore-level Introduction to Aerospace Engineering course and a senior-level Space System Design course at the University

of Michigan. We also delivered a slightly-revised lesson in a sophomore-level Aerospace Vehicle Design Laboratory at the University of Colorado Boulder in Spring 2025. In addition to these lessons, we developed a new lesson for a junior-level Spacecraft Dynamics course at the University of Michigan. This new lesson addressed a regulatory issue relevant to the course material: the FCC's rule that all spacecraft must be deorbited 5 years after end-of-mission [13].

The instructor of the Spacecraft Dynamics course had implemented lessons in the previous two offerings of the course, and we worked with him to create this new lesson. This lesson was influenced by conversations with Sarah Stanford-McIntyre, assistant professor in the Herbst Program for Engineering, Ethics & Society, who reviewed the previous macroethics lesson in Spacecraft Dynamics. In the lesson, we began by describing the concept of macroethics, introducing the concept of positionality and giving students a few minutes to reflect on their own, and presenting dialogue norms. We then introduced the scenario by describing how, in 2020, the FCC asked for public comment on proposed regulatory changes, including reducing the time to disposal to 5 years and requiring the ability to maneuver spacecraft in an orbit above 400 km. Students were split into 6 groups, each given a different organization with varied roles and agendas, and asked to read that organization's public comments to the FCC. Students were asked to work to understand their organization's position and *why* the organization took this position. They also assessed how much power their organization had in influencing the FCC's decision and how much the organization would be impacted by the FCC's decision. To end the activity, students shared through a "jigsaw" activity. This lesson was impactful because of its development in collaboration with the Spacecraft Dynamics instructor, connection to the technical course content, use of primary sources, and dialogue of power and impact. In the next year of the project, we plan to implement this lesson in an orbital mechanics course at Embry-Riddle Aeronautical University, Prescott.

Conclusion

Whether it is acknowledged or not, engineers face a multitude of macroethical questions when designing technology. Even if they follow an industry code of ethics, there is still vagueness and bias in the ways in which engineers assess the impact of their work. To give aerospace engineering students the ability to confront these realities of their future careers, we are working to conduct research and develop curricula that gives them the opportunity to build their critical consciousness [4]. Future work on our project involves the development and administration of the next iteration of our mixed-methods student survey, analyzing the results of our interviews and focus groups, and using conjecture mapping [14] to move from our individual macroethics lessons to a unified macroethics curriculum.

Unfortunately, future work will also likely increasingly require arguing the fundamental premise of social justice as a goal worth pursuing. The efforts of right-wing politicians, capitalist overlords, and technocrats threaten to significantly worsen existing hierarchical stratification within American society by suppressing all change-making initiatives, whether truly "radical" in nature or not. This noise has created a permission structure by which engineers, engineering instructors, and engineering administrators can aggressively reject any discussion of engineering as a political and social enterprise. If aerospace engineering is ever to be repurposed as an

enterprise toward social good, rather than a tool for the benefit of billionaires and imperialists, this is the critical moment when both academics and practitioners will need to actively reject the current trajectory of the field. The consequences of our failure to do so will be catastrophic.

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