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Macroethical Equity in Aerospace Education: Ethical Access Gap and Structural Pathway Inequality through an AWoP Lens

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Abstract

Ethics in aerospace engineering is often treated as an imperative rather than a shared professional responsibility, yet the ability to recognize and reason through ethical issues is shaped by those who get to learn, belong, and persist in the field. Using the seven identity domains from the Academic Wheel of Privilege as keywords, this paper develops a theoretical framework, the Macroethical Equity in Aerospace Education (MEAE) framework, that connects patterns in structural capital, identity foundation, cognitive-motivational factors and wellbeing to three recurring themes in aerospace education: structural inequity (barriers to entry), institutional mediation, and ethical access gap. The MEAE framework provides a systems-level diagnostic and design logic for understanding and addressing inequities in macroethical engagement. It also generates testable propositions to guide future research on how ethical access and participation are shaped in aerospace education.

The paper draws on Goal Congruity Theory (Diekman et al.) to explain how aerospace roles are often framed as purely technical and agentic, limiting appeal for students who value communal and ethical goals. Social Cognitive Theory (Bandura) further illuminates how limited representation and the absence of relatable role models undermine self-efficacy, particularly for women and students of color who navigate intersecting biases. Recent aerospace education studies documenting gendered classroom climates, financial barriers, and first-generation access gaps substantiate these mechanisms (Cech, Verdin). The resulting Macroethical Equity in Aerospace Education (MEAE) Framework positions ethical learning as both an educational and a social-justice concern. Including macroethical reflection and inclusive mentorship in aerospace curricula, programs can move toward an aerospace education that not only broadens access but also results in better design outcomes in terms of safety and sustainability, and more representative of diverse human needs.

Introduction

Ethics education in aerospace engineering is often assumed to be an individual responsibility despite the complex nature of the field that should allow conversations about ethics at large. Ethical competence is more than often tied to exist at an individual level and students are expected make principled decisions for the collective when faced with ethical dilemmas when they have never have had the right tools or understanding of the collective, institutional and societal dimensions of ethical responsibility in engineering.[1,2] Ethics is not recognized as something salient to engineering decisions but seen as assumption that engineers must have when they enter educational institutions and even professional settings.[3] Drawing on Lisa Delpit's concept of the hidden codes of power within institutions hosting multicultural and multinational students, this assumption obscures how professional conduct is governed not only by formal rules but also by unspoken cultural knowledge that is rarely made explicit to newcomers.[4] Within highly selective research institutions, these hidden codes intersect with demographic composition in ways that further shape whose behaviors and ethical voices are normalized. Students are also systematically taught that ethical concerns are peripheral to the technical problems at hand and they must prioritize technical problem solving over public welfare,[5] leading to the notion that engineering culture is objective and apolitical. These misinterpretations can lead differences in ethical engagement to be explained in terms of individual motivation or preparedness, rather than unequal access to educational, cultural, and institutional resources. When this access is unevenly distributed, ethical responsibility becomes stratified rather than collectively shared. This insight motivates the Macroethical Equity in Aerospace Education (MEAE) Framework developed in this paper, which conceptualizes ethics education not simply as the transmission of ethical principles, but as a structurally mediated process shaped by identity, institutional pathways, and access to opportunity. Instead of attributing disparities in ethical engagement to individual preparedness or motivation, MEAE offers a way to visualize how systemic conditions influence who is able to develop, exercise, and be recognized for ethical agency within aerospace education.

To situate this argument, we draw on concentric models of ethics that conceptualize ethical responsibility as operating across multiple, interacting levels rather than residing solely within the individual. A useful visual diagram appears in prior work,[6] which adapts Bronfenbrenner's Bioecological Systems Theory alongside the International Association for Measurement and Evaluation of Communication (AMEC) framework to depict ethics as layered across individual, relational, institutional, and societal contexts. Bronfenbrenner's model emphasizes that human development is shaped by nested systems which starts from immediate environments to broader cultural and policy structures that interact dynamically over time.[7,8] The AMEC framework similarly recognizes that outcomes cannot be evaluated solely at the individual level, but must be understood across organizational and societal layers. Formally, macroethics has been defined as "the collective social responsibility of the engineering profession and society's decisions about technology," in contrast to microethics, which focuses on individual conduct and interpersonal responsibility.[1] At the microethical level, students develop personal values like integrity, and self-regulation, alongside a sense of responsibility for their actions. Ethical decision-making at this level is strongly influenced by psychological and motivational factors such as mindset, self-efficacy, and well-being. Research in social cognitive theory suggests that individuals'

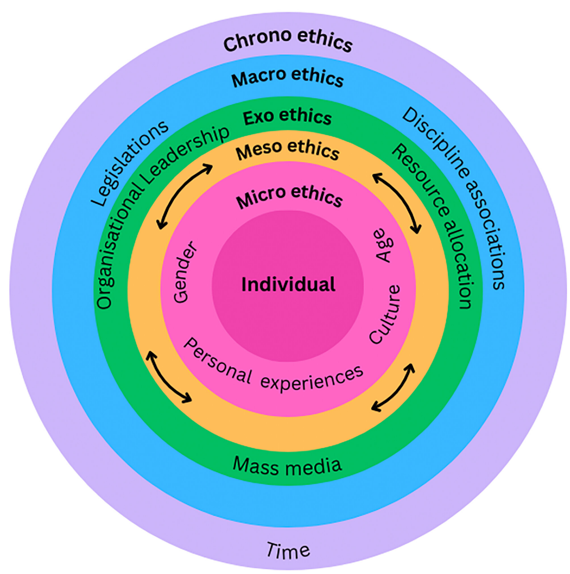

Figure 1: Nested ethical contexts[6]

confidence in their ability to act ethically and to speak up in technical environments is tied closely to prior mastery experiences, social feedback, and perceived legitimacy.[9]

However, it must not be forgotten that the microethical behaviors are shaped by macro-level structures that define whose ethical concerns are heard, whose risks are prioritized, and whose values are included in design decisions. In this sense, microethics and macroethics are not competing frameworks but interconnected and mutually reinforcing. While these concentric models acknowledge how ethical responsibility evolves over time, most engineering ethics applications remain focused on the individual core, with limited attention to how structural forces shape ethical capacity. Prior work in aerospace engineering education emphasizes that ethical questions in the field frequently tend to arise at the system level rather than as isolated individual dilemmas faced by individual engineers.[2] The authors here note that students and practitioners regularly confront questions related to public safety, sustainability, national and international responsibility, and the societal implications of aerospace technologies in professional settings, yet these macroethical concerns are often absent from required undergraduate coursework. By reframing ethics as both an educational and a social-justice concern, the MEAE framework provides a lens for understanding why ethical engagement varies systematically across students and how aerospace programs can design environments that support ethical agency, inclusion, and long-term professional responsibility, instead of prescribing a fixed curriculum.

In Aerospace Engineering particularly, the large impact on society is carefully bypassed to show that the technical problem-solving is more complex and important and unrelated to ethics. For example, satellite constellations have become incredibly useful for internet access, however, the impact of such technology on light pollution impacting astronomers as well as distressed political scenarios is more than often not discussed. At one of the satellite conferences the first author attended in 2025, she failed to find even one company who had taken this socio-technical aspect into consideration, further proving the point of how much this topic is overlooked. Aerospace systems operate in high-risk, high-impact contexts as well, where failures can result in loss of life, environmental harm, geopolitical consequences, and lasting societal effects. However, to a young student entering the field, the understanding of the impact is assumed to be implicit even though throughout their learning structure, it is rarely brought up as a topic of importance. As a result, students may graduate with strong technical competencies but without the conceptual tools needed to critically examine how aerospace decisions affect communities, environments, and future generations. This gap is particularly striking given that ironically enough, ethical and professional responsibility is a core ABET student outcome, required across all accredited engineering programs. Specifically, ABET Student Outcome 4 requires graduates to demonstrate "an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, considering the impact of engineering solutions in global, economic, environmental, and societal contexts".[10] Building on this layered perspective as shown in 1, this paper extends concentric ethics beyond descriptive framing to examine how structural inequities and other factors constrain ethical learning and participation in aerospace engineering education. Without explicit attention to macroethical context, students may learn ethical rules without understanding their societal implications or limitations and the distinctions become larger and prominent when they move to aerospace professions. Astronauts, for example, operate in tightly coupled systems where ethical decisions directly affect crew safety, mission success, and international cooperation. In a dissertation exploring Multiculturalism in international manned spaceflight missions, the author, C.K. Wong, found that different cultures may prioritize group consensus, respect for authority, or individual autonomy in decision making situations and with multicultural crews, ethical dilemmas may arise when crew members have conflicting beliefs about what is considered appropriate or fair. The same study found that American, Canadian, European, and Japanese personnel sometimes differed in how much they valued independent thinking, cooperation, and respect for leadership when solving problems and making decisions.[11]

These differences will persist not only in operational scenarios but also in design engineering and production scenarios. Aerospace design engineers and production engineers make decisions routinely whose consequences unfold across time and space, influencing public safety, environmental impact, and access to technological benefits. In all these roles, microethical judgment is inseparable from macroethical context because it is shaped by access to training, institutional norms, professional legitimacy, and opportunities to participate in important decision-making. Thus, the MEAE framework is built to support interpretation, diagnosis, and future empirical inquiry that potentially could help mitigate the broader differences. The uses of the MEAE Framework is stated below:

MEAE as an Interpretive Diagnostic Lens First, MEAE functions as an interpretive diagnostic lens for examining where and how ethical learning and participation break down within aerospace education systems. By explicitly modeling identity substrate (AWoP), structural capital, identity foundation, wellbeing, and the cognitive–motivational engine, MEAE allows educators and researchers to distinguish between different sources of inequity that are often conflated.

MEAE as a Design Logic for Educational Interventions Second, MEAE is meant to function as a design logic that connects specific forms of inequity to more targeted educational and institutional responses. Rather than assuming that a single ethics module or small curricular addition can fix systemic problems, MEAE emphasizes the need to align the source of a constraint with the type of intervention used to address it. For example, if ethical voice is limited by low self-efficacy or identity threat, then simply adding more ethics content is not going to be effective. However, shifts in framing, mentoring relationships, or representation may have a much greater impact than changes to the syllabus alone. MEAE functions as a conceptual guide for thinking about where intervention is most needed, with future work focused on translating this logic into practical curricular, co-curricular, and policy-level strategies. An experiment is already underway exploring how different framing of questions influences student outcomes. But if those interventions are useful is still unknown.

MEAE as a Generator of Testable Propositions Third, MEAE generates testable propositions that can guide future research in aerospace engineering education. These propositions are theoretically grounded claims that can be evaluated using qualitative, quantitative, or mixed-methods approaches. Examples include reduced representation within aerospace programs association with lower self-efficacy, linking ethical risk-taking and leadership behavior, framing changes to aerospace design problems around communal and societal goals linking ethical engagement, and institutional support structures' effect in shaping learning approach and ethical participation. These propositions are intentionally broad to accommodate different methodological traditions and institutional contexts.

Model Construction

Academic Wheel of Privilege:

The Macroethical Equity in Aerospace Education (MEAE) framework is grounded in the premise that students enter aerospace education with differentiated social positions that shape their access to resources, legitimacy, and ethical voice. To conceptualize these differences without reducing identity to single-axis categories, this work adopts the Academic Wheel of Privilege (AWoP) as the identity substrate of the model. Originally developed to support reflection on research integrity, social justice, and principled education, the AWoP provides a structural lens for understanding how students enter academic spaces carrying unequal configurations of identity, access, and constraint.[12] The AWoP is composed of twenty identity types spanning seven broad categories: living and culture, caregiving, education and career, gender and sexuality, race, health and wellbeing, and childhood and development. These identity types are visually represented as interconnected circles arranged within three concentric rings-outer, middle, and inner with increasing privilege as the circle moves inwards. It thus shows how individuals positioned closer to the center are more likely to accumulate additional advantages over time, while those at the periphery encounter compounding barriers.

Figure 2: Academic Wheel of Privilege[12]

It must be noted that while AWoP functions as an identity exposure map, it does not aim to predict academic performance, persistence, or success in isolation. It only captures the social, cultural, and developmental contexts that students carry with them into academic and professional spaces.

The MEAE Framework (WIP):

Building on the Academic Wheel of Privilege (AWoP) as an identity substrate, this section introduces the Macroethical Equity in Aerospace Education (MEAE) Framework as an integrated, systems-level model for understanding how ethical learning, participation, and voice are shaped in aerospace education. The broader level of the framework synthesizes identity, structure, wellbeing, and cognition into a coherent explanatory system that accounts for persistent inequities in access to ethical reasoning and professional legitimacy. As illustrated in Fig. 3, the MEAE framework concept map comprises four interrelated system components:

1. Structural Capital, which captures how socially patterned resources such as socioeconomic status, institutional support, representation, and access to opportunity shape students' educational pathways.

2. Identity Foundation, which reflects how race, gender, culture, and belonging co-produce students' sense of legitimacy and fit within aerospace spaces.

3. Cognitive-Motivational Engine, which encompasses self-efficacy, motivation, and mindset, and governs how students interpret challenges, take risks, and approach learning and ethical participation.

4. Wellbeing System, which includes psychological health, social support, and health behaviors, modeled as a mediating structure that shapes students' capacity to engage.

Together, these components define MEAE as a macroethical equity framework, one that situates ethical learning within broader systems of access, identity, and institutional design rather than treating it as an isolated cognitive skill. The framework also uses directional arrows to represent both within-system reinforcement and cross-system influence, and color-coded pathways to distinguish different types of relationships:

- Red arrows represent the primary ethical translation pathways to macroethics, showing how each major system contributes to macroethical engagement through distinct mechanisms.

- Orange arrows represent within-system couplings, where components mutually reinforce each other inside a single system (e.g., psychological health and health behaviors within the Wellbeing System).

- Dark blue arrows represent inter-system component connections, indicating how one system conditions or constrains another (e.g., Institutional Support shaping race and gender identity and belonging).

- Gradient, thick arrows represent dominant cross-system pathways, where structural or identity-based forces exert strong influence across multiple systems.

- One thick, blue arrow linking individual ethical core to performance.

At the center of the framework is the individual, situated within nested ethical layers (micro, meso, exo, macro, chrono). The MEAE framework is explicitly macroethical: it models how system-level conditions determine who develops ethical sensitivity, who can act on it, and whose ethical judgments ultimately shape aerospace practice.

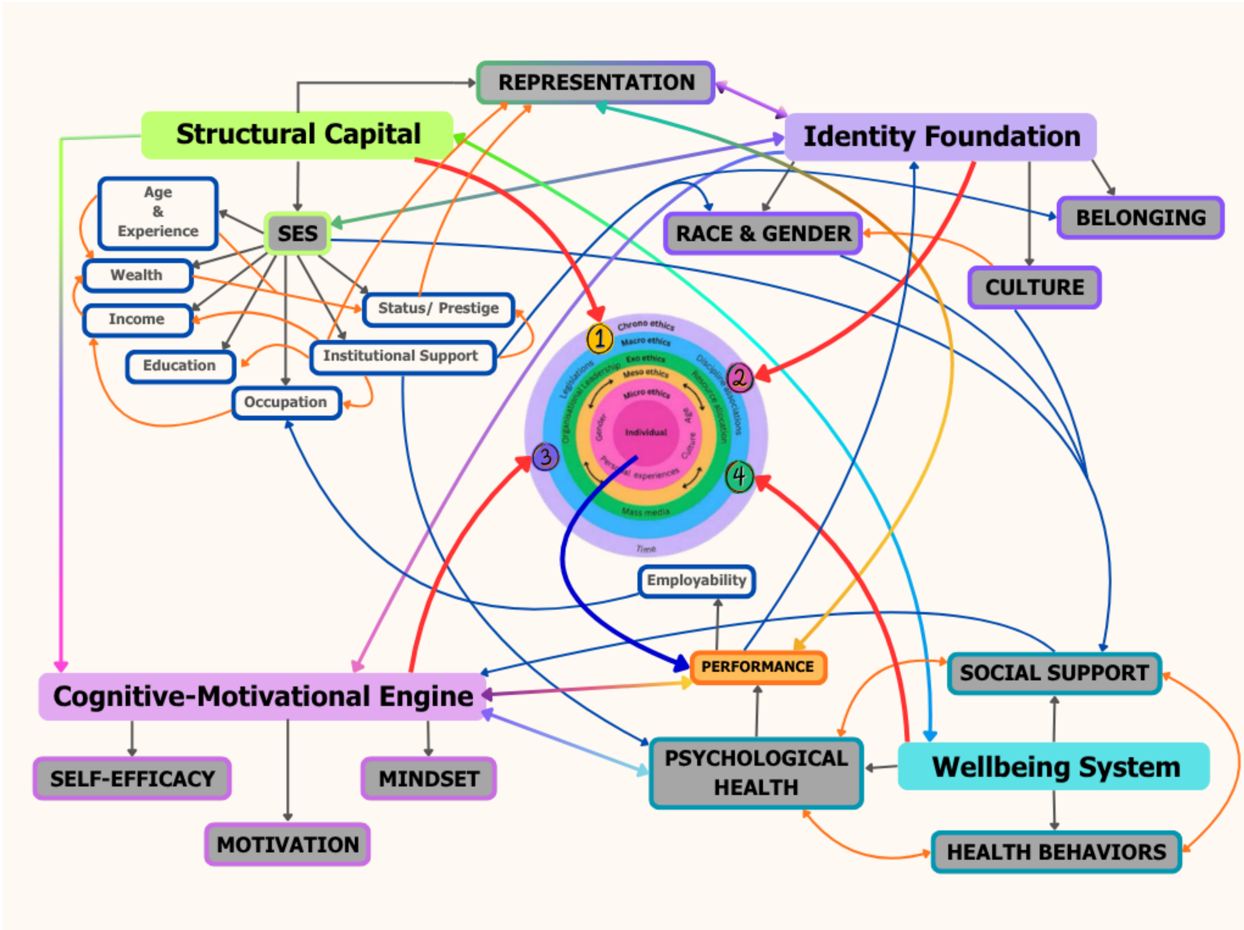

Figure 3: Concept Map Overview of MEAE Framework

The Four Primary Macroethical Pathways

1. **Structural Capital - Macroethics: Ethical Access Gap**

   The first link between Structural Capital to macroethical outcomes is defined in MEAE as the Ethical Access Gap. Factors such as socioeconomic status, representation, institutional support, and access to prestigious opportunities shape who is able to participate meaningfully in ethical learning and decision-making in the first place. This pathway shows that macroethical engagement is not a matter of values or awareness, it is also a matter of access. Ethical outcomes, therefore, are shaped not only by individual beliefs, but by structural forms of gatekeeping that determine whose ethical voices are heard and legitimized.

2. **Identity Foundation - Macroethics: Ethical Legitimacy and Belonging**

   The second link connects Identity Foundation (race, gender, culture, and belonging) to macroethical participation, capturing who is perceived as a legitimate ethical actor within aerospace systems. Identity positioning shapes entitlement to question norms, ethical reflections and assertiveness when raising concerns. When belonging is fragile or identity threat is present, students may withhold ethical judgments even when they clearly recognize potential harm. Thus, this pathway highlights that macroethics is not only about knowing what is right, but about being socially authorized to say it and be taken seriously.

3. **Cognitive-Motivational Engine - Macroethics: Microethical Agency to Practice**

   The third link connects the Cognitive–Motivational Engine to macroethics by tracing how microethical processes scale into macroethical action. Factors like self-efficacy, motivation, and mindset determine how individuals perceive risks, persist in ethical reasoning under pressure or unfavorable circumstances and translate moral awareness into action. In MEAE, this pathway explains why ethical knowledge alone is insufficient and must be supported by confidence and motivation in order to transform ethical sensitivity to ethical practice.

4. **Wellbeing System - Macroethics: Capacity for Ethical Endurance**

   The fourth link connects the Wellbeing System to macroethics and is described as ethical endurance and sustainability. This pathway emphasizes that macroethical participation is not a one-time act, but a long-duration process. Experiences of burnout, isolation, and psychological distress narrow cognitive bandwidth, reduce risk tolerance, and incentivize withdrawal, even among individuals with strong ethical commitments. Thus, the Wellbeing System shows who can continue to care as a function of well-being. It links directly to chrono-ethics by explaining how structural stressors erode ethical participation over time.

The MEAE framework relies on feedback and nonlinearity. MEAE rejects simple cause-effect explanations and rather adopts a dynamic systems perspective, where inequities are reproduced through interacting mechanisms over time. In this paper, the following subsection will only do a deeper dive into Structural Capital - Macroethics: Ethical Access Gap with Institutional Support in the middle as shown in Fig 4 with expected interference from other systems.

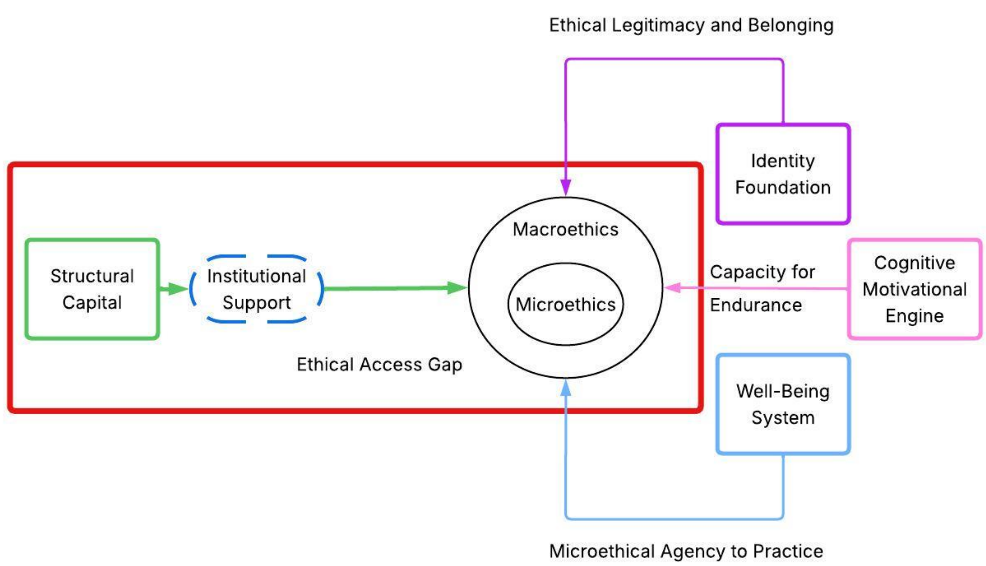

Figure 4: Primary Pathways of MEAE Framework with a focus on Ethical Access Gap

Structural Capital

Structural capital constitutes the first operational layer of the model, describing how accumulated material, social, and institutional resources enable students to navigate aerospace education and participate fully in its learning and ethical practices. These resources include socioeconomic positioning, institutional support, representational legitimacy, and access to influential networks. Structural capital is unevenly distributed and historically patterned, reflecting not only individual circumstances but also broader social structures that differentially allocate opportunity and recognition. Dimensions captured by the AWoP shape the amount and type of structural capital available to students, influencing how easily they can access key resources and whether they are recognized as legitimate participants in aerospace spaces. This subsection conceptualizes structural capital through two central components—socioeconomic status (SES) and representation—and links them to Structural Pathway Inequality, defined here as differential access to entry points, mentoring, research credibility, and ethical voice.

SES

SES functions as the first component of structural capital because it shapes access to material resources, time, mobility, networks, and institutional navigation long before students enter aerospace programs. SES is typically measured using indicators such as family income, parental education, occupational status, and neighborhood/school resources; however, in educational pathways it often shows up through constraints on time, risk tolerance, and opportunity access. For example, students with limited financial support may be less able to accept unpaid or low-paid research positions, attend conferences, participate in costly design teams, or take course loads structured around extracurricular "enrichment" expectations, activities that frequently act as informal gateways into prestige trajectories. Recent engineering education research has emphasized that inequity in engineering pathways cannot be understood solely as academic preparation; it is also shaped by whether students can translate their experiences into forms of capital that institutions recognize and reward. Verdín[13] shows how first-generation engineering students' "funds of knowledge" can be meaningful assets, but whether these assets function as capital depends on institutional recognition and support structures. Similarly, Martin et al.[14] argue for anti-deficit framings of first-generation engineering students, showing how persistence is shaped not just by individual grit but by how social relationships and institutional contexts enable access to engineering identity and opportunities.

SES also intersects with age and experience, which can influence access to wealth and income (e.g., older students may have more work experience but also greater caregiving responsibilities or financial precarity). These dynamics matter because aerospace programs frequently assume students have discretionary time and financial flexibility, embedding "hidden costs" into professional formation that disproportionately disadvantage those with fewer resources. These include costs associated with membership fees for professional societies, and time-intensive participation in design teams or extracurricular projects that are often informally expected for competitive aerospace careers. At a theoretical level, these patterns align with bioecological systems theory, which emphasizes that individual development and learning are shaped by nested environments and cumulative interactions across time (proximal processes) rather than by isolated traits.[8] Bourdieu conceptualizes economic, cultural, social, and symbolic capital as resources that can be accumulated and converted, producing durable advantage in institutional settings.[15] Education systems, in turn, reproduce inequality by treating dominant cultural norms and dispositions as neutral standards, thereby rewarding those already aligned with them.[16] Within aerospace education, this explains how parental education, occupational background, and institutional prestige shape outcomes even when students demonstrate similar technical ability. These inequities are further compounded for international students, who face structural barriers beyond financial constraints. Many prestigious aerospace fellowships, government-funded research opportunities, and scholarships such as those supported by NASA, the Department of Defense, other federal agencies and now commercial companies too, are restricted to U.S. citizens. Thus, access to high-status networks, recommendations, research opportunities, and leadership opportunities are affected, reinforcing disparities in who is able to access, participate in, and ultimately shape aerospace systems and decisions.

Representation:

The second major component of structural capital in MEAE is representation. Representation functions as a form of capital because it shapes how students develop their identities, whether they perceive themselves as fitting into the field, their sense of self-efficacy, and the social risks they associate with participation. This is why representation is treated as part of Structural Capital rather than Identity Foundation within the framework. Social Identity Theory provides a useful starting point for how group membership structures self-concept and belonging, especially in contexts where intergroup comparisons and status hierarchies are visible.[17] In aerospace education, underrepresentation can signal that certain identities are "atypical" for the field, shaping both how students see themselves and how others interpret their competence which affects their performance and hence success. Representation is also central to social cognitive theory, where self-efficacy is built through mastery experiences, social persuasion, physiological states, and crucially, vicarious experiences (seeing people "like me" succeed in the role).[9] When students lack access to relatable role models, or only see tokenized or stereotype-confirming narratives, their self-efficacy and professional identity development can be undermined even when academic performance is strong for a specific time since with time, performance is susceptible to decline as well. These processes connect directly to goal congruity theory, which explains how social roles are perceived to afford or block valued goals. STEM fields that are framed as technical and agentic can appear misaligned with communal or prosocial goals, reducing motivation and sense of fit for those who prioritize communal impact.[18,19]

Recently, with astronaut Christina Koch's participation in the Artemis II Mission, there has been a visible and meaningful shift in how young girls perceive their place within aerospace. Seeing a woman in such a technically demanding, physically exhausting and historically male-dominated role expands the boundaries for many for what is possible. A similar impact can be observed with Victor Glover, whose role in Artemis II holds profound significance for children of color. For many young students, especially those who are gender minorities or people of color, representation at this level challenges the historical patterns of exclusion in aerospace and places hope in the hearts of so many young students that they can also one day not only reach for the stars but also occupy critical positions on the ground, such as flight directors, engineers, or systems leads in Mission Control environments that have long lacked gender, racial and ethnic diversity. Representation matters here because role models and disciplinary narratives signal what goals are legitimate within the field. Underrepresentation also amplifies vulnerability to stereotype threat, defined as the situational risk of confirming a negative stereotype about one's group, which can impair performance, increase anxiety, and shape domain disengagement.[20] Importantly, stereotype threat is not just an internal feeling; it is activated by contextual cues such as demographic scarcity, evaluative climates, and cues of exclusion. In this vein, Dasgupta's "stereotype inoculation" model argues that exposure to ingroup experts and peers in high-achievement contexts can increase belonging and resilience against stereotypes[21] resulting in mapping MEAE's representation segment shaping participation pathway.

Institutional Support as a Mediating Structure:

As evidenced above and shown visually in Fig 5, Institutional Support implicitly functions as a mediating structure that emerges from the effects of both SES and Representation and are converted into differential access to opportunity, legitimacy, and participation within aerospace education. While SES shapes access to material resources, time, and prior exposure, and representation shapes belonging, visibility, and perceived legitimacy, institutional environments determine how these factors are interpreted, valued, and translated into opportunity. This mediation occurs through what MEAE defines as Structural Pathway Inequality (SPI), which captures how institutions differentially enable or restrict access to a set of tightly coupled resources that collectively determine how inequities propagate downstream to affect macroethical judgement and engagement, influencing ethical access and ultimately microethical participation. MEAE defines **Structural Pathway Inequality** as differential access to four tightly coupled pathway resources:

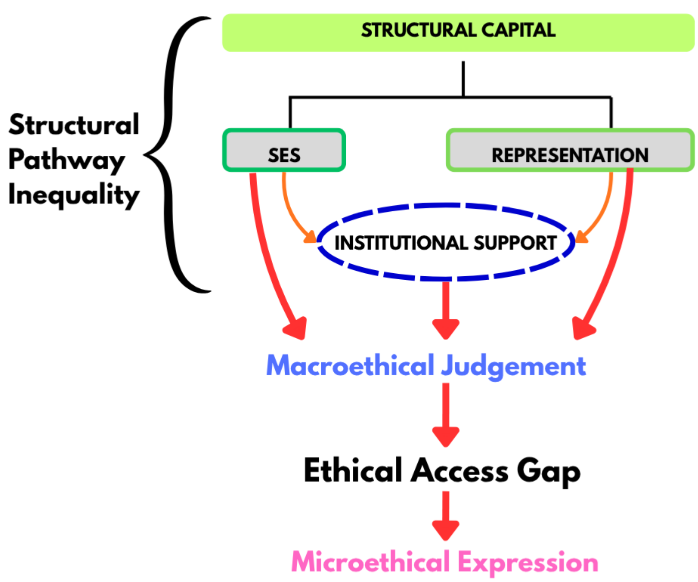

Figure 5: MEAE: Structural Pathway Inequality (SPI) to Ethical Access Gap (EAG) Model

1. Entry points

   Access to gateway opportunities (advanced coursework, research positions, design teams, internships) that open the aerospace pipeline. These often have hidden prerequisites like time, networks, nationality or insider knowledge, linked to SES and representation. One important example in aerospace engineering is the impact of International Traffic in Arms Regulations (ITAR) and related export control policies on student participation in research and design activities. Empirical and policy analyses have documented that ITAR restrictions often limit students' ability to participate in certain laboratories, projects, data environments, and industry collaborations, even when students possess the requisite technical skills. From an educational standpoint, these restrictions have consequences for student performance and professional identity formation. Participation in authentic research and design experiences is associated with increased self-efficacy, skill development, and persistence in engineering fields. When access to such experiences is limited by citizenship status, students may have fewer opportunities to demonstrate competence, build research credibility, or engage deeply with aerospace systems, that ultimately affects employability and long-term career trajectories.[22,23] Educationally, these constraints disproportionately affect doctoral students, for whom research access is inseparable from funding, degree progress, and professional identity. Unlike undergraduates or coursework-based master's students, PhD students' advancement depends on sustained participation in funded research programs, authorship, experimental access, and alignment with sponsor-defined deliverables.

2. Mentoring

   Differential access to high-quality mentoring relationships that provide navigation, sponsorship, and advocacy. Mentoring is not evenly distributed; it is shaped by institutional structures and who is seen as a "good investment." Evidence from broader higher-education research shows first-generation and underrepresented students are less likely to access informal mentoring networks, not due to lack of motivation, but due to structural and cultural barriers that limit interaction and recognition.[13,24] This affects access to tacit knowledge about research directions, funding, and career pathways.

3. Research credibility

   Unequal accumulation of signals that confer legitimacy (authorship, lab affiliation, conference exposure, recommendation networks). Credibility is often socially constructed and mediated by access to capital and prestige.[15]

4. Ethical voice

   Differential ability to raise concerns, challenge norms, and participate in ethical discourse without social penalty. Ethical voice depends on legitimacy and safety. Psychological safety research shows that speaking up is shaped by whether individuals believe they can take interpersonal risks without fear of negative consequences.[25] In MEAE, ethical voice is therefore not a purely individual trait; it is an outcome of structural capital, representation, and institutional climate.

Thus, Structural Capital with SES and Representation, explains how students can occupy the same classroom yet experience fundamentally different ethical and professional trajectories. Students with greater structural capital are more likely to access prestigious opportunities, accrue credibility, and speak with authority, including in ethical discussions while students with less capital may face higher costs for participation and greater risk when asserting ethical concerns. When these pathways are unequally distributed, ethical participation itself becomes stratified, reinforcing the Ethical Access Gap. Thus, institutional support is not peripheral to ethics education; it is a central mechanism through which who gets to shape macroethical practice is determined.

Ethical Access Gap (EAG): From Institutional Mediation to Microethical Expression:

Differences in macroethical judgment do not translate uniformly into action but instead gives rise to what MEAE defines as the Ethical Access Gap (EAG), which is a structural disconnect between recognizing ethical implications and having the opportunity or capacity to act on them. As mentioned earlier, macroethics is understood as the collective responsibility of the engineering profession and its role in shaping societal outcomes[1] and requires engagement at the level of systems, policy, and long-term impact. However, engineering education has been shown to systematically underemphasize these dimensions, fostering a "culture of disengagement" in which technical problem-solving is prioritized while social and ethical considerations are treated as peripheral.[5] As a result, students may develop varying degrees of macroethical awareness depending on their exposure to interdisciplinary thinking, societal framing of engineering problems, and opportunities to engage with real-world consequences of design decisions.[3]

The Ethical Access Gap emerges when this uneven macroethical exposure intersects with differences in participation and legitimacy, producing disparities in who is able to carry ethical reasoning forward into practice. Research in engineering education suggests that learning environments shape not only knowledge acquisition but also whether students perceive ethical reasoning as central to engineering work.[3,26] In aerospace contexts, this is evident in design practices that prioritize performance metrics while overlooking concerns such as environmental impact, orbital congestion, or societal consequences of space infrastructure.[27,28] Even when students recognize these issues, the absence of structured opportunities to engage with them is limited especially when it is not perceived as one of the problems industry is driven by.

This gap at the macro level directly shapes microethical expression, defined as how individuals interpret, articulate, and act upon ethical concerns in immediate contexts. Microethical behavior that includes raising concerns, questioning assumptions, or intervening in team decisions, is strongly influenced by perceived agency and self-efficacy, both of which are shaped by prior experiences and environmental reinforcement.[9] When students have limited access to macroethical engagement, they are less likely to develop the confidence or perceived legitimacy required to act on ethical concerns. This aligns with broader findings that ethical behavior in professional contexts is not solely a function of individual values, but is shaped by situational and structural factors that influence risk perception and willingness to act.[29] Consequently, the Ethical Access Gap serves as the critical mechanism through which disparities in macroethical judgment are translated into uneven microethical expression, reinforcing differences in who ultimately participates in and shapes ethical practice within aerospace engineering. The next section further discusses the roles of other systems within MEAE framework in contributing to this gap of ethical engagement.

Influence of Idenitity Foundation, Cognitive-Motivational Engine, and Wellbeing on Macroethics:

Within the MEAE framework, macroethical engagement in aerospace engineering is not solely determined by structural capital, but emerges from the interaction of identity foundation, cognitive–motivational processes, and wellbeing capacity. These systems collectively determine who recognizes ethical issues, who feels able to act on them, and whose perspectives ultimately shape aerospace systems and decisions.

Identity foundation, shaped by race, gender, and belonging, influences whether individuals perceive themselves as legitimate participants in aerospace decision-making spaces. While role of representation has been discussed before, Dasgupta's stereotype inoculation model directly links representation to belonging and resilience: exposure to ingroup experts and peers in high-achievement settings can reduce identity threat and increase belonging and self-efficacy, functioning as a protective social mechanism against stereotypes.[21] Historically, Aerospace has been historically a white-male dominated field, a pattern that continues to persist due to structural inequalities. Even in popular US universities, this is very evident in contrast to other engineering disciplines; according to 2023 NSF data,[30] women and minorities in engineering overall ranges between 15-20% and Aerospace is often below or at the lower end of that range, also confirmed by 2022 ASEE Engineering and Engineering Technology by the Numbers.[31] This imbalance is reinforced through engineering education systems which provides unequal access to different demographic groups and focuses only on technical competence while marginalizing identity, belonging, and societal relevance as already discussed by Cech (2014).[5] But, there is evidence from Diekman's research[18] that women are more likely than men to endorse communal goals, such as contributing to society and helping others, likely due to more prosocial behavior and higher levels of empathy.[32] As evidenced by Pew Research Center's report, communities of color often show more inclination to give back to their communities, civic participation and develop community-based support systems.[33] Since race and gender operate as central anchors of identity foundation, they structure how students are perceived and treated within historically stratified STEM contexts. Social Identity Theory explains that people derive part of their self-concept from group membership and that group status hierarchies shape belonging and identity salience in ways that influence participation and motivation.[34] Now, belonging in aerospace engineering is not solely shaped by race and gender, but also by how disciplines within the field are defined, valued, and organized. Aerospace programs are often implicitly structured around a binary of aeronautics and astronautics, reinforcing a narrow perception of what constitutes "core" aerospace work. This framing can marginalize students working in areas such as human factors, materials science, computational methods, or even engineering education despite aerospace engineering being inherently interdisciplinary. Studies on belonging in STEM further demonstrate that a lack of alignment between students' interests and perceived disciplinary norms can lead to disengagement and reduced persistence.[35,34] Theses are thus limiting factors in Aerospace Engineering as a field to fully reflect its multidisciplinary reality and constraining who feels they belong within it.

Cognitive-Motivational Engine refers to the set of psychological mechanisms through which students interpret their learning environments, decide how to engage, and develop the confidence and agency to participate, especially in high-stakes technical and ethical contexts. It translates identity positioning into action through self-efficacy, motivation, and mindset. Self-efficacy governs whether individuals believe they can intervene effectively, while motivation determines whether they perceive ethical engagement as meaningful or misaligned with disciplinary norms. Within Self-Determination Theory, environments that fail to support autonomy, competence, and relatedness shift students toward controlled motivation, leading to disengagement or surface-level participation.[36] Expectancy-Value Theory further explains that students' engagement depends on both their perceived likelihood of success and the value they assign to the task, including perceived cost.[37] In aerospace education, where problems are often framed in terms of optimization, performance, and efficiency, ethical and societal considerations are frequently marginalized. For example, satellite design projects typically emphasize coverage, latency, and cost, while rarely prompting students to consider impacts such as light pollution, environmental consequences, or ground-based societal effects of large constellations.[27,28] The International Astronomical Union has highlighted these impacts as collective concerns, yet they remain peripheral in most curricula.[38] This framing reinforces agentic goals and suppresses communal and ethical motivations, consistent with Goal Congruity Theory.[18] As a result, students may recognize ethical concerns but refrain from raising them because they fall outside what is perceived as "real" engineering work, leading to ethical silence.

Wellbeing System here is a mechanism through which structural conditions like SES constraints, restricted access to mentoring, research spaces actually translate to differences in learning approach, persistence, and ethical participation.[36,39] Social support buffers stress and reduces the harm of adverse contexts, while psychological distress can reduce help-seeking, shrink social engagement, and make support networks harder to access.[40,41] Within aerospace education, this matters because many structural constraints (financial stress, identity-based marginalization, exclusion from research spaces, gatekept mentoring) are chronic rather than episodic. In these conditions, students with robust mentoring and peer networks may maintain stable psychological functioning and continue to engage deeply, whereas students without support may experience cumulative stress that narrows attention, increases threat sensitivity, and reduces participation and ethical voice. Decades of research show that social support plays a protective role in high-demand environments by helping people manage stress, maintaining stable psychological health, and enabling continued engagement in complex cognitive and ethical tasks.[40] Within the MEAE framework, social support also interacts with structural capital and identity foundation. Students with greater structural capital such as institutional familiarity, representation, and access to high-status networks are more likely to form supportive relationships organically, while those with less capital may face barriers to initiating or sustaining support, including cultural mismatch, time constraints, or perceived illegitimacy. As a result, social support becomes one of the ways through which structural inequality is reproduced, shaping who has the relational resources necessary to navigate difficulty, recover from setbacks, and engage ethically in aerospace education.

Discussion

This paper develops the Macroethical Equity in Aerospace Education (MEAE) framework to understand how ethical learning, participation, and voice are shaped within aerospace education. It gives a systems-level account of how ethical engagement is produced, distributed, and constrained within aerospace education. By integrating the Academic Wheel of Privilege with structural capital, identity foundation, wellbeing, and cognitive–motivational processes, MEAE reframes ethics from an individual competency to a structurally mediated outcome. Central to this account is Structural Pathway Inequality (SPI), which explains how institutions differentially allocate access to entry points, mentoring, and research credibility—resources that determine who participates in consequential aerospace work. These structural differences propagate into the Ethical Access Gap (EAG), a disconnect between recognizing ethical implications and having the capacity or opportunity to act on them. This gap is reinforced by curricular incentives that privilege technical performance over ethical reasoning, cultural and identity-based differences in how ethics is interpreted and expressed, time-constrained and technically dense programs, and the complex positioning of aerospace within military and defense contexts that often discourages open ethical discourse. Together, these conditions explain why macroethical awareness does not consistently translate into microethical expression. MEAE therefore challenges the prevailing assumption that ethics can be addressed through isolated curricular additions, arguing instead that ethical participation is contingent on how institutions structure access, legitimacy, and risk. Framing ethics in this way links questions of inequity directly to questions of ethical access, and creates a basis for future work on how educational environments can support both ethical responsibility and social inclusion.

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