Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025
Paper ID #47384

[Work in progress: Intersection of Design and "X" Research Papers] Global means local too: Integrating anti-oppressive practice into community-based capstone design projects.

Ms. Kerry Eller, Duke University

Kerry Eller is a 4th year PhD Candidate in the Center for Global Women's Health Technologies at Duke University's Biomedical Engineering Department. Kerry is working to develop cervical cancer screening technologies that are more accessible for both patients and providers but is also excited about engineering education and design pedagogy.

Dr. Megan Madonna, Duke University

Megan Madonna is an Assistant Research Professor in Biomedical Engineering at Duke University. She serves as the Director of Ignite, a human-centered design-based engineering program that links engineering and local, community-based issues to encourage empathic and creative thinkers and broaden participation in engineering. In addition, she works as the Assistant Director of Education for the Center for Global Women's Health Technologies at Duke University.

Abstract

As global health challenges grow increasingly complex, engineering students are motivated to develop innovative solutions that are both technically sound and socially equitable. This paper presents the design and implementation of a senior capstone course at Duke University, a predominantly white, private university in the southern United States. The course integrates principles of human-centered design (HCD), project-based learning (PjBL), and anti-oppressive pedagogy (AOP) to foster students' critical understanding of their roles as engineers addressing global and local health challenges. Through community-based projects, the course emphasizes ethical responsibility, cultural humility, and sustainable design practices, encouraging students to shift from designing for communities to designing with them. Through student reflections and evaluations, this work in progress model for design shows initial trends towards a shift in the students' perspectives on biomedical engineering, the role of engineers, and global health. By combining technical training with critical reflection on systemic inequities, this course equips students with the skills and mindsets necessary for inclusive, impactful engineering practice. The findings underscore the potential of integrating AOP into engineering education to cultivate socially conscious, globally engaged engineers capable of co-creating equitable solutions with diverse communities.

1. Introduction

As global connectivity and communication networks continue to grow, so too does awareness of the disparities in health, resources, and opportunities across different regions of the world. This heightened awareness has spurred a shift among engineering students, who are increasingly interested in addressing global challenges. In biomedical engineering particularly, students often enter the discipline because they are interested in problem-solving at the intersection of engineering and public health. Global health problems present some of the most pressing and complex issues of our time, requiring innovative and sustainable solutions that account for diverse cultural, social, and environmental contexts. Despite this enthusiasm, many engineering students lack a structured introduction to the ethical and practical challenges inherent in global health design projects. To create meaningful and sustainable change, engineers must approach these challenges using frameworks that emphasize ethical responsibility, cultural humility, and long-term impact.

Two educational frameworks that have proven to be effective in engaging students with real-world problems are human-centered design (HCD) and project-based learning (PjBL). HCD prioritizes empathy and collaboration by focusing on the needs, priorities, and goals of the end-users of a design solution [1]. It encourages students to develop solutions that are both functional and useful to the communities they aim to design for. Similarly, PjBL involves students in active, hands-on projects that address real-world problems [2]. By combining theory with practice, PjBL helps students build a deeper understanding of technical concepts while fostering teamwork, problem-solving, and communication skills. Together, HCD and PjBL move students beyond mere technical training, encouraging them to consider broader social, ethical, and cultural dimensions of engineering design [3].

While HCD and PjBL have demonstrated significant benefits, addressing global health challenges also requires an explicit focus on systemic inequities and power dynamics. Critiques of HCD have noted that it focuses too explicitly on an individual, rather than thinking about the broader system and environment as well as power structures surrounding the problems being addressed [4]. Anti-oppressive pedagogy (AOP) offers a critical framework to address this gap. AOP is an educational approach that aims to challenge and dismantle systemic oppression within both educational settings and society at large. It emphasizes the need for students to critically examine how their actions, assumptions, and designs may perpetuate or disrupt existing power structures [5]. In the context of global health and engineering, AOP highlights the importance of developing solutions that are equitable and respectful of local knowledge and autonomy [6]. This is largely accomplished by helping shift the focus from designing *for* to designing *with* communities and community members, as the individuals closest to the problem are often those best suited to solve the problem. This is part of an epistemological shift to value lived experiences and local knowledge. Incorporating AOP into engineering education can help students develop the cultural humility and critical thinking skills needed to address complex global challenges responsibly.

There has been a recent emphasis globally on the call for the "decolonization," of curricula and pedagogy in higher education, particularly in global health and STEM fields. Decolonization involves challenging colonial narratives, dismantling power structures, and integrating diverse knowledge systems [7], [8]. Strategies for decolonizing include treating local partners as equals, compensating hosts, capacity building, and promoting critical thinking among students [9]. In global health education, there is a growing awareness of the lingering impact of colonial legacies on partnerships between high-income and low- and middle-income countries [10]. To address these issues, scholars recommend adopting transformative learning approaches, incorporating Indigenous knowledge systems, and fostering equitable collaborations to improve sustainability [8], [10]. However, challenges remain in actualizing decolonization efforts, as meanings and implementations vary across geographical, disciplinary, and institutional contexts [7]. We have created a continuum of decolonizing engineering education that progresses from exclusionary practices to fully community-led approaches (**Figure 1**). This continuum is created from AOP, HCD, and decolonial perspectives and aims to push students towards an understanding of engineering that is rooted in community empowerment and agency [11], [12], [13], [14]. It is largely an adaptation of the work done by the Anti-Oppression Resource and Training Alliance with specific applications for engineering design work [15]. This continuum is created with the knowledge that a predominantly white Western higher education institution will never achieve fully decolonized design; engineers and designers from local communities must have full agency over the entire design process for this to occur. Despite this, harm can be reduced in engineering by making genuine (as opposed to superficial or performative) attempts to move along the continuum axes towards this goal.

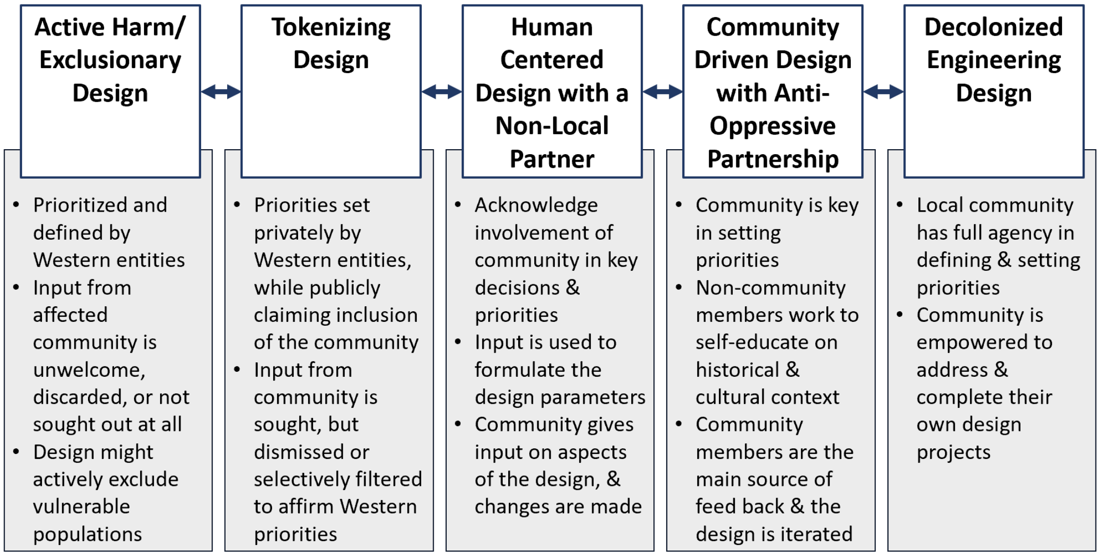

Figure 1. Continuum of decolonizing engineering design. This continuum is a reflection of the journey from top-down, exclusionary practices to a more equitable, anti-oppressive and community-led approach in engineering design. It emphasizes the importance of moving away from impositions of external agendas and recognizing the knowledge, expertise, and needs of local communities.

We previously developed and piloted an interdisciplinary design course for lower-level undergraduate students to bridge these frameworks and explore anti-oppressive design through partnerships [16]. In this pilot implementation with one project (n=5), we showed that through the class, student appreciation for understanding the historical context of a problem improved, and that students learned that community members and users are crucial collaborators, and best able to set priorities and give feedback throughout the design process. Expanding this pilot class into a senior design course makes it possible to both place a greater emphasis on the technical components of design, and to have projects from multiple countries to highlight the distinct needs of different communities with their unique geo-political backdrops.

Accordingly, we have designed a senior capstone course that integrates the principles of HCD, PjBL, and AOP at Duke University, a mid-size, wealthy, predominantly white private institution in the southern part of the United States. This course aims to equip undergraduate students with the skills and perspectives necessary to engage in anti-oppressive design practices that are rooted in meaningful community partnerships. The curriculum builds on the strengths of HCD and PjBL by incorporating modules that emphasize the historical and social contexts of global health, encourage students to reflect on their own positionality and privilege, and challenge them to design solutions that prioritize equity and sustainability. This notion of co-learning and co-developing with individuals with different lived experiences and background knowledge to bring to a solution is vital for these projects; however, this skill is directly applicable for senior undergraduates poised to graduate and join existing projects in industry, existing laboratories in academia, or other project teams. By working on course projects sourced from both global and local community partners, students are encouraged to recognize that systemic inequities exist everywhere and that addressing local issues can be just as impactful as tackling global challenges.

The integration of HCD, PjBL, and AOP in this course represents a novel approach to engineering education that has the potential to produce more socially conscious and effective engineers. One of the primary goals of this course is to help students develop a deeper understanding of the interconnectedness of global health and engineering, and in turn, translate that understanding into more sustainable and ethically-minded design solutions. By exposing them to real-world challenges and encouraging them to reflect on their own roles as engineers, the course aims to shift their perspectives from a purely technical focus to a more holistic view that integrates knowledge of systemic inequalities into all phases of the design process, strengthening students engineering aptitude while developing students ability to think outside the traditional engineering box. We hypothesize that this approach will lead to improvements in students' design skills while challenging students to position themselves as engineers and designers within a global, imperfect system.

2. Literature Review

The theoretical frameworks employed in the course design are synthesized here to showcase the evidence-base for the integration of HCD, PjBL, and AOP in a senior-design course.

2.1. Human-Centered Design

Human-Centered Design (HCD) is a problem-solving approach and design philosophy that prioritizes the needs, experiences, and perspectives of the people who will interact with a product, system, or service. It emphasizes empathy, collaboration, and iterative feedback to ensure that solutions are functional, accessible, and meaningful to end users [17], [18]. HCD is sometimes referred to as "design thinking," the slightly less descriptive term for the model and tool-kit developed by IDEO to popularize the concept [19].

HCD has been implemented in a variety of structures to meet the needs of different academic classrooms, but usually features some variation on three main phases in a cyclical design process: hear or define and empathize with a community challenge, create or ideate a solution, and deliver the solution back to the community or otherwise implement it [3]. Another group has explicitly linked the HCD framework to engineering design activities, creating a toolkit with which traditional engineering courses can integrate the principles of HCD while meeting ABET requirements [18]. Lawrence et al. created an HCD taxonomy for trans-disciplinary learning [20] while Shehab and Guo have validated metrics for assessing the impact of HCD on learning in higher education courses [21].

Case studies on HCD have shown that the HCD process can improve students' perception that user-research and input is a critical component of the design process [22]. HCD has also been shown to greatly benefit the creative problem-solving ability of students over the duration of a class [23], and engage students more thoroughly to retain them in STEM when introduced to HCD early in their engineering careers [24].

2.2. Project-Based Learning

Project-based learning (PjBL) has emerged as a transformative approach in undergraduate engineering education, fostering practical skills, critical thinking, and student engagement. Studies highlight its integration across curricula to address real-world challenges, preparing students for the complexities of 21st-century engineering [25], [26]. Case studies show its success in teaching design skills through realistic problem-solving, enhancing teamwork and communication [27], [28].

Best practices in PjBL emphasize structured project phases, industry collaboration, and iterative design [29]. Enhanced PBL methods, such as interdisciplinary and technology-integrated approaches, further amplify learning outcomes [30]. For freshmen, PjBL promotes engagement and foundational skill-building, while multi-level training strategies adapt to diverse learning needs [31], [32].

2.3. Anti-Oppressive Praxis/ Pedagogy

Paulo Freire's Pedagogy of the Oppressed is a seminal work in education and critical theory that explores the dynamics of oppression and liberation in the context of education [33]. This work is often connected to the root of anti-oppressive pedagogy; it offers a philosophical foundation for transformative education and practice. Freire's pedagogy emphasizes critical consciousness, collaboration, and the dismantling of systemic inequities. This has given rise to anti-oppressive praxis in engineering design, which asserts that incorporating critical theories and emancipatory approaches to address systemic inequities and foster inclusive practices is vital. Frameworks for anti-oppressive design link theory to practice, providing conceptual scaffolds to challenge oppression through design processes [34]. Anti-oppressive research highlights epistemological distinctiveness, promoting methodologies that prioritize community voices and co-creation [35]. These methodologies are further enriched by critical and queer theories, offering tools to navigate identity and systemic power dynamics in academic and design contexts [5].

Case studies demonstrate how design and participatory research can address power asymmetries, aligning projects with community interests rather than institutional priorities [6], [34]. Anti-oppressive frameworks also intersect with pedagogy, offering strategies to nurture inclusive identities among educators and students [36], [37]. In engineering education, tools like the Anti-Oppressive Social Work Design (AOSWD) framework integrate social justice values into design thinking and project-based learning [38]. Collectively, these insights underscore the transformative potential of anti-oppressive praxis, bridging research, education, and design to create equitable and inclusive systems.

3. Course Design and Methodology

3.1. Course Design

First, the instructional team worked to identify our key partner organizations and to secure projects that would be feasible and educational for students. We also gave students the opportunity to source their own projects over the summer and worked with students to develop an appropriate scope and partner relationship. These partnerships grounded the course in real-world contexts and helped students learn to adapt design practices to diverse needs. We had eight projects that the six teams of students were able to select from, partnering students with organizations in the US (3 local options in Durham, NC or surrounding area), Peru (2 projects), Malawi, Uganda, and Nigeria.

Next, we developed the lab and instructional content that would support the students' technical and theoretical development respectively. The class was structured to have a 3-hour lab segment in a design space, and two 75-minute periods in a traditional classroom. The lab sections focused on technical elements and prototyping skills. The classroom sessions focused on providing a conceptual understanding of the design process, a theoretical framework to apply these lessons to design, historical context on global health, and case studies to provide concrete examples of how all of this ties together.

The lab section of the class was hosted in the university's makerspace, which offers 3D printing, prototyping tools, and other resources. We started with foundational topics, like forming team contracts and defining needs statements, and moved into practical skills like 3D modeling and fabrication techniques. After building this foundation, lab activities ranged from creating initial prototypes to testing design requirements, with each lab structured to support iterative improvement and align with the students' specific project goals.

The "lecture" components of the class were hosted in a traditional classroom. These sessions consisted mostly of short introductory lectures, which then transitioned into full class discussions of the week's readings that largely focused on the different activities surrounding design and the history, ethics, and equity in global health. We selected a range of readings and case studies that would guide students in understanding how colonial legacies, systemic inequities, and cultural context shape global health challenges and their potential solutions. We intentionally spent time working to create a syllabus that was reflective of the communities we partner with and authored by a majority of minority authors from diverse backgrounds. By incorporating these elements, we aimed to provide the theory that students could apply to their projects and partnerships.

In accordance with the learning for liberation model, we aimed to not lecture at students for the majority of class time, but to instead draw them into discussions. To prepare students for discussions, all assigned reading had a required annotations component. The Hypothesis integration with Canvas was central to this, allowing students to complete social annotations on readings. This tool allowed students to provide a combination of insights, thoughts, comments, or replies to other students on various sections of the reading and come to class ready to share and discuss for the majority of the period. While it is our intention to also analyze the content of these social annotations to track the thought progression of students over the course of the class, this is outside the scope of this WIP paper. Time was usually reserved at the end of class for students to get together with their project groups to make plans for upcoming work periods and reflect on the class-period as a group.

Assignments were scaffolded intentionally to mirror the phases of the human-centered design process: from identifying needs to prototyping and testing. By requiring continuous documentation, peer evaluations, and reflections, we aimed to cultivate students' sense of accountability to their teams and their projects. We also worked to ensure that students maintained contact with partners throughout the semester, requiring that design updates be based on feedback they had received from partners and that meeting minutes or documentation of contact be submitted. An overview of the course parameters and assignments is detailed below, with key aspects highlighted that help apply an AOP lens to traditional HCD and PjBL models, moving the course further along the continuum of decolonized engineering design education (**Figure 2**).

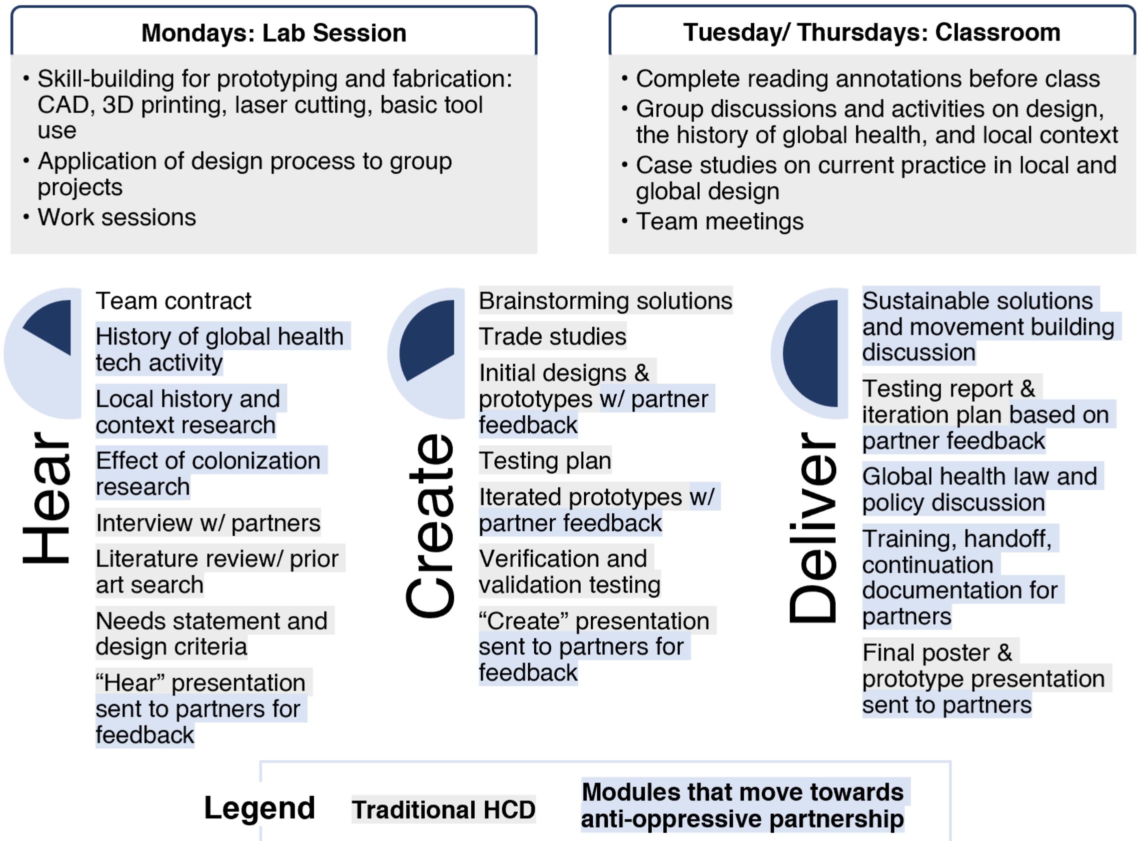

Figure 2. Course structure and implementation overview.

3.2. Methodology

A key focus of this research is to explore how students' perspectives on their roles as engineers evolve due to participation in this course. To capture these changes, students completed reflective exercises at both the beginning and end of the semester. The initial reflection assessed their baseline engineering self-efficacy, prior experience in global health, and motivation for enrolling in the course. The final reflection examined how their views on global health, engineering, and the design process have changed over the course of the semester (see **Appendix 1** for details).

We have deductively analyzed these reflections through direct content analysis with predetermined codes aligned with the course objectives and research objectives. Namely, we looked to identify key shifts in students' understanding of their roles as engineers, their approaches to global health challenges, and their engineering self-efficacy. Coding and analysis were completed in NVivo v14. Descriptive statistics for each category are provided alongside demonstrative quotes.

Additionally, the final course evaluation asked students questions from the Global Engagement Survey (GES) to measure cultural humility and critical reflection outcomes [39]. The GES was developed in 2015 as a way to assess community-based global learning outcomes, and has been used by more than 37 institutions to assess their global programming. The 12 Likert items related to cultural humility (α=0.66 for cultural adaptability and α=0.78 for openness to diversity) and the 8 Likert items related to critical reflection (α=0.80) were included in the anonymous course evaluations [40]. These questions were not included in the pre-survey for the course (though they will be in future iterations of the course) so changes over the course could not be directly measured. Instead, the mean of each Likert scale item for each component of global learning was averaged, and descriptive statistics are provided. These cannot be matched with student reflections due to the anonymity of the course evaluations, but overall themes from the class can emerge. A supplemental Likert scale asked students how much they agreed with the statement "I became more aware of multiple perspectives on issues of diversity due to the course" as another proxy measurement for the impact of the course on the students' thinking.

All research was approved by the Duke University Campus Institutional Review Board (protocol number 2025-0212).

4. Results and Discussion

23 out of 24 students in the class both completed reflections and gave consent for their responses to be analyzed. A qualitative analysis of themes from the students' reflections is provided here, with representative quotes for each theme in Table 1.

All students in the class mentioned that there was at least one aspect of the course that was novel to them. Seven students wrote about the new technical skills throughout the duration of the course. 16 students said that this was the first class opportunity they had to combine engineering and global health ideas, particularly in actually working towards designing a solution. 19 students detailed that this course provided a unique way to engage in the design process, either by highlighting the importance of community-engagement and interaction with partners or by reframing design as a holistic rather than purely technical process. This is supported by the anonymous course evaluations in which 16/21 students who responded said the course was either "very good" or "excellent" at providing intellectual stimulation, where the course "made [the student] think in new ways, encouraged [the student] to adopt different points of view, or challenged [the student] to develop new skills."

All of the students also explicitly mentioned in their final reflections that the class changed their view on biomedical engineering (BME), the role of engineers, or their perspective on global health (21 in each specific category). Students reported a shift from viewing BME narrowly as device development or technical work to understanding it as a multidisciplinary field with the potential for societal and global impact. This fed into their shifting perspective on their role as engineers, leading to the realization that engineers from Duke University should prioritize partnerships with local engineers who have a deep understanding of community needs. They had an increased understanding that effective solutions emerge from co-creation, listening, and respecting the lived experiences of the communities they partner with. In learning more about the importance of lived experiences, several reflections noted a shift towards a more critical view of existing global health structures. They particularly noticed biases, inequities, and the potential for neo-colonial tendencies in the way the global health work has traditionally been conducted. There was a shared understanding that global health efforts should aim for equity and empowerment rather than imposing solutions.

18 students (78%) directly mentioned human-centered or community-centered design in their reflections as being an important aspect of what they learned during the course. Many students emphasized the importance of designing solutions that prioritize the needs and experiences of the end-users. For the students, this involved listening to and collaborating with community partners, ensuring solutions were not imposed but developed alongside the people with the lived experience to best constrain the design space. Many students contrasted the human-centered approach of the course with their traditional engineering curricula, which often focused on technical problem-solving without sufficient consideration of societal impacts. Many students reflected that this course challenged these norms and expanded their perspective on engineering's role in addressing global health challenges. This aligns with the students' sentiment that interaction with their partners was a vital component of their design process, which was directly mentioned by 21/23 students. Regular communication with clients and partners provided valuable insights that kept the design on track and ensured it met the actual needs of the community. The students found that in addition to helping them refine technical solutions to make sure they were practical and sustainable, the meetings with their partners helped motivate them to be more engaged in the design process.

Besides the core project component of the course, students found that the readings and the case studies were most effective in supporting their understanding of the material from the class. Though students were not prompted to discuss what aspects of the course were most helpful, eleven students (47.8%) highlighted the readings in their reflections, and ten mentioned the case studies (43.5%). The students additionally found that presenting on the case studies helped diversify the class format, and helped them learn the material more thoroughly in order to present it.

All 23 students correctly perceived at least one component of the course objective: to teach engineers to design responsibly, ethically, and effectively for global health challenges by prioritizing community collaboration, understanding local contexts, and focusing on sustainable, appropriate solutions. Students reflected that this course should continue to be offered to help bridge the gap between engineering and global health and educate engineering students on the benefits of human-centered design. Students acknowledged the challenges of designing for communities different from their own, noting the risk of inadvertently causing harm or imposing assumptions. However, there is a strong sense that this course can begin to equip students with the awareness and tools needed to avoid such pitfalls, giving them this much-needed perspective before integrating it into their professional engineering careers.

Table 1. Representative quotes from deductively analyzed themes in student reflections.

Novelty of the course	Developed new technical skills	"However, the course provided a comprehensive introduction to the **design process**, guiding me from initial problem definition to solution development. Since taking this course, I've gained lot of experience with CAD and building **mechanical solutions** for low-

		cost innovations in low-resource settings."
	Combining global health and engineering	"While I came into this course with some knowledge of global health, it helped me see how I can apply this understanding directly to biomedical projects. The focus on **community involvement and sustainable solutions** made me think critically about how I can approach global health challenges in my future work. This course reinforced my belief that global health issues cannot be solved with a one-size-fits-all approach and that **understanding cultural and contextual nuances is key**."
		"This course was the first time global health frameworks and engineering ethics were incorporated seriously since [...] freshman year, and I think even then you don't have a deep or broad enough background as a freshman to understand truly how relevant the downstream effects are to you as an engineer."
	Unique way to engage with the design process	"The course really emphasized the importance of human-centered design (HCD), and I began to see design not just as a technical skill but as a process that needs to be shaped by **empathy, ethics, and a deep understanding of the community**."
		"BME 462 has taught me that the **most complicated and advanced design may not always be the best** for the people you are making the solution for. I think this is something that we're not really taught throughout the 4 years that we're here and I think it's something that we should start realizing and teaching."
Changed viewpoint on…	biomedical engineering	"My perception of Biomedical Engineering (BME) has evolved over this semester. Previously, I thought of BME as somewhat less directly human-focused compared to, say, doctors, who are face-to-face with patients. However, I've come to realize that **BME professionals carry a parallel responsibility**: we influence patient outcomes and societal health on a large scale through the devices and systems we create."

	the role of engineers	"I think Duke engineers should be well versed in global health and public policy, and be able to meaningfully contribute to research and discourse in the field in collaborative ways. In addition, there is a responsibility for engineers Duke to be **accountable — to engage in partnerships** in meaningful, non-paternalistic and empathetic ways and focus on ways to address key disparities."
	global health	"This course has deepened my understanding of global health by showing how human-centered design principles can be applied to health interventions, while also discussing different global health initiatives with a **critical lens**."
Human-centered design	Importance of partner engagement	"This course has really opened my eyes to how much **community involvement is necessary** for good design. Particularly with my project, we were in constant communication with [our partner organization]."
	Importance of knowing local context	"the course seeks to equip engineers with design frameworks and critical analysis skills needed to **effectively practice community-centered design** and (maybe) deconstruct some of the notions of objectivity that I think we build up in engineering coursework — theory on one hand and practice on the other. To me, this course has pointed toward the notion that engineers don't and can't know everything without turning to the **expertise and subjective experiences of community partners**."
Class components that contributed to learning	Readings	"I think several key readings and discussions helped form my thoughts around this — what immediately comes to mind are those focusing on decolonising design, empowering knowledge systems of the subaltern or historically marginalized, and projects that **integrate into the culture and resources of a given place**."
	Case studies	"[...]the discussions were insightful as they brought up themes that I hadn't discussed before: like directionality of research with LMICs, frugal innovation, human-centered design, etc. Our case study on the Ponseti technique particularly appealed to me as it allowed me to **understand how innovation from LMICs can be brought back to higher income healthcare systems** and the barriers to this."

Student perception of course goals	Goal	"I think the main goal of this class is to encourage us to think critically about **the type of engineers we want to be** and how we approach global problems. It really pushed me to examine my own biases, as well as the broader biases in the world. We also learned how important it is to work with community partners in a culturally sensitive way, treating them as equals despite our different backgrounds."
	Benefit outweighs risk	"While designing for LICs from an HIC setting is inherently challenging and imperfect, this course opens critical discussions and provides tools to navigate these complexities as thoughtfully as possible. It serves as an essential step toward **addressing the inequities in global health through design**."

Results from the global engagement survey questions on the anonymous course evaluations support that students leave the class with strong critical reflection skills and decent cultural humility **(Figure 3**). Though there is no pre-class score with which these scores can be compared to note any changes or improvements, out of the 21 respondents, 18 students (78%) "agreed" or "strongly agreed" that they "became more aware of multiple perspectives on issues of diversity" as a result of the course ($\bar{x}$ = 4.19, where 5 is "strongly agree").

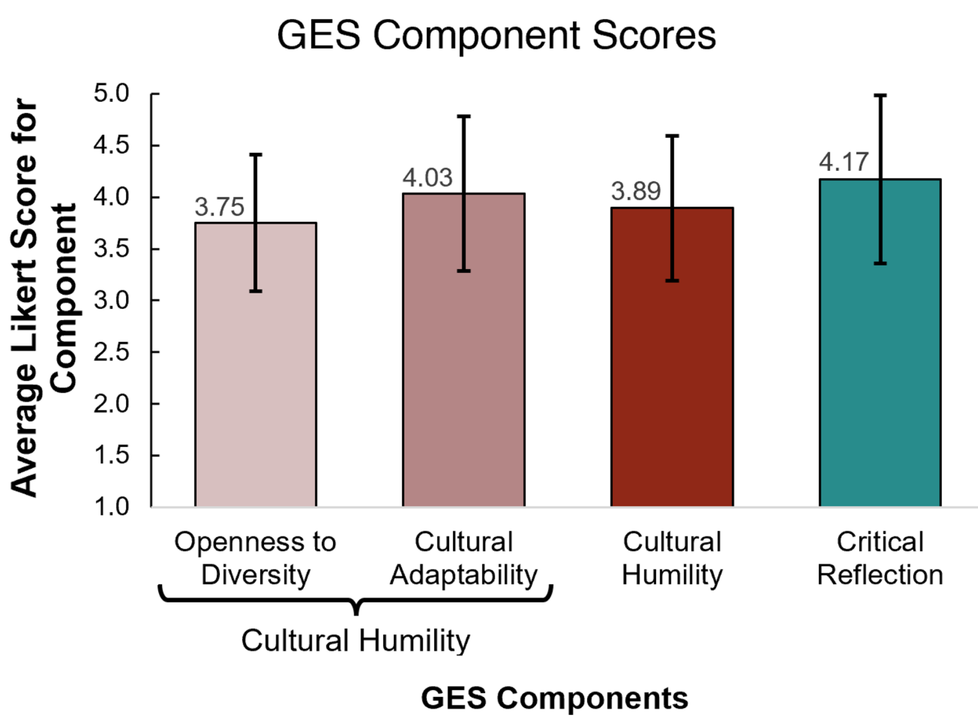

Figure 3. Global engagement survey component scores. The average of the scores for each component on a scale from 1-5 are shown, with 1 being "strongly disagree" and 5 being "strongly agree" with each Likert item. The cultural humility component is a summation of openness to diversity and cultural adaptability ($\bar{x}$ = 3.89). Eight Likert scale items make up the openness to

diversity component ($\bar{x} = 3.75$), and five encompass the cultural adaptability component ($\bar{x} = 4.03$). Critical reflection is made up of eight Likert scale items ($\bar{x} = 4.17$).

According to the GES survey toolkit, cultural humility is defined as a commitment to critical self-reflection and lifelong re-evaluation of assumptions, increasing one's capacities for appropriate behaviors and actions in varying cultural contexts. It also involves awareness of one's positionality and openness to deconstructing biases and assumptions to address historical inequities. Critical reflection is defined as engaging in a learning process that recognizes and critiques ideology (political, economic, social, and cultural), uncovers hegemonic assumptions, and examines relations of power with the goal of becoming critically aware of how each distorts our worldview [40]. These axes of community-based global learning were selected for their relevance to anti-oppressive human-centered design. From the students' reflections, it seems likely that these scores were improved by the class, as main takeaways included the importance of community voices and the necessity of partner engagement (openness to diversity), learning to examine their own roles as engineers and the biases they carry with them (cultural adaptability), and to critique neo-colonialism in global health work and re-center lived experience in design (critical reflection). In future implementations of this class, these will be directly measured through coupled pre- and post- surveys; however, it is important to note that pre-measurements using metrics such as these may also suffer from response shift bias [41].

5. Conclusion

In conclusion, preliminary results support that the course had its intended impact on students' understanding of engineering and global health, with a strong focus on human-centered design. Students recognized the importance of combining technical engineering skills with a deep understanding of community needs, marking a significant shift in their approach to both biomedical engineering and global health. The course's emphasis on community engagement and collaborative design played a role in changing students' views on their role as engineers, highlighting the need for partnerships with local engineers and the value of co-creating solutions based on the lived experiences of the communities they serve. This shift led many students to critically reassess traditional global health structures, noting biases and inequities that could be perpetuated through top-down approaches.

Integrating anti-oppressive pedagogy into human-centered design is central to the mission of the course because it challenges the power dynamics in which outside organizations or engineers impose solutions on communities without understanding their context. Through active listening, co-creation, and collaboration, students learned that effective solutions arise not from assumptions, but from deep engagement with the people most impacted. This helps dismantle the imposition of external solutions that center the designer in the solution. Instead, this model fosters a sense of ownership, agency, and empowerment among local communities, addressing power imbalances that can lead to oppression.

By recognizing how global health has historically been shaped by dominant, Western-centric ideologies, students were able to critically assess these practices and advocate for more equitable approaches. This begins by teaching students to understand their own positionality and biases while engaging with diverse communities. This perspective is fundamental to anti-oppressive design, which demands an awareness of how privilege, power, and historical context influences the design process. Through regular communication with community partners, students learned how to adapt their solutions to be culturally relevant, sustainable, and responsive to the unique challenges faced by the communities they worked with.

A common criticism in design frameworks is the over emphasis on the creation step without due attention to the beginning, information gathering stage or the end, implementation of designs. A goal for this course was to engage students across the entire design process by challenging them to remove their team of engineers from the center of the solution, instead centering the end-user or community at the heart of the design process. The handoff component, whether to a partner or a future engineering team, is critical in moving towards anti-oppressive design to ensure the design process is not extractive, and that it will be either iterated on or acceptable to the partners. While it adds a burden to the instructional team, requiring additional training and support, it allows students to experience at least one full design loop—moving from concept to community feedback and iteration. This process helps students critically reflect on the project's current stage, allowing them to assess their role and the project's evolution.

Though the class has largely met its learning objectives, there is always room for improvement. Students had several suggestions on ways that the class structure could enhance the course outcomes. A few students wanted the theory on partnerships and global health to be better integrated into the written assignments and to their projects to help tie together the lecture and design aspects of the course. Some felt the readings began to be repetitive towards the end of the semester and suggested spacing the case studies out over the duration of the class rather than saving them for the end. These suggestions are being implemented in the Spring semester iteration of the course.

In addition to changes in materials presented to the students, this paper remains a work in progress as data collection methodology is being improved for the Spring semester implementation. A limitation for the study presented so far is the lack of direct comparison in quantitative data between the beginning and end of the semester. In the future, GES metrics will be assessed at both timepoints to assess the impact of the course directly on their responses. More direct questions related to the goals of the course will also be asked in the initial reflections to gauge these changes in the qualitative data collected at both timepoints. Despite these limitations, initial results point to the course meeting its objectives.

By fostering an anti-oppressive mindset in the HCD process, the course prepared students to engage in solving global challenges in a way that is inclusive, equitable, and sustainable. This helps ensure that the students are better equipped to tackle the complex challenges of a diverse and interconnected world as they leave college and find careers in engineering.

6. Authorship Reflexivity Statement

As white, cis-female researchers studying and teaching at a Duke University, a mid-size, wealthy, predominantly white private institution in the southern part of the United States, we, as authors, acknowledge our position as students and continuing learners surrounding equitable design and partnerships between universities and communities both local or across the globe. We made attempts to center voices different from our own across the syllabus, cases, and projects, though we welcome any suggestions towards our goal of continuous improvement in this area. We both understand the privilege we hold and how we have benefited from the systemic inequity that we have aimed at fostering better awareness of in our students.

With every project, design decisions were proposed or approved by community partners before iteration with local sustainability at the forefront. It is the goal for every project to conclude with the complete handover of prototypes, design files, and training documents to be owned by the community partners. We extend sincere thanks to our community partners for working with our instructional team and students and acknowledge that the constraints of a one-semester design course may impose tighter timelines onto partners.

References

[1] C. Titus, C. B. Zoltowski, and W. C. Oakes, "Designing in a Social Context: Situating Design in a Human-Centered, Social World," presented at the 2011 ASEE Annual Conference & Exposition, Jun. 2011, p. 22.444.1-22.444.11. Accessed: Sep. 28, 2023. [Online]. Available: https://peer.asee.org/designing-in-a-social-context-situating-design-in-a-human-centered-social-world

[2] M. E. Beier, M. H. Kim, A. Saterbak, V. Leautaud, S. Bishnoi, and J. M. Gilberto, "The effect of authentic project-based learning on attitudes and career aspirations in STEM," *J. Res. Sci. Teach.*, vol. 56, no. 1, pp. 3–23, 2019, doi: 10.1002/tea.21465.

[3] K. Breen *et al.*, "Community-Centered Design Thinking as a Scalable STEM Learning Intervention," *Adv. Enginering Educ.*, vol. 11, no. 2, 2023, doi: 10.18260/3-1-1153-36042.

[4] "Rethinking Design Thinking: Part I: Design and Culture: Vol 3, No 3." Accessed: Jan. 08, 2025. [Online]. Available: https://www.tandfonline.com/doi/abs/10.2752/175470811X13071166525216

[5] L. Weber and A. Hermanson, "Anti-Oppression and Academia: Applying critical methodologies to study identity and student experiences in university settings," 2015. Accessed: Jan. 08, 2025. [Online]. Available: https://www.semanticscholar.org/paper/Anti-Oppression-and-Academia%3A-Applying-critical-to-Weber-Hermanson/95f3cbfabfb6623add3133b89ec6af5d56e98a6e

[6] R. A. E. Gutierrez, M. Sonsteng-Person, S. King-Shaw, and M. T. Valmocena, "For the institution or for the community?: toward an anti-oppressive research praxis in conducting participatory action research," *J. Community Pract.*, vol. 31, no. 3–4, pp. 284–296, Oct. 2023, doi: 10.1080/10705422.2023.2272162.

[7] R. A. Shahjahan, A. L. Estera, K. L. Surla, and K. T. Edwards, "'Decolonizing' Curriculum and Pedagogy: A Comparative Review Across Disciplines and Global Higher Education Contexts," *Rev. Educ. Res.*, vol. 92, no. 1, pp. 73–113, Feb. 2022, doi: 10.3102/00346543211042423.

[8] S. Porter and Y. Siddiqui, "Addressing colonial and militarized themes in STEM education," *Front. Educ.*, vol. 9, p. 1480199, Sep. 2024, doi: 10.3389/feduc.2024.1480199.

[9] S. R. Hawks, J. L. Hawks, and H. S. Sullivan, "Theories, models, and best practices for decolonizing global health through experiential learning," *Front. Educ.*, vol. 8, p. 1215342, Nov. 2023, doi: 10.3389/feduc.2023.1215342.

[10] Q. G. Eichbaum, L. V. Adams, J. Evert, M.-J. Ho, I. A. Semali, and S. C. Van Schalkwyk, "Decolonizing Global Health Education: Rethinking Institutional Partnerships and

Approaches," *Acad. Med.*, vol. 96, no. 3, pp. 329–335, Mar. 2021, doi: 10.1097/ACM.0000000000003473.
[11] S. M. Syal and J. Kramer, "Design and Justice: A Scoping Review in Engineering Design," *J. Mech. Des.*, vol. 147, no. 051404, Nov. 2024, doi: 10.1115/1.4066847.
[12] C. C. Cruz, "Decolonizing Philosophy of Technology: Learning from Bottom-Up and Top-Down Approaches to Decolonial Technical Design," *Philos. Technol.*, vol. 34, no. 4, pp. 1847–1881, Dec. 2021, doi: 10.1007/s13347-021-00489-w.
[13] S. Paananen, M. Suoheimo, and J. Häkkilä, "Decolonizing Design with Technology in Cultural Heritage Contexts - Systematic Literature Review," in *[ ] With Design: Reinventing Design Modes*, G. Bruyns and H. Wei, Eds., Singapore: Springer Nature, 2022, pp. 1839–1855. doi: 10.1007/978-981-19-4472-7_119.
[14] J. S. Cicek, S. Masta, T. Goldfinch, and B. Kloot, "Decolonization in Engineering Education," in *International Handbook of Engineering Education Research*, Routledge, 2023.
[15] "Continuum," A O R T A. Accessed: Jan. 15, 2025. [Online]. Available: https://aorta.coop/continuum
[16] K. Eller, M. Madonna, A. Hernandez-Martinez, and N. Ramanujam, "Tech Design for Global Health: Understanding an engineer's role in global health through anti-oppressive design partnership," presented at the Biomedical Engineering Society Annual Meeting, Seattle, WA, Oct. 11, 2023.
[17] C. B. Zoltowski, W. C. Oakes, and M. E. Cardella, "Students' Ways of Experiencing Human-Centered Design," *J. Eng. Educ.*, vol. 101, no. 1, pp. 28–59, 2012, doi: 10.1002/j.2168-9830.2012.tb00040.x.
[18] T. Tucker, A. Pagano, and S. Shehab, "Merging Human-Centered Design with Engineering Design: Synthesizing a Human-Centered Engineering Design Framework," *2023 ASEE Annu. Conf. Expo. Proc.*, p. 43626, Jun. 2023, doi: 10.18260/1-2--43626.
[19] "Design Kit." Accessed: Jan. 08, 2025. [Online]. Available: https://www.designkit.org/resources/1.html
[20] L. Lawrence, S. Shehab, M. Tissenbau, T. Rui, and T. Hixon, "Human-Centered Design Taxonomy: Case Study Application With Novice, Multidisciplinary Designers," Nov. 2020. doi: 10.3102/1690347.
[21] University of Illinois at Urbana-Champaign, USA and S. Shehab, "Measuring the impact of integrating human-centered design in existing higher education courses," *Learn. 2021 Engag. Chall. Des. Educ.*, Sep. 2021, doi: 10.21606/drs_lxd2021.04.254.
[22] L. Oehlberg and A. M. Agogino, "Undergraduate Conceptions of the Engineering Design Process: Assessing the Impact of a Human-Centered Design Course," presented at the 2011 ASEE Annual Conference & Exposition, Jun. 2011, p. 22.1563.1-22.1563.15. Accessed: Jan. 08, 2025. [Online]. Available: https://peer.asee.org/undergraduate-conceptions-of-the-engineering-design-process-assessing-the-impact-of-a-human-centered-design-course
[23] S. Guaman-Quintanilla, P. Everaert, K. Chiluiza, and M. Valcke, "Impact of design thinking in higher education: a multi-actor perspective on problem solving and creativity," *Int. J. Technol. Des. Educ.*, vol. 33, no. 1, pp. 217–240, Mar. 2023, doi: 10.1007/s10798-021-09724-z.
[24] P. Dickrell and L. Virguez, "Engineering Design & Society: A First-Year Course Teaching Human-Centered Design," *2018 World Eng. Educ. Forum - Glob. Eng. Deans Counc. WEEF-GEDC*, pp. 1–4, Nov. 2018, doi: 10.1109/WEEF-GEDC.2018.8629644.

[25] R. Savage, K. Chen, and L. Vanasupa, “Integrating Project-based Learning throughout the Undergraduate Engineering Curriculum,” *J. STEM Educ.*, vol. 8, no. 3, Mar. 2008, Accessed: Jan. 08, 2025. [Online]. Available: https://www.learntechlib.org/p/173698/
[26] S. M. Gómez Puente, M. van Eijck, and W. Jochems, “Towards characterising design-based learning in engineering education: a review of the literature,” *Eur. J. Eng. Educ.*, vol. 36, no. 2, pp. 137–149, May 2011, doi: 10.1080/03043797.2011.565116.
[27] K. Gavin, “Case study of a project-based learning course in civil engineering design,” *Eur. J. Eng. Educ.*, vol. 36, no. 6, pp. 547–558, Dec. 2011, doi: 10.1080/03043797.2011.624173.
[28] J. Uziak, “A project-based learning approach in an engineering curriculum,” vol. 18, pp. 119–123, Jan. 2016.
[29] A. Shekar, “Project-based Learning in Engineering Design Education: Sharing Best Practices,” presented at the 2014 ASEE Annual Conference & Exposition, Jun. 2014, p. 24.1016.1-24.1016.18. Accessed: Jan. 08, 2025. [Online]. Available: https://peer.asee.org/project-based-learning-in-engineering-design-education-sharing-best-practices
[30] K. J. Chua, W. M. Yang, and H. L. Leo, “Enhanced and conventional project-based learning in an engineering design module,” *Int. J. Technol. Des. Educ.*, vol. 24, no. 4, pp. 437–458, Nov. 2014, doi: 10.1007/s10798-013-9255-7.
[31] M. S. Carpenter, C. Yakymyshyn, L. E. Micher, and A. Locke, “Improved Student Engagement through Project-Based Learning in Freshman Engineering Design,” presented at the 2016 ASEE Annual Conference & Exposition, Jun. 2016. Accessed: Jan. 08, 2025. [Online]. Available: https://peer.asee.org/improved-student-engagement-through-project-based-learning-in-freshman-engineering-design
[32] M. Ricaurte and A. Viloria, “Project-based learning as a strategy for multi-level training applied to undergraduate engineering students,” *Educ. Chem. Eng.*, vol. 33, pp. 102–111, Oct. 2020, doi: 10.1016/j.ece.2020.09.001.
[33] P. Freire and D. P. Macedo, *Pedagogy of the oppressed: 30th Anniversary Edition*, 30th anniversary edition. New York: Bloomsbury Publishing, 2014.
[34] “Sensemaking for Power Asymmetries in Anti-oppressive Design Practice - ProQuest.” Accessed: Jan. 08, 2025. [Online]. Available: https://www.proquest.com/docview/2676547798?fromopenview=true&parentSessionId=HjJmnTGZL6qeFX059xO1A5zIPXV9yZT0ML6iQ4a%2BIJc%3D&pq-origsite=gscholar&accountid=10598&sourcetype=Dissertations%20&%20Theses
[35] R. Rodney, M. Hinds, J. Bonilla-Damptey, D. Boissoneau, A. Khan, and A. Forde, “Anti-oppression as praxis in the research field: Implementing emancipatory approaches for researchers and community partners,” *Qual. Res.*, vol. 24, no. 4, pp. 872–893, Aug. 2024, doi: 10.1177/14687941231196382.
[36] V. Ichikawa, “Complicated but Not Blurred,” in *Handbook of Anti-Discriminatory Education*, A. Eizadirad and P. P. Trifonas, Eds., Cham: Springer Nature Switzerland, 2025, pp. 1–18. doi: 10.1007/978-3-031-47411-8_65-1.
[37] A. R. Aqil *et al.*, “Engaging in Anti-Oppressive Public Health Teaching: Challenges and Recommendations,” *Pedagogy Health Promot.*, vol. 7, no. 4, pp. 344–353, Dec. 2021, doi: 10.1177/23733799211045407.
[38] A. Sinha, “Innovating with social Justice: Anti-oppressive social work design framework,” *DISCERN Int. J. Des. Soc. Change Sustain. Innov. Entrep.*, vol. 1, no. 1, Art. no. 1, Nov. 2020.

[39] "Community-Based Global Learning: The Theory and Practice of Ethical Engagement at Home and Abroad," Routledge & CRC Press. Accessed: Sep. 30, 2024. [Online]. Available: https://www.routledge.com/Community-Based-Global-Learning-The-Theory-and-Practice-of-Ethical-Engagement-at-Home-and-Abroad/Hartman-Kiely-Friedrichs-Boettcher/p/book/9781620360880

[40] N. Reynolds, B. Lough, and E. Hartman, "The Global Engagement Survey: A Multidimensional Assessment of Global Learning." Accessed: Jan. 08, 2025. [Online]. Available: https://www.researchgate.net/publication/350923061_The_Global_Engagement_Survey_A_Multidimensional_Assessment_of_Global_Learning

[41] K. Miller, T. Espinosa, I. Araujo, and I. Gallegos, "Response-shift bias in student self-efficacy during an actively taught physics course," *Phys. Rev. Phys. Educ. Res.*, vol. 19, no. 2, p. 020167, Dec. 2023, doi: 10.1103/PhysRevPhysEducRes.19.020167.

Appendix One: Reflection Questions

Initial Reflection Guidelines:

Purpose: The purpose of the initial reflection is to provide an opportunity for each student to express their personal experience with design, perceptions of global health, and rationale of choosing BME 462 as their senior design course.

Instructions: Use the outline below to compose a journal (first person is acceptable) entry-styled composition (1-2 pages, single space, 11/12 pt Times/Ariel) in response to the following prompts/questions.

You must 'cite' your answer, in-line, to each of the questions. *For example: "During ..... I thought.... (Q5)."*

Name:

Intended Plan after Graduation (as of Aug 2024):

1. What is your experience with design or building?
2. When/why did you decide on BME as your major?
3. Have your thoughts on BME changed since deciding on your major?/Is your motivation the same or different on continuing with BME as your major?
4. What is your experience with global health-related topics or courses? Have you ever worked on or thought about global health issues related to design? Provide examples of any projects or discussions that had a significant impact on you.
5. What motivated you to enroll in this design course? Discuss any specific interests or goals you had when you chose this course.

Final Reflection Guidelines:

Purpose: The purpose of the reflection is to provide an opportunity for each student to express their personal experience with design and this course and perceptions of global health.

Instructions: Use the outline below to compose a journal (first person is acceptable) entry-styled composition (1.5-2.5 pages, single space, 11/12 pt Times/Ariel) in response to the following prompts/questions.

If you find it helpful, you can 'cite' your answer, in-line, to each of the questions. *For example: "During ..... I thought.... (Q5)."*

Name:

Intended Plan after Graduation (as of Dec 2024):

1. What is your experience with design or building?
2. How has the course material influenced your understanding of design? Provide examples of any projects or discussions that had a significant impact on you.
3. Have your thoughts on BME changed this semester? Is that related to the course or your time as a senior?
4. Has this class impacted your idea of engineering? How?
    1. How does this impact your view of the role of Duke engineers in global health and public policy?
    2. What would the role of local engineers be ideally in solving local problems?
5. What is your experience with global health-related topics or courses? Have you ever worked on or thought about global health issues related to design? Provide examples of any projects or discussions that had a significant impact on you.
6. How will this class impact your idea of global health?
7. How did each member of your time provide leadership and create a collaborative and inclusive environment that established goals, planned tasks, and met objectives? Or how did your team fall short?
8. How would you improve the structure of this class?
9. What do you perceive as the goal of this class?
10. Does it make sense for this class to exist at all? Are we doing more harm than good?

Appendix Two: Global Engagement Survey Questions

Global Engagement Survey items by scale
*Note that the survey items are randomized for students, so they don't appear in this order
*Closed-ended questions are asked using a 5-point Likert scale. Options are: strongly agree, agree, neither agree nor disagree, disagree, strongly disagree

1. Cultural Humility
Closed-ended items

Openness to diversity
By interacting with people who are different from me, I have learned that I am flexible in my thinking and ideas.
I am very comfortable talking about diversity with people of different cultures.
I have a very strong appreciation of other nations, cultures, and customs.
I am able to communicate in different ways with people from different cultures.
When I am in a cultural space that is different from my home culture, I make efforts to adapt my language to include local language, sayings, or speech patterns.
When I am in a cultural space that is different from my home culture, I adjust my expectations and defense of personal space.
I enjoy when my friends from other cultures teach me about our cultural differences.
I am open to people who strive to live lives very different from my own lifestyle.

Cultural adaptability
I adapt my behavior and mannerisms when I am interacting with people of other cultures.
I often adapt my communication style to other people's cultural background.
I can easily adapt my actions in response to changing circumstances.
I can easily resolve misunderstandings with people from other cultures.
I work to develop and maintain relationships with people of backgrounds different from my own.

Critical Reflection
I think a lot about the influence that society has on other people.
I think a lot about the influence that society has on my own behavior.
I enjoy analyzing the reasons for people's behavior.
I carefully consider how privilege affects people's opportunities.
I carefully consider how dominant cultural assumptions reinforce inequalities.
When I stop to consider what I know about the world, I realize that even my strongest "truths" are open to change.
I believe it is important to analyze and understand our own thinking processes.
I tend to "see" people that otherwise often remain "invisible".