Encountering Axiology: Engineering Graduate Students' Experiences with Values in an Engineering Research Center

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Abstract

This research paper examines research axiology and value transfer by examining engineering graduate students' research experiences in an Engineering Research Center (ERC). Students constantly encounter cultural behaviors, norms, and espoused values, and are taught "this is how we do things around here," and "this is why we do those things." For individuals established within a field, many of these cultural realities become invisible, as they have already been incorporated into the field and play a major role in perpetuating the culture encountered by new members. By focusing on students' experiences, there is an opportunity for rich depth in the description of engineering research values through the natural salience afforded by introduction into a new community and profession. To begin to answer these questions, we interviewed five engineering graduate students engaged in research in a Gen-4 ERC. We found that on the surface, students communicated a good understanding of the overall values and goal of the ERC, aligned with them, and felt as though they were making a difference in the world. However, for some, there were experiences of tension and friction with their own personal and long-term goals and values. Additionally, discussion of certain values seemed performative for some students (namely topics of diver**si**ty, equity, and inclusion), and potential internalization of certain values over others.

Introduction

Graduate students engaging in research education are vying for admission to a community of scholars, learning to operate within specific requirements, regulations, and expectations in each field of study [1]. Shifts in how doctoral students view themselves and their peers, their mentors, the field, and generated knowledge occur throughout the research education process. Simultaneously, students proceed through the process of taking on or rejecting values and value systems (axiology) that are proliferated and perpetuated in their professional field of study. In addition to messages conveyed from graduate development within engineering environments, graduate students also bring their beliefs about knowledge, expertise, experiences, values, and goals with them. The interplay of contexts, embedded values, and personal values shapes graduate students' professional development and futures in engineering [1]. Without an understanding of how the individual operates within these systems, it becomes difficult to understand what perspectives are lost, prioritized, or transformed during research education. Similarly, while graduate education and developing research capability is a unique moment in time, understanding how graduate students operate within this space may provide insight into how others operate within the engineering research enterprise as well.

As navigating a graduate program is naturally complex, strategies for pursuing a research direction and proceeding through a degree program include knowledge of critical sources and relying on expertise and guidance from faculty advisors and others in mentorship roles [2], [3], [4]. Students must know enough about the epistemic paradigms, method modality, and existing dogma within their fields and disciplinary neighbors to be able to communicate, navigate, and collaborate with others in their field [5], [6], [7] To develop novel information and push the field forward, students must be willing to challenge previously held beliefs and dismiss any taken-for-

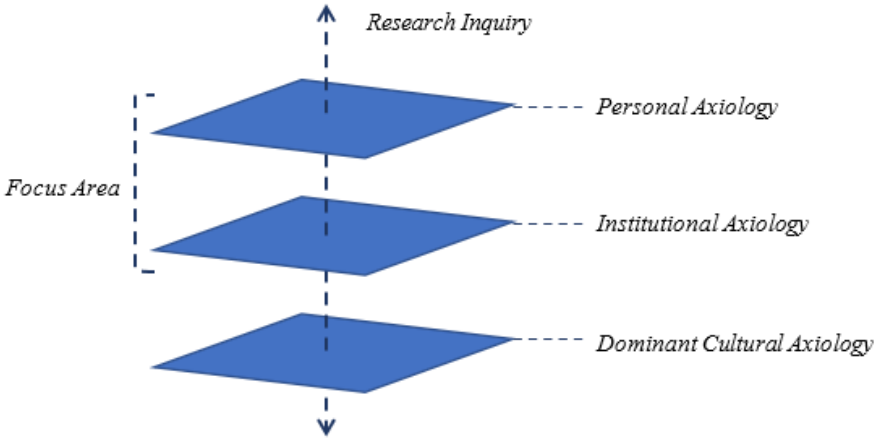
granted views of the world around them [8]. Kent and colleagues [9] contended that those in the early stages of their research careers are prime catalysts and change agents in shifting systemic norms in research culture. This proposed study continues in this vein and is an exploration of how these systems of cultural indoctrination influence and change graduate students on their pathways to becoming engineering researchers. This study focuses primarily on students involved in an engineering research center.

The site was chosen to explore engineering research culture as an exemplar [10]. ERCs are hubs of leading engineering research, are well-funded, and necessarily employ the foremost researchers in any given context. Similarly, ERCs explicitly espouse their intended goals and values, with constant communication of how the Centers are fulfilling those goals through site visits, annual reviewing, and other measures. We argue there is a need to understand how the process of research is carried out in these contexts to both learn from and critique how engineering research culture is developed and maintained in an ERC. Cross [11] argues understanding how a community chooses to educate new members is the most straightforward way to understand community values (especially espoused values). Students constantly encounter cultural behaviors, norms, and espoused values, which may become invisible to individuals established within a field over time. There is an opportunity for rich depth in the description of institutional practices, values, and beliefs through focusing on students' experiences. The following research questions guide this study:

> **RQ1.** What are engineering graduate students' perceptions of values in an engineering research center?
> **RQ2.** How do students navigate the process of becoming researchers?

Conceptual Framework

This study provides a deeper understanding of the axiological landscape that engineering graduate students encounter during their graduate education and as they do research. However, as previously discussed, axiology is complex, as individuals working to do research often bring their values to their work as well as the values of the surrounding institutional context they are working within. The broad, systemic values that exist outside of research contexts influence the personal and institutional axiological underpinnings. To place boundaries around the area of



study, our focus was intentionally limited to include the interplay of personal and institutional values, and how they were revealed within the experiences of engineering graduate students.

Institutional Context and Axiology

In many cases, axiology and values are discussed in terms of culture, specifically, the underlying beliefs, assumptions, and goals that are embedded within institutions and organizations. Schein and Schein [12] argue that culture is embedded and integral throughout any given organization and is often difficult to fully conceptualize. Culture is often related to directly observable phenomena, such as physical structures, behavioral norms, rituals, and language. However, a focus on this level reveals only the symptoms or byproducts of culture, rather than the full picture. These aspects of culture are "artifacts" or feelable manifestations of culture that can provide insight into deeper cultural characteristics that are more difficult to perceive, such as underlying values and beliefs.

This study is situated at a large, research-intensive institution, interviewing students involved in an engineering research center (ERC) focused on transformative energy technologies. ERCs often have a direct or strong tie to industry and innovation [13]. ERCs are funded to research cutting-edge or zeitgeist-related scientific and technological areas, patent and develop innovative discoveries, promote, and sustain interdisciplinary work, and prepare a diverse engineering workforce [13]. Alongside providing space for communication and collaboration of personnel, ERCs also provide an avenue for strong industry collaboration with companies, policymakers, and other government bodies. This study examines graduate student involvement with a fourth-generation (Gen-4) ERC, which is part of a call to develop convergent research that will prioritize lasting societal impact, engineering workforce development (EWD), creating a diverse culture of inclusion (DCI), and developing innovation ecosystem (IE) [14].

Positionality

H. Ronald Clements (Ronnie) is a Black cis man from the U.S. and is a 4th-year engineering education Ph.D. candidate at Purdue University. He feels it is important to communicate that this work partially comes from the difficulty in his graduate journey and finding his path. All the participants in this study were international students in traditional engineering disciplines, and some of the assumptions that he brought into the research process could have led to blind spots about the experiences of the students. He initially presented questions about dissertation topic selection based on his own experiences with graduate school, without recognizing the vastly different expectations for dissertation research across engineering disciplines. While the research team was not initially involved with the ERC, Ronnie and Alex collaborated with the EWD and DCI teams at the Center. Students were made aware of this and may have felt as though they were being assessed or needed to provide the "right answer."

Alexander Struck Jannini (Alex) is a White cis man from the U.S. and is a 4th-year engineering education Ph.D. candidate at Purdue University. With narrative analysis, he felt it important when reviewing the data to stay true to the meaning of the participant's stories. Points of contention may have occurred, as his path may have been different from the participant's journey through their education. All the participants were international students, and as a domestic student, Alex recognizes that their journeys and challenges within engineering will be different

than his. Alex's role and background within engineering became important during the analysis process, as it allowed him to empathize with some of the participant's stories as someone who has also been in a graduate engineering program outside of engineering education. As Alex focuses primarily on quantitative research methods, he also wanted to acknowledge that his data analysis may have leaned into his understanding of how data is collected, interpreted, and prepared for dissemination.

Methods

This study is concerned with understanding engineering graduate students' pathways and navigation through their doctoral education (while engaged in research at an ERC); as such, narrative inquiry provides a methodology to explore students' stories of these experiences. Narrative inquiry studies human experiences by exploring the stories people tell in their everyday experiences [15]. Narrative inquiry focuses primarily on both context and chronology, placing the experiences an individual has in the order that it was experienced. Narrative researchers tell stories collaboratively with the participants as they walk them through their experiences. Narratives can often provide insight into complex ideas, such as belonging, identity, or cultural attitudes [16], [17], [18]. Narratives are powerful units of communication that require the storyteller and listener to organize events, emotions, perspectives, and experiences in meaningful ways. We often use stories to organize information, making events and experiences more memorable, and impactful. Stories are the "fundamental unit that accounts for the human experience" [19, p. 4]. Narrative researchers use this human tendency to organize, communicate, and interpret information to make sense of lived-in experiences [19]. Narrative inquiry has multiple approaches and perspectives, but the unifying thread of narrative research is the use of stories in developing knowledge [20]. In this case, a narrative approach will be leveraged to understand better the stories graduate students tell about themselves, and their journeys to becoming researchers. Through this study, we hope to gain insight into what role surrounding culture and values play in students' stories, and how they navigate the espoused and underlying values present in an ERC.

Interviews

To gain insight into graduate students' research experiences, research motivation, and perceptions of culture, we interviewed five engineering graduate students participating in an ERC at a large, midwestern university. Participants were recruited via an e-mail sent by the researchers and forwarded by a director within the ERC. Interviews were semi-structured and took anywhere from 45-90 minutes, with four interviews taking place on Zoom and one in person (based on participant preference). We asked the participants to describe their motivations for pursuing their graduate degree, how they came to study in their current program, and how they became involved with the ERC. We also asked them questions about their research experiences, identities, and perceptions of the research culture within the ERC. Participants were compensated with a $30 gift card for their time. Once the interviews were complete, the audio recordings were transcribed using an AI-driven online transcription service (Otter.ai) and then edited for clarity alongside the audio recording. Afterward, the transcripts were then de-identified, and each student was given a pseudonym (Table 1). Following interview transcription, we conducted an initial pass through each transcript with accompanied audio to develop brief, descriptive codes to ground further analysis.

Table 1.

Pseudonym	Area of Study/ Degree Program	Gender Identity	Race/Ethnicity	International Student
Omar	M.S. in Civil Engineering	Man	White, Hispanic/Latino	Yes
Zenith	Ph.D. in Electrical and Computer Engineering	Woman	Asian	Yes
Baker	Ph.D. in Civil Engineering	Man	White, Hispanic/Latino	Yes
Natasha	M.S. in Environmental and Ecological Engineering	Woman	Black or African American	Yes
Dana	Ph.D. in Electrical Engineering	Woman	Middle Eastern	Yes

Smoothing and Analysis

We used a thematic analysis of narratives to pull together the students' stories and explore broader commonalities and differences across the students' stories. Narrative inquiry takes shape in multiple forms, with traditional approaches focusing on the structure of told stories, including characters, tone, plot, and the sequence of events. Constructed narrative analysis takes data from single or multiple participants, and the researcher constructs new narratives through restorying and smoothing to develop claims and new theoretical perspectives [21]. In a thematic analysis of narratives, the researcher then compares multiple narratives to make claims and generate theory [21]. Restoring and smoothing are often the most criticized parts of constructed narrative analysis, as this process can seem to dilute, clean, or misrepresent the lives of the participants in exchange for whatever the researcher wants to present. Researchers must engage in smoothing iteratively and reflexively, avoid overlooking potential counternarratives, and ground findings in the participants' experiences [22]. As narrative work is both theory and method and is heavily centered on researcher interpretation throughout the entire process, reflexivity and clear communication of the researcher's position are critical in grounding findings [23].

In considering the ethical validity of this study, we followed concepts used to indicate and maintain quality qualitative research more generally [24], and in narrative inquiry specifically

[25]: (1) centering of the data used to generate knowledge between the participant and researcher; (2) capturing events that seem commonplace in a way that shows underlying significance or profundity; (3) ensuring ample context has been provided to the reader so they can judge for themselves the applicability to other scenarios and contexts; (4) providing enough information to ensure the reader of the authenticity of the narrative; (5) transparency and development of trustworthiness through open disclosure of researcher position and accurate representation of participant experiences; (6) ensuring believability of the narrative given the context; (7) communicating with participants to ensure no misunderstanding or misrepresentation of their lived experiences.

Findings

Theme 1. Navigating Interest and Value Convergence and Divergence

When the participants discussed their experiences in the ERC, they often began by talking about how their journey into their graduate program began. For most students, pursuing a graduate degree in engineering was fueled by a desire to be an agent of change in the world. Zenith directly linked her experiences as a child in the Middle East:

> I was in Pakistan immediately before coming to [Midwestern University]. Before that, I spent my entire life in the Middle East. I was in primarily Saudi Arabia, but we moved around where my dad moved around, but it was all within the Gulf. So, Qatar, Dubai. Mainly Qatar and Dubai. And then Saudi Arabia. I grew up in two industrial cities in Saudi Arabia, one on the East Coast, and one on the west. And I grew up in the one on the East Coast. Every single day to and from school, we drove by this multi-mile stretch of industry. And as a kid, it's like, oh, look at that fire coming out. That's so cool. But it definitely impacted how I thought and impacted my interest in engineering, generally not electrical at this point. So, I knew I wanted to do something with what was going on here, because that was fascinating to me. And then as I got older, there was a time when—so Saudi's entire economy was built on oil. And they thought, "oil is never gonna run out." And we're golden. And then the oil prices tanked. And like political things happened with OPEC. And in Saudi, there was a wake-up call, like, "oh, my God, we are not as profitable as we thought we were." So, then they started doing things like, "oh, my god, line all the deserts with solar," and start doing all these other things. And, that—not that it impacted me in a way where it changed my quality of living, but it was a wake-up call, like, okay, this is not how the world works. That's what brought me to want to do something related to energy, electricity, sustainability, and resilience. That's why I did my bachelor's in electrical, and then it made sense to pursue that major forward in my Ph.D. I've always been kind of like the "logical building things" kind of personality from very young age. I knew that this kind of hands-on building doing something in an engineering field was something I always wanted to do along with just wanting to make a difference. (Zenith)

Zenith presented a desire to make a difference in energy and sustainability as central to her professional goal, evoking the shifting economic and political landscape she experienced during her childhood. She became involved with the ERC during the first semester of her Ph.D. program

and felt as though it was a fit for her and her interests, highlighting an example of convergence between her values and those of the ERC:

> I went to this ERC annual meeting, which was my first real exposure. I started to become really excited about what we were doing. I think the work done in the ERC is very forward-thinking and driven in terms of the big goals that they want to accomplish. So, it's not just about what we want to put out at the end of this year, it's about the change we want to make in the world. And I think the Center leadership, the faculty members, everybody that's involved, does a good job of instilling that mindset in every member at every level. Now, when you step outside of the Center, you'll have like your run-of-the-mill person who's working to deliver something by the end of the quarter. I'm sure their company has visions too, but not at every level in their company. Whereas to we're–in the Center, this might be a little I, but I think at every level everyone really, truly believes and feels and echoes that sentiment, which is pretty amazing. Sometimes when I'm stepping out of who's directly involved with the Center, I feel the difference. That because they're not, like, motivated and inspired by what the Center is doing, they don't echo the same, you know, motivation and optimism and like inspiration. So, I think I actually got really lucky getting involved with the Center. I probably would not have had this opportunity at any of the other graduate programs I was looking into. We are working on very important things, directly related to what I'm interested in. Sustainability, engineering workforce development, and making engineering more inclusive and diverse. From a consumer standpoint, we need to make sure it's sustainable in terms of business, we need to make sure it's sustainable in terms of the people who are going to then manufacture this and the companies that are going to start up from this, who are going to carry this forward because we've come up with a technology we're not going to manufacture for all of America. Right? I think sustainability heavily ties into affordability, which, money makes the world go round. So, like, that's very important to consider. It's not just that we don't want to maintain this technology every five years, it's that we want to make sure this idea is sustainable, not just the product.

Zenith felt a sense of belonging and pride from working in the research center, highlighting that she was excited about the "change we want to make in the world." She recognized that in many other contexts, she may not be able to pursue the same type of work. Zenith appreciated and internalized the messages of the Center. She felt that the messages were inspiring due to the tangible sincerity she felt from others working in the Center. Baker shared a similar appreciation for the work in which he was engaged and felt like many graduate students did not get to engage in work that drives change: "What I'm doing, it's a small, small, piece that can help society. Some people are doing PhD studies that–I don't think will really make any difference. For me, I'm happy to know I can make this small difference." Natasha presented a different perspective, showing some value divergence. While there are parts of Natasha's values and goals that did align with the Center, there were differences in perspective that drove Natasha to have a different experience and approach than Zenith:

> I got into environmental engineering because I'm very interested in resource management and lifecycle assessment. So, like, seeing a product from cradle to grave all of the environmental and social impacts it has. I'm from a country where a lot of the raw

> material extraction of elements like lithium happens. The stuff I'm doing with the Center right now, it's directly linked to my own personal interest along those lines. I was able, with a colleague, I was able to kind of steer it that way. We've been given a lot of freedom to study what we want to. I'm not sure if it's always what the Center wants, but we're able to study stuff that is kind of critical of what the Center does sometimes. Everyone's just happy to be like, 'dude, we have this transformative technology and that's great.' And not thinking about material extraction. In this side of the world, in the US, it's mostly the manufacturing process, and so you don't really look into the raw material extraction. And that's the part that I'm really interested in. I saw the impacts of you know, that extraction, and that's what I, I want to bring into the Center, like, yes, we talk about this lithium stuff, and it's great. But you also need to realize, like the impacts it has on the other side of the world. So that's more my own personal thing. I think it has always been at the back of my mind, just because, like, culturally like I mean, my home country is really pretty young. If you look from a colonized/anglo perspective, we got our "independence" [*air quotes*] recently. And so, culturally, we always talk about like, like, our lens is very like focused on colonialism. And so when you talk about our resources in my country we're like, "we need to be careful" because like, "colonizers are gonna come get them," you know, it's just a normal thing to talk about. And so, it was just, normal in my in my mind to think about resources. Where the resources are coming from–from the people, like where it's being taken out of, a lens like that. It was how I always thought about it. But also, just growing up there and seeing the impacts of that colonialism and seeing how a lot of why my country is the way it is, all the waste, and all of that the pollution. (Natasha)

Natasha presents a critical value frame based on where she came from, what she's seen, and the perspective that that affords her. She recognizes that this is a different perspective than what she perceives the Center as valuing, and calls into question the underlying motivations of the Center. Still, she has carved out a space for her to pursue her interests and communicate her values to others:

> I'm glad that the Center involves a university outside the U.S. because some of the researchers here are very, like, U.S.-centric in their mindset, so I get why they don't think about this stuff. And it's not necessarily their fault, you know like America is a very individualistic society. An example, to me, instead of focusing on like, EVs and stuff, like maybe focus on public transportation, you know what I mean? Like, it's just a different way of thinking and a different way of framing the problem. The problem is that we're making too much carbon dioxide, right? Okay. So then, why are we going to all have individual cars? Which, right now, are inevitably going to emit CO2, even if they're electric. It just adds different steps to the lifecycle assessment. We could just like have a different solution that's more focused on like, public transportation, if that makes sense. But individual cars, it's what they already know, they're comfortable with it. Because we also already have all this data, we know that there's X amount of cars, and if you just replace them with EVs, then we are going to reduce emissions somewhat. But that's also just very limited, within the boundaries of, again, the lifecycle of EVs. It's not like producing EVs is "clean." Me and my colleague, we've raised awareness about issues like this. We have had "degrowth" talks with some of the environmental engineering

> faculty and students. Our message is not just for this specific context, we're looking at how degrowth is the only way to the future for sustainability. Even if we're talking about the work the Center is doing as a whole, we keep developing this technology, and we want to keep building–resources are finite. And thinking that we've gotta keep growing, gotta keep expanding, is just not truly sustainable, no matter what. Even if we pick what seems like a sustainable solution at the moment. And so, it's definitely interesting to be involved with the Center, where everyone has kind of this optimistic idea of new technology. I'm just like, "hey, did you think about this other stuff?" And not everyone wants to hear it. But I will still say it, it's fine. I realize my position. I don't have that much power yet. But I will still mention it.

While Natasha felt that there were gaps in the Center's approach and disagreed with some of the foundational beliefs rooted in the work of the Center, she had the space to openly communicate her perspective with others in the Center. While she felt as though she did not have the power to sustain or generate broader changes, she bolstered her position and continued to pursue the work that she valued. Zenith and Natasha highlight different approaches to navigating work in the Center amidst convergence and divergence of values. Omar's perspective, however, differed from both Natasha and Zenith. Omar did experience some divergence, but rather than positioning himself counterculturally like Natasha, he chose to shift his short-term goals to better align with those he perceived from the Center:

> I come from a very poor country, and I was fortunate enough to live a completely radically different life than 95% of my country. I say that because it's important to acknowledge that privilege. I was always taught to be really conscious of that growing up. My father had a completely different life than I did, he had it rough, and he worked his entire life to give us, his kids, a different lifestyle. As I was growing up, he helped me develop a drive to make changes for my country. Big changes, actually. He pushed me to think about how I could use my privilege to bring change. So, I would say that to be honest, that's one of the biggest driving forces for me to pursue engineering, the kinds of things that I want to generate in my country at some point because there are changes, and at a large scale, not just like local changes. It's still within my plans to go to my home country at some point and make those changes, but I don't know if I would describe my work right now as fully related. Right now, it's mostly about developing myself so I can be fully prepared, and someday we'll go back. But for the work I'm doing, I'm kind of like realistic in that it isn't fully towards my goal—sadly, my country is really poor. There are a lot of other structural issues that we have to solve first in my country in order to even start thinking about things like the work we are doing in the Center. So as of now, I think our focus should be first on developing technology in the U.S., making sure it actually works. Still, this is a really complex task we have. It's nice and everything being the pioneer, but there's so many challenges to this because you're dealing with unknown variables the entire time, and new things to solve. First, we have to focus on specific things in order to—if we want to advance it even more. And after we have that, we can start thinking about how we can apply this in other places. Now, personally, I'm of the belief that this might be like, like COVID. We just need any one of these projects to work so that we can show that this is possible, show that this is feasible. And after that, I'm really confident that once we have this, it's going to spread, spread through the U.S., and

> eventually keep evolving. Once we have a pretty developed here, we can start thinking about new, new things, you know, how can we take this to different places, we can start giving ourselves the privilege to think about applying it in developing countries. But, for the sake of science, I think it's really important and critical to focus on one thing at a time.

Omar admitted that the work he was doing in the Center did not fully align with his long-term vision—there were other goals he had that were separate from what he perceived as being done in the Center. Omar chose to shift his short-term goals, focusing on personal development to resolve the dissonance. Ultimately, he internalized the goals set forth by the Center, and saw his work as a great opportunity to help stir change in the world:

> I think to myself, what we are doing at the Center is really important. And that motivates me to push even harder. Sustainability, that's, that's one of the biggest things driving the work. The fact is, we've been killing the Earth, overall, and out of all the economic sectors that generate greenhouse emissions to the atmosphere, the transportation sector, it's what emits the highest amount of greenhouse gas emissions. In this context, there have been a lot of moves to like, or a lot of options to start solving this. But realistically, when it comes to something like transportation, it's about achieving certain numbers, achieving a percentage of adoption. Adoption is restrained by a lot of factors, like expense, infrastructure, and accessibility. And limited resources make everything expensive. And that's where we come in. We're some of the pioneers transforming the sustainable transportation landscape. Specifically, at Midwestern University, for example, we're one of the very first in the world to actually build a working version of this technology. I'm really grateful, grateful to be part of this pioneering group because we're the ones developing this. This plays a lot also into my personal development because I'm able to leverage all my civil engineering and construction knowledge and help solve a difficult problem. (Omar)

Theme 2. "Diversity and Culture of Inclusion": Internalization or Performance

As discussed previously, Gen-4 ERCs directly embed the ideas of diversity, equity, and inclusion into the work. Maintaining diversity and a culture of inclusion (DCI) is presented as central to the work, not only in the way the ERC is governed but also in the outputs generated from the work that is done. Questions of diversity and inclusion were presented to the participants, and there were varying responses to how students thought about DCI within the Center. Each student, however, did communicate that they felt empowered in some way in their role at the Center and that they were seen as valuable contributors to the work that was done in the Center. An example from Zenith's story:

> A couple of months ago, or like a month ago, they asked, they were doing Women Appreciation Month, and they were asking us to talk about our role models, and I actually struggled to come up with who my female role model is. And I think that's, for me, that's a very important thing to know about. But in this industry, in engineering particularly, or in technical STEM fields, you don't see a lot of women at the top. So, I think one thing I really appreciate about the Center is they definitely encourage me, and they value my

> voice. Not only are they doing things around me to make me feel more welcome, but then they're also verbally saying things to me, like, “hey,” you know, “give us your feedback. We value what you think.” And it's not because I'm the chair of the [student leadership committee] SLC, even if I wasn't, I know they're doing the same with everybody else. So as a woman, as I'm paving my own way, I value the Center’s efforts to uplift students like me. It helps me know where my career's heading, and also empowers me in terms of my research where I'm not thinking, “hey, this is a male-dominated area, and maybe I'll never get to work in this so I shouldn't bother,” you know. Yeah.

While Zenith expressed feeling welcomed and empowered, she expanded her discussion of diversity and inclusion to also include the work that was being done in the Center:

> From a technical standpoint, I know that [ERC] is also working on two very important things. They're trying to make sure they change the culture in this engineering space to be more inclusive and diverse. And then they're also very heavily focused on engineering workforce development, which I think is probably the first time I’ve seen that in a more corporate kind of setup. I know I'm like, I don't have 20 years of experience that maybe other people do this. But for me, personally, this is the first time I've seen it so heavily focused, and I think that's great. So, I see that they value developing future professionals, they value maintaining diverse voices, and they value all of these in terms of research as well. For example, what I saw, from a research standpoint, the Center presents sustainability as having several different meanings. For one, this technology should be sustainable, we shouldn’t have to maintain it all the time, and it should last long and should be reliable. Then the grid needs to work well, we need to build infrastructure, that's where we're simulating things and all of that. Then when I came into my SLC leadership role, I had these discussions with the Center leaders about diversity, about workforce development, and it was like, from a consumer standpoint, we need to make sure it's sustainable. In terms of business, we need to make sure it's sustainable. In terms of the people who are going to then manufacture this and the companies that are going to start up from this, who are going to carry this forward, this needs to be sustainable. Because we've come up with the technology but we're not going to manufacture for all of America, right? So that's where the workforce development, industry partnerships, and community support come in. We need sustainability in terms of diversity, we need to bring people from different backgrounds into the process. We need to do you know, research and surveys in communities that have less access to these technologies and find out, what might be some of the hindrances stopping them from adopting this technology. What’s holding them back economically, environmentally, or otherwise? We need to educate people about what we're doing. So, sustainability means a lot of different things to a lot of different people in the Center, and I know that they're all working on it from their angle simultaneously to make sure it's sustainable all around. It's not just that we don't want to maintain this technology every five years, it's that we want to make sure this idea is sustainable, not just the product.

Zenith echoed her view of sustainability as being broader than just feeling comfortable in interpersonal interactions with others in the Center. Zenith discussed equitable sustainability as a part of the way she saw the Center’s work. By holding a student leadership position in the

Center, she had the opportunity to engage with center leadership, reinforcing ideas she encountered. However, not all the students shared this experience:

> To be honest, I have seen a lot of the work that the Center does along the lines of diversity. I think it's, it's fantastic. It's so fantastic. Helping those communities in need, and also bringing inclusion into the project itself. Because, people, different people bring different perspectives to the table. Different cultures also have different ways of interpreting things. And, and, us and us as guys have different ways of seeing the world. And then girls do, or, or whichever your gender is, in this context, different perspectives that are brought up into the project benefit the project overall. If we just had one group of people, one culture or gender of people, it wouldn't be as fruitful as it is, because it's the different perspectives. For example, my entire life has made me who I am today. That has granted me the ability to do the things I am doing. And that's exactly what happens with every single person involved with the Center. I feel proud of that. I'm proud of the fact that we have to work under an organization that takes close focus and cares about this. From what I understand, we are focused on helping those communities in need, including many more people from minorities, like myself, including more, more women in the project, because many times engineering tends to only be guys. In civil engineering, you go to class and there are 50 guys and 2 girls. So, bringing that inclusion of gender into the project itself, but I'm pretty sure there are more specific things that I'm missing, but I'm more focused on the science part. Given that I'm also an underrepresented minority, I feel that I'm fulfilling my part of it. What I told you it's correct? Some of like, the goals? Like, was I close?

Omar communicated that he appreciated and is aligned with the efforts to promote diverse perspectives within the Center. However, Omar looked to the interviewers for clarity and affirmation, which the researchers inferred as him feeling the interview was an assessment. Similarly, Baker sees inclusion and diversity as reducing the number of problems he or others encounter in interactions with other members of the Center:

> I know that the Center has these values of diversity, equity, and inclusion. Sometimes in the meetings, they say things about it. But for now, then, so, so far, and for now, at least in about I mean, it's difficult to say because I have never had any problems. So maybe this is because there are these values. So, they are there, but I can't see. Let's say that I let's say that. I would be aware that they didn't exist if they didn't exist, but if they exist, I can't see them.

Discussion

The students in our study chose to limit or invoke specific beliefs, values, and experiences during their time within an ERC. While there were ranging responses, the interaction between institutional and personal values took a central role in each of the stories of the participants. We found that when encountering institutional axiology, students first contended with value convergence and divergence. Following these initial moments, students were faced with a decision of whether to internalize the values they were encountering or to position themselves as outside of the axiological framing presented to them.

Convergence and Divergence

When there was an overlap between the underlying beliefs and values of students and the institution, they felt excited about the work they were engaged with and communicated a sense of belonging and excitement for their work. While far from the only benefit from these outcomes, when students are intrinsically motivated by their graduate work, it helps maintain effort and increase the likelihood of degree completion [26]. Opportunities for interaction with the broader community of the Center and interactions with leadership that centered on students' voices were integral to students taking ownership of the work done in the Center. When students perceived a disconnect or dissonance between personal beliefs and values and those of the institution, there was a new approach that arose. Natasha chose to embrace the dissonance and used it as an opportunity to communicate a different perspective to those in the Center to stir change and maintain her personal goals and drives. While initially, the value divergence between Natasha and the Center seemed like a hindrance to her goals and trajectory, ultimately, her axiological differences afforded a mutually beneficial opportunity for herself and the Center. By providing Natasha the support needed to pursue work outside of the value frame maintained by the Center, Natasha was able to highlight growth opportunities and provide the Center with a more holistic approach to sustainable practices, pushing beyond typical approaches [27], [28], [29], [30]. Still, Natasha saw change was slow, feeling as though people "may not want to hear this," and that "I don't have the power to change things right now." Future work must continue to ask how we can integrate the perspectives graduate students are bringing and help them be active agents of change.

Natasha's approach was different from Omar's, who approached value divergence differently. After perceiving a divergence between his and the Center's goals, Omar chose to shift his perspective and find a way to align himself with the goals of the Center in pursuit of his broader career goals. Omar's story is complex–while it is beneficial to see his journey as one of adaptability and resilience, it also provides an example of a lost opportunity. Omar believes that he needs to make concessions to his broader goals in pursuit of "science" and that goals and values he has that are not directly related to technology development in the U.S. and similarly developed nations are detrimental to the scientific process. Natasha and Omar were the only two participants to discuss the value divergence between themselves and the Center, and their academic backgrounds and graduate journeys were quite different. At the time of the interview, Natasha was involved in both engineering education and environmental engineering work, while Omar was in a civil engineering program. Disciplinary differences may have informed their perspectives and underlying beliefs about the purpose of scientific inquiry and engineering research [31], [32] Additionally, Natasha specifically highlighted the support that she had through a colleague and the faculty member she was working with at the Center, which may have played a large role in her ability to pursue work that was originally outside of the axiological landscape of the Center.

Zenith, Omar, and Natasha were all operating within an institutional context that was not built for them. All our participants self-identified as international students and are operating in an institutional context that is primarily U.S.-centric in its goals and outcomes. Still, each of them exhibited different forms of navigational capital in finding ways to make a place for themselves

within the Center [33]. Providing students space for exploration of personal values and goals within their work can help to motivate and sustain during the process of professional becoming, while also providing the opportunity for novel, transformative approaches in engineering research work.

Internalization

While the center the students were involved in internally and externally communicated embedded values of pursuing sustainable technology, developing a culture of inclusion, and prioritizing equitable outcomes, perception and internalization of those values varied between participants. When it came to discussions of equity and diversity, there may have been barriers for students based on time in the Center, involvement with the Center, and interaction with leaders and faculty that centralized these ideas. Additionally, all five of the participants were international students. While race, ethnicity, and gender are socialized constructs sharing similarities across cultures, discussions of these constructs may look different in contexts outside of the U.S. From Zenith's perspective, the diversity and culture of inclusion of the Center were visible both in the way she interacted with members of the Center and in the work that was carried out by the Center. She felt as though inclusion and equity were integral to the work, and that sustainability implied considering and empowering a diverse body of perspectives and voices from the researchers, industry, and communities in which the technology would be developed and maintained. Omar, in contrast, had a more difficult time articulating what he perceived as the role of diversity and a culture of inclusion within the Center. He discussed that he valued the wide backgrounds of individuals within the Center and focused mainly on ensuring that everyone feels welcome within the Center. In discussing his experiences, he looked to the interviewers for confirmation that his responses were appropriate, and mentioned that efforts in diversity, equity, and inclusion were out of his scope. Initially, the researchers felt Omar's responses could have fit in broader systemic issues such as greenwashing or performative allyship [34], [35], but in reflection following the interview process, the researchers felt Omar might have been uncomfortable, or felt he was being assessed, leading him to look for the "right" answer. However, Omar perceived his work as separate from efforts in diversity or equity, the "science side of things." Later in the interview, Omar also mentioned that he did not have a lot of involvement with the Center outside of his lab, lab work, and advisor. Omar may not have been exposed to the importance of inclusive or equitable practices in the way Zenith was, due to her involvement with the student leadership committee.

Limitations

While the ERC participants were involved in spans across multiple institutions, all the students were from one. Experiences with values in the center may vary across others, with institutional culture playing a role in the way students perceive or experience research values. Additionally, all five students had only been a part of the Center for 1-2 years and may have different opinions or perspectives after engaging with the research center for a long period. While the researchers were both outsiders to the Center, during recruitment, the researchers were presented as affiliated with the DCI and EWD thrusts of the Center. This may have led the participants to believe the interviews were an internal assessment tool. While students were explicitly asked about the values of the Center and whether they align with those values, the students were asked primarily

about their motivations for pursuing graduate education and research to better understand their personal beliefs and values.

Conclusions and Future Work

Graduate students bring their own beliefs and values with them as they navigate educational and research spaces. Providing space for students to bring their whole selves to their work provides an avenue for them to leverage their varied experiences and goals, while also providing an opportunity for new perspectives to be brought into the field of engineering research. Providing space for students to bring their whole selves into their work while providing faculty support can help students feel ownership over their work and help increase matriculation. Diverse perspectives in engineering research are valuable in maintaining equitable innovation and sustainable practices. Findings from this study are being used to develop a case study further examining the values of graduate students in an engineering research center. Future work will also include interviews with faculty and content analysis of Center documents to paint a better picture of the context of the engineering research center. While ERCs are primarily engineering focused, Gen-4 ERCs are widely interdisciplinary. Future student interviews will be broadened to include non-engineering graduate students and faculty to paint a better picture of how engineering research is carried out in an interdisciplinary context.

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