

Work in Progress: Toward Understanding Engineering Research Culture

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Abstract

This work-in-progress paper provides a preliminary exploration of literature on engineering research culture and engineering research paradigms, with a focus on academic engineering research spaces. I define research as systematic investigation undertaken to establish knowledge claims, and culture as the shared values and beliefs that undergird the social contexts in which research takes place. Engineers occupy a critical role in broadening an understanding of the built, sociotechnical world while developing, designing, and constructing systems that are rooted in dominant society and dominant societal values. While engineering research shares many epistemic and methodological characteristics with traditional scientific fields, engineering research differs from pure, scientific research by applying scientific solutions for global, economic, environmental, and societal needs. These values are made salient in engineering research, as they both limit and invoke the work the community is motivated to research, as well as what work is valued, promoted, and funded. As this paper is a work in progress, I hope to receive and incorporate feedback in this ongoing work. While engineering research is a broad field full of many unique disciplines, I believe that this work can identify unifying cultural characteristics that exist across the field of engineering as a whole and provide better insight into the engineering research enterprise. I would like to explicitly note that this paper does not report on preliminary findings from the first stages of a scoping literature review, but it is a narrative literature review to lay a foundation for further exploration. The themes discussed in this paper include the exclusionary practices, research paradigms, and funding practices present in engineering research.

Positionality and Purpose

To begin, I feel it is valuable to disclose my position as an author, including the identities I hold, the privileges I am afforded, and the perspective I bring to understanding engineering research culture. I am a Black, cisgender man, and a Ph.D. student studying engineering education. I am also a recipient of a stipend from the National Science Foundation (NSF), so I am a direct beneficiary of the engineering research “culture,” or system as it stands. This work-in-progress paper is directly tied to my own experience and the experiences of colleagues that are also engaging in engineering research culture. Through rich conversations and reflection about the spaces in which engineering researchers operate, I began to question the underlying value systems that guide engineering research. I, and many of my colleagues, while noting the history of marginalization of people who look and think like us in engineering contexts, began questioning the value systems that undergird the engineering research enterprise in which we operate. We noted discrepancies between the espoused values of the enterprise and those that were enacted by some of the agents that operate in engineering research spaces. For example, in our graduate context, we noted an espoused desire for equity and inclusion alongside a perpetuation of stress culture, a centering of White theories in our foundational classes, and a lack of accommodation for non-traditional and neurodivergent students. We began to question other value systems having to do with research outcomes, and the difficulty of “playing the game” or “following the money,” aligning our research goals with those we know would have

the best chance of receiving recognition, funding, and career mobility. In our experience, we noticed that this approach could limit how we frame the work in which we engage. I find myself perpetuating and acting within this system regularly as an engineering education researcher, often questioning the “so what” of work I do, attempting to frame any work I do to the NSF’s goal of developing a diverse, innovative body of engineers for U.S. global competitiveness. There are tangible benefits that are gained from these endeavors, but these underlying values directly or indirectly influence any decisions I make as a researcher. In our context, what would it look like to pursue justice, fairness, or equity as ends of their own? Would this approach even be possible given the current system in which we operate, or are we continually limited in what we can pursue as researchers? Is this possible at all? I am certain these questions exist in many different forms throughout other engineering fields as well. This reflection led me to approach the question of “engineering research culture” from a critical perspective—what are the underpinning value systems that are communicated and perpetuated in engineering in the U.S. and similar Western contexts? For this paper, “engineering research” will refer specifically to engineering research in academia.

Introduction

Attempts to understand research culture are not new, and there are examples of scholars mapping, analyzing, and critiquing research culture in the sciences. Some examples are studies ranging from ethical concerns in psychology research [1], critiques of the underlying philosophical assumptions of scientific research [2]–[4], developing a framework for scientific research in the life sciences [5], to social and political critiques of funding practices in the STEM research enterprise [6]–[8]. Following these trends, scholars have explored the nature of engineering and the cultural underpinnings that guide the field in both practice and training of future engineers [9]–[13]. These works are often concerned with developing a deeper understanding of the paradigms that undergird engineering education, practice, and industry [12], [14]–[17]. Typically, these explorations are concerned with the paradigms, or beliefs about knowledge (epistemology), the nature of being (ontology), and methodological threads in engineering education. Many scholars also study the sociocultural norms and assumptions that exist within formative engineering spaces [18]–[22]. However, one underexplored area is engineering research more broadly. Most work examining engineering culture concerns itself with connections to the education and training of new engineers. Explicitly exploring the space of engineering research, which is often occupied by graduate students, engineering faculty, and research scientists, would provide critical insight into what work is valued (axiology) in engineering. Engineering researchers occupy a unique space, holding identities as both academic researchers and engineers, leading to an interesting intersection of beliefs about knowledge and approaches to problem-solving. While this intersection does provide an added benefit to the kind of work engineering researchers do, many of the same systemic challenges that are faced by those in scientific research, academia, and practice all bleed into the culture of engineering research.

One reason cultural explorations of engineering research as a field may be limited is the vast reach of engineering research work. For example, civil engineering research could differ widely from work done in industrial or software engineering research. However, engineering fields are often linked by a common set of underlying assumptions and philosophical goals often described

as engineering thinking, being, and doing [12], [16], [23], [24]. Engineering academic research in academia across disciplinary lines also holds shared contexts, such as funding and university organization, typically through colleges or schools of engineering. By engaging in this literature review, I hope to distill that which does connect these varied engineering research fields.

Developing an understanding of engineering research culture explicates the values and worldviews that are integral to engineering research. Understanding these underlying cultural paradigms can help to provide moments for reflexivity and change in engineering research, and help to identify the intellectual boundaries or “borders” of the field [25]. The outcomes of this work would highlight specific cultural characteristics that restrict or support entry into the field (or “border crossing”) for a diverse body of future researchers [25]. Some of this work is already being discussed at social and philosophical levels [13], [26].

Cultural influences directly influence the process and outcomes of research [27]. Without having a developed understanding of engineering research culture, we risk restricting the capacity for systemic change and hindering the opportunity for unique approaches to engineering research. Embedded in each of these practices are deep cultural assumptions: what work is considered rigorous engineering research? What work is considered to have the most value? What is valued by the dominant cultural and political voices? This work-in-progress paper provides current findings as a brief narrative exploration of literature on engineering research culture, and the paradigm(s) that lead engineering research work that was guided by the following question: what are the research and cultural paradigms that guide engineering research?

As this question is ambiguous and broad, I would like to explicitly note that this paper does not report on preliminary findings from the first stages of a scoping literature review, but it is a narrative literature review to lay a foundation for further exploration. This paper serves as a precursor to an in-depth scoping literature review of what is currently known about engineering research culture.

Methods

In this section, I outline the nature of and justification for this narrative review. In the future work section at the end of the paper, I will highlight my approach for the next steps and scoping literature review.

Narrative Literature Review

Culture is a loaded, ambiguous term, that can refer to several different ideas. Likely because of this ambiguity, it was difficult to find literature explicitly discussing culture in engineering research spaces through initial database searching. While I did find a few papers, I realized that I would need to define what aspects of culture more specifically I was interested in studying. The result of this was a rich conversation with other engineering scholars, hand-searching, and reflection on what I meant by culture. This approach led to “traditional,” or narrative literature review, with the goal of “surveying the state of knowledge on a particular topic” [28, p. 312]. Thus, the purpose of this paper is to start a conversation and highlight the boundaries set for further review rather than describing a systematic state of the field [28]. Through this initial

process, I found three areas of interest: (1) sociocultural influences on engineering research, (2) engineering research paradigms, and (3) engineering research funding practices.

Brief Narrative Literature Review

Sociocultural and Identity Influences on Engineering Research

First and foremost, I want to acknowledge the history of systems of oppression within engineering in the United States. While there are efforts and movements to uproot discrimination based on gender, race, class, sexual orientation, disability, and neurodiversity through policy change and hiring practices, these systems of oppression and marginalization continue to plague the field [29], [30]. While more tangible discrimination continues to be seen through stereotyping, microaggression, and systemic inequity in engineering spaces [19], [31]–[34], there are also unseen values that perpetuate these systems of discrimination more subtly and quietly [13], [18], [35]. Some of these unspoken enacted values include objectivity, meritocracy, and beliefs about what it means to be an engineer or succeed in engineering [18], [36]–[38]. Yet if an individual without social capital chooses to push back on the dominant narratives and values of the academic community surrounding them, they can often face de-legitimization [39]. Distilling cultural characteristics in engineering research spaces can help provide insight into issues that researchers may face, including mental health and psychological safety [26], [40].

Without an understanding of challenging the underlying paradigms within engineering research, we risk perpetuating the status quo within engineering, while supporting cultural norms of whiteness, masculinity, and other exclusionary practices that limit who feels as though they belong in engineering research spaces, and what is considered rigorous work [13], [39], [41], [42]. By restricting who can participate in engineering research or hindering feelings of belonging among a diverse body of researchers, we simultaneously exclude novel, transformative ways of knowing that a diverse body of researchers brings to the field through their experiences and worldviews [27]. Even in our current climate where knowledge of racial and gendered discrimination is more widespread, we still see issues that could potentially be remedied by developing and maintaining a diverse body of researchers, and questioning whether our technological advancements perpetuate inequity [43], [44].

Engineering Research Paradigms

When needed and appropriate, engineering research work often borrows philosophical norming from the natural sciences. Often, this framing of research leads to a predominant reliance on rigorous measurement of observable phenomena and a stark separation between knowledge and the observer (positivism and post-positivism) [45]. (Post)positivism and traditional quantitative methods are powerful tools, quantifying and simplifying complex phenomena. However, when they are used as the only methods of inquiry in social contexts they essentialize knowledge and perpetuate inequity [45], [46].

The nature of engineering, afforded by design, the malleability of the subject of study, and the presence of human factors and social contexts [23], invokes a need for complexity in research paradigm and approach. Engineering, as a sociotechnical field, often deals with messy, complex,

and wicked issues that often do not have a clear, singular solution [47], [48]. Engineering problems fall within natural science, modeling, mathematics, design, development, human factors, and social science [48]–[50]. This domain leads to incredibly diverse, poly-paradigmatic work in engineering research, encompassing quantitative, qualitative, and design research. Based on the area of engineering research work, engineering researchers take on different philosophical modes based on the end goal of the work, but these approaches and assumptions may not be discussed when disseminating work [51].

Due to this complex nature of engineering, many have argued that through design, approaches to engineering problems should be understood as frames rather than solutions [11], [52]. Often, outcomes in engineering are attempting to reach a decided value based on context and perceived need rather than a universal solution. For this reason, it is impossible to remove the underlying value systems of engineering from the outcomes that are developed. While there are infinite potential directions for technological or societal advancement, the underlying values that guide design serve to reduce the complexity of the problems engineers encounter [53]. This value frame is even more apparent in research design, which pushes the boundaries of what we know and intentionally pursues questions that have not been answered. While these communicated value frames do reduce complexity, they also set the trajectory for what will be discovered through the research enterprise. The tension of practicality alongside knowledge generation is palpable in engineering research work, as engineering scientists often balance and blend postpositivist and naturalistic approaches. Due to the applied nature of engineering research, engineering research work often takes a pragmatic approach, employing whatever epistemic and methodological modes seem to best answer the question presented [54].

Engineering Research Funding

Funding availability and source hold a salient position in all threads of research work, and it is no different for engineering. Research always comes at a cost to someone—Leydens and Lucena raised the key question of who does “engineering” serve? That is, who benefits from the work of engineers [37]? Those whose interests are served by engineering are typically those who are financially capable of supporting the work being done (i.e., industry, funding agencies, and military bodies) [37]. While many efforts in engineering, especially government-funded work, do push for societal betterment [52], it is also critical to question whether the solutions and developments generated are equitable [43]. Take, for example, climate change research. While work on sustainability and stemming the effects of climate change are very well funded and incentivized, one of the most critical areas that need to be explored in climate change work is directly related to humans and social issues—yet work aimed at understanding this human and social issues is disproportionately underfunded compared to other forms of research in climate change. Only 0.12% of all research funding went to work in understanding the social science of climate mitigation [55]. Similarly, much of climate change research is built upon assumptions that continue to marginalize developing countries, while many are also the most vulnerable to rapid climate change [56], [57].

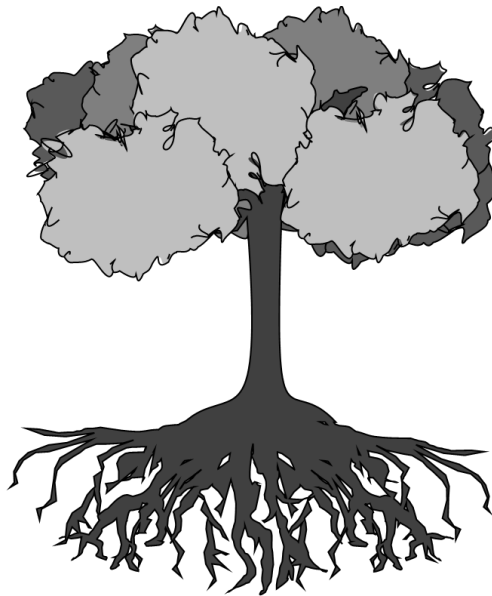
As a limited and critical resource, funding and associated funding practices directly influence the climate of engineering research spaces. At times, funding practices can lead to hyper-competition that can unintentionally encourage lapses in research ethics, hostile labs, and department climates, and limiting epistemic frames for research work [1], [26], [35] This climate influences

entire research communities, from program officers to faculty, to graduate students. For example, funding source and availability were both commonly cited external motivators for dissertation topic choice, as well as topic feasibility [58]. Beyond the role of funding for graduate students, research funding type has also been found to have an impact on scientific output: Goldfarb [59] found that faculty who maintain contact and funding from an industry sponsor as opposed to other forms of funding showed a decrease in scientific output. Commercial values are often different than that of academia, so traditional measures of academic research success, such as citations and publications, may not be adequate for measuring the commercial or social value of certain types of applied research. “Pragmatic and mission-oriented” institutions, even large governmental institutions, may press to produce more readily useful knowledge production in exchange for the traditional outcomes of academic research [59, p. 1].

Discussion and Reflection

This work-in-progress paper is the beginning of understanding the idea of engineering research culture. I would like to use this space to share some of my reflections on engineering research culture from this process through an analogy—a tree (figure 1). I use this analogy to describe my preliminary findings and how researchers can start to think about transformative change in engineering research.

Figure 1.



While characterizing engineering research culture as a tree holds its limitations, and there are certainly alternatives, many insightful parallels can be drawn. The tree of engineering research has a storied past, first developing its roots many years ago. While “engineering” existed far before we developed titles and created boundaries around the profession [60], the main purpose of the tree is to reflect the cultural assumptions about engineering and engineering research embedded within primarily Western contexts. The professional fields of engineering and subsequent engineering research have grown over time to include many systems of branches and directions, encompassing a myriad of different perspectives and disciplines. The tree is resilient,

having weathered many different contexts and climates as the landscape of culture and society has changed.

The underlying assumptions guiding engineering research are the twisting root system that sustains the entire tree. Everything stems from these roots that house applied and societally-centered values, with some being held in tension: (post)positivism, whiteness, maleness, heteronormativity, determinism, and capital gain. Shallow roots reveal other underlying goals and assumptions such as rigor, meritocracy, economic growth, optimization, and global competition. The trunk, representing funding systems and locales of research, is directly sustained by these values and brings additional contextual cultural influences, values, and goals, of its own. In a U.S. context, these influences include funding bodies calling for work that focuses on national interests, such as broadening participation and promoting innovation for U.S. global competitiveness and societal benefit [8]. However, these outcomes are inseparable from the values present in the root system and can be seen in the continuation of systems of oppression even amidst calls for change.

The roots and trunk of the tree eventually feed into the interweaving branches, representing the actual doers of engineering research work in academia, as individuals and groups in labs, departments, and colleges. Each of these additionally has its contextual influences, bringing new perspectives, values, and philosophies about why they are motivated to do the work that they do, and how they choose to do that work. These contexts may look like adhering to methodological traditions to maintain recognition or using specific theoretical frameworks that are widely accepted in the field.

Regardless of the beliefs that are held at this personal level, researchers find themselves beholden to the entire system. To exist sustainably within engineering research culture, one must “play the hidden game” and align themselves with the goals and cultural norms of the field to gain support, gain funding, and develop a career in engineering research. Ultimately, this leads to the leaves, representing the research work itself. The leaves play an important role, as they play a key role in sustaining the tree, but these branches and leaves are also the most influenced by the surrounding environment and climate of the outside world.

Characterizing engineering research culture using this analogy helps center the interconnected nature of engineering research culture from the unspoken directives in the root system, all the way to the outcomes of research work.

Future Work

Following this exploration of literature, I plan to develop an in-depth scoping literature review to better understand the academic landscape surrounding engineering research culture, guided by the research question listed above. In the following literature review, I hope to better define and build out the broad cultural factors that guide engineering research, and how they are reflected in the outcomes, practices, and experiences of those engaged in engineering research.

From my initial surveying, engineering *research* culture seems to be an understudied space. This lack of inquiry is likely due to the wide array of potential directions that can be taken when

considering culture, and the different names studies of culture often fall under. This ambiguity creates difficulty in “visuali[zing] the range of materials that might be available” that would be required for engaging in a systematic review [61, p. 21], [62]. For this reason, I intend to employ two strategies to help identify related information in this space. I plan to (1) create explicit boundaries around what aspects of research culture I am interested in understanding (which this paper is meant to help serve), and (2) use a scoping literature review to better understand the landscape of topics in this area. This process will follow the scoping literature review method outlined by Arksey and O’Malley and Levac and colleagues’ 5-step process meant to scaffold the review [61], [63]. This process includes (1) research question identification; (2) identifying relevant studies; (3) study selection (post-hoc inclusion and exclusion criteria); (4) charting the data through narrative or descriptive analytical literature review; and (5) collating, summarizing, and reporting results. While Levac and colleagues do posit that research questions in a scoping review will be broad, they recognize the need for a clear definition of boundaries to provide a road map for the review [63]. The initial, surface-level research question that led this work-in-progress up to this point is quite broad and has not provided adequate boundaries for a reasonable scoping literature review. For future work, I plan to proceed with a new research question: what is currently known about the underlying sociocultural influences, research paradigms, and funding practices that guide the academic engineering research enterprise?

The intended goal of the scoping literature review will be to develop and distill a better idea of the knowledge landscape surrounding engineering research culture, and the broad underlying values that guide the enterprise in the U.S. (and similar Western contexts) from the perspectives discussed in this paper. Future studies could benefit from this work by embedding these ideas into empirical study of the experience of doing research in engineering, and how some of these cultural pieces influence what work engineering researchers feel as though they are empowered to do. As this is a work-in-progress, I welcome any suggestions, feedback, or opinions about engineering research culture, with emphasis on the process of engaging in a scoping literature review, or reflections on lived experiences within engineering research culture that might inform this work.

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