Metaphors in Engineering Education Research: Prisms to Analyze the Epistemological Spectrum

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Introduction

Knowledge creation and synthesis are the core of research. How we engage in research or knowledge creation is deeply intertwined with our experiences and the language we use to make sense of the world around us. For us, the co-authors of this paper, the triad concept of Kaya (Body), Vacha (Speech), and Manas (Mind) in the Indian philosophy of ethics and spirituality points to the interdependence of experience, language, and knowledge. Lakoff and Johnson [1] present the same idea as the core motivation for their germinal book *Metaphors We Live By;* they suggest that dominant views on meaning-making in Western philosophy and linguistics are inadequate for the way we understand our world and ourselves. They propose that our language shapes the way we think, act, and make meaning, and this language is structured by conceptual metaphors based on our everyday experiences. Metaphors help us understand our world by giving a concrete foundation to abstract ideas. As metaphors offer an avenue to express or recognize abstract ideas, our paper proposes metaphors as a linguistic approach to understanding epistemologies in engineering education research (EER).

Metaphors are ubiquitous; we use them every day and everywhere, intentionally, or not. In research, we do not always clarify the metaphors we use, even when they are sprinkled liberally in our thinking and writing. Like light and shadows, every metaphor reveals and conceals different aspects of the idea it describes. Yet, we do not always consider the implications of the metaphors we use to illuminate a concept. In EER, consider how the narrative of broadening participation was primarily discussed using a pipeline metaphor but soon evolved to include metaphors of pathways or ecosystems [2], [3], [4]. These scholars emphasize that linguistic changes can change the perspectives of engineering educators, researchers, and institutions. Each metaphor has different implications for research and policy [2], [4], and the metaphors we use for our research impact our inquiries, insights, perspectives, and resulting recommendations [2], [3], [4]. For instance, the pipeline metaphor oversimplifies the complex journeys of diverse students in and out of educational institutions [2], [3], [4] or stigmatizes non-traditional pathways. Lord et. al. [4] illustrate how changing metaphors can open new forms of data analysis and visualization for more nuanced insights, and resulting policy recommendations. Thus, metaphors not only influence how we understand a phenomenon but also how we respond to it [1], [5].

In this work-in-progress (WIP) paper, we recognize that metaphors are one of the ways in which researchers engage in epistemological boundary-making. So, we propose investigating the metaphors used by engineering education (EE) researchers for epistemologies. Studying different metaphors and appreciating diverse perspectives can help to foster epistemological pluralism in EER. With this aim, we present a literature review and research design to investigate the question: **How are metaphors used for epistemological boundary-making in engineering education research (EER)?**

The first section on *epistemological views in EER* defines epistemology and synthesizes literature to illustrate 1) why it is essential to study epistemologies in EER, 2) why EER needs epistemic pluralism, and 3) why it is significant to reflect on the language we use to engage with diverse epistemologies. The second section *on crystalizing epistemological lenses* synthesizes

literature across disciplines to show how metaphors crystallize the fluid concept of epistemology. Finally, in the section on *seeing the spectrum*, we briefly review how metaphors have been used in EER to clarify epistemologies and propose a study design to investigate how EE researchers use metaphors for epistemological boundary-making.

Literature review

Reflecting on epistemological views in EER

The narratives we use, or the stories we tell as engineers, educators, and researchers, significantly impact how we define engineering beliefs, values, and knowledge and the nature of engineering for our audiences [6], [7]. Our beliefs about what counts as engineering knowledge and how this knowledge is or should be produced are defined as engineering epistemologies. In short, epistemologies are the theories of knowledge we rely on [8]. We use these theories of knowledge, or epistemologies, to define our work and disciplines to determine what counts as evidence and what should be valued in education and research. For these reasons, engineering epistemologies were identified as a critical area of research in the special report *The Research Agenda for the New Discipline of Engineering Education* (RAEE) [9]. However, in a recent review of EER from 1992-2022, Katz et al. [10] point out that epistemologies in EER were the most understudied from the five research areas laid out in the 2006 RAEE special report [9]. They urge researchers to take stock of previous work and design the next research agenda. Surprisingly, they do not directly highlight the need to focus on engineering epistemologies, even though epistemologies remain understudied in engineering education.

Douglas et al. [11] reviewed EE literature to explore how our field develops, introduces, or rejects epistemological diversity. They corroborate the fact that discussions on the role of epistemology in engineering education are missing from our scholarship. Riley [12], [13] writes that despite education being a social scientific field, engineering education researchers prioritize positivist epistemologies borrowed from the scientific worldview of engineering. Relying solely on the scientific method for generating knowledge is called positivism by philosophers [13]. Positivism is based on assumptions that knowledge and evidence produced using the scientific method are quantifiable, objective, and generalizable and, therefore, more desirable in research [14]. In addition to Douglas et al. [11], this tendency to prioritize positivist epistemologies even in qualitative research in EER is echoed in a literature review by Kellam and Jennings [14].

Over-reliance on positivist epistemologies excludes other forms of knowledge beyond the 'conventional' boundary of what is considered engineering and engineering education research [11], [14]. Additionally, this approach puts current 'outsider' knowledge on a lower standing than that which fits the positivist lens. Epistemological boundary-making is concerned with whose knowledge and which knowledge is recognized as valuable, and engineers, engineering educators, and researchers engage in boundary work to make decisions about inclusion and exclusion in our professions and disciplines [15]. These decisions about epistemological boundary-making are enactments of power. Riley [12] points out how engineering educators readily dismiss ideas from schools of education on how to teach better. She provides examples of scholars who only adopt specific approaches based on 'learning sciences' and deem only certain epistemologies and methodologies worthy of transfer from education into engineering education [12]. Douglas et al. [11] make a compelling case for the need for epistemological diversity in

EER to promote robust scholarship based on equity, acceptance, interdisciplinarity, and collaboration. Moreover, despite the lack of studies on epistemology pointed out by Katz et al. [10], there is no shortage of researchers calling for epistemological diversity in engineering education research [12], [14], [16], [17], [18], [19], [20].

Epistemology is an abstract concept. Yet it is crucial to understand and clarify our epistemologies because of their impact on how we conduct research and how we understand and improve the teaching and learning experiences [14]. Recognizing and using diverse epistemologies requires further challenging our imagination. In this WIP paper, we argue that metaphors can help us ground the discussions on epistemologies and epistemological diversity and light the way towards fostering epistemic pluralism in EER.

Crystallizing epistemological lenses with metaphors

How can metaphors help us clarify our assumptions about what counts as knowledge and how it is created? To delve into this inquiry, we conducted a comprehensive review of the usage of metaphors across various disciplines and found that metaphors are like those subtle marketing tools that don't just promote a product but an entire experience. Since the significance of an experience might vary depending on the context, metaphors convey different meanings when used in different contexts. Cognitive and neuro-scientists study metaphors to understand how the brain processes metaphors and how they shape thought, memory, and problem-solving [21]. Psychologists have leveraged metaphors to study the mental states of subjects and analyze their cognitive processes [22], [23], [24]. Philosophers research metaphors to understand the ethical and epistemological implications of using metaphors to convey ideas [25], [26], [27]. Researchers in the fields of cognitive linguistics and phenomenology study the structure, usage, and evolutions of metaphors to gauge the resulting conceptual understanding [28], [29], [30]. We found that across disciplines, metaphors are used to understand how we crystallize abstract concepts to make them more tangible and easier to understand.

We all use metaphors to understand concepts, as well as to communicate and convince others of our ideas. Communication studies utilize metaphor research to study the science of persuasion, rhetoric, and creating narratives [31], [32]. Sociologists and anthropologists research metaphors to understand cultural narratives, social constructs, identities, and beliefs [33], [34]. Finally, and most importantly, educators rely heavily on metaphors to facilitate teaching and learning processes [35]. Martinez et al. [35] collected reflections from 50 experienced teachers and noticed that most draw on the idea of teaching and learning as a transmission of knowledge. A few consider it a constructivist endeavor or a social process. They add that integrating studies of metaphors in instructional psychology and curriculum design can drive home the point that metaphors are like the blueprints of thinking about teaching and learning, and the blueprints we use to shape the classrooms we build [35]. Studies exploring how metaphors are used for understanding and communicating abstract ideas are prevalent across disciplines. The next section will summarize the studies on metaphors in EER. Branching from this work, we propose our study investigating how engineering education researchers use metaphors to explore, understand, and communicate epistemologies in their research.

Seeing the spectrum of epistemologies in EER

In engineering education, metaphors have been studied to inquire into the personal epistemologies of engineering faculty [6], [15], [36], as well as epistemological tensions

experienced by EE researchers [37]. What language do engineering education researchers use when they respond to calls for redrawing epistemological boundaries? What values are implicit in our metaphors as we recognize diverse ways of knowing, doing, and being? Values are often separate from their enactment in spaces of education and research. For instance, scholarship that recognizes the value of marginalized epistemologies often uses metaphorical language focusing on capital such as community cultural wealth, social capital, funds of knowledge or identity, and asset- or resource-based pedagogies [38], [39], [40], [41], [42], [43]. This metaphorical language of capital prioritizes principles of accumulation and ownership in ways that may be dissonant with the marginalized epistemologies we seek to conceptualize. Thus, language is also an enactment of power and reflects the values, beliefs, and priorities of those who hold power.

If language and epistemological boundaries are enactments of power, then it is worth exploring the language EE researchers use for epistemological boundary-making in pursuit of equity and social justice. Kellam and Jennings offer the metaphor of voices to create space for diverse viewpoints to co-exist and, more importantly, be in conversation [14]. Scholars in engineering education [2], [3] have pointed out how we need a diversity of metaphors to illuminate the complicated realities around structural issues that exclude the diverse ways of knowing, doing, and being in engineering education. We hope to understand the metaphors EE researchers use to understand epistemologies and spark conversations about the range of metaphors we could use to ground our understanding of epistemology and enact those beliefs. Through this WIP study, we aim to get a deeper understanding of the use of metaphors, not only to understand how epistemologies are conceptualized but also to investigate how new conceptions can help us foster epistemic pluralism in EER.

Research Design

To investigate our research question, we propose using a qualitative research design. A qualitative research design will allow us to understand what meaning participants assign to metaphors during research [44]. Further, it will also give participants a chance to reflect on their usage of metaphors and allow us to capture how they implicitly draw epistemological boundaries when they assign meanings to metaphors they use during research. Additionally, it will challenge participants to think about the implications of metaphor usage on EE scholarship. Next, we discuss our proposed study design, including participants, data collection, and analysis strategy.

We propose collecting data for our study using activity-oriented focus groups. Focus groups create space to elicit detailed responses from the participants and facilitate a discussion where one individual's point of view may stimulate others' thoughts [45]. Often, focus groups offer an ideal setting to engage participants with exercises or activities where they "do" something individually or as a group and then debrief together [46]. When embedded in focus groups, activities allow participants to chalk up their ideas and reflect on them before responding [46]. Given the potential of using focus groups with activities, we propose a workshop-like focus group format for our study. We initially plan to recruit between 6 and 10 focus groups, each with 4 to 6 participants. This number is typical in many qualitative studies that use focus groups [47]. Our focus group will be semi-structured, with five prompts (discussed below) and a discussion for each prompt. This focus group will follow a two-stage approach where participants first explore metaphors used in research individually, followed by a discussion with a partner in their

group. Our participants will consist of EER researchers from academia who have diverse backgrounds, genders, and ethnicities. We will advertise our study via email to universities globally that have EER clusters and recruit participants from these clusters.

We will ask participants the following prompts: (1) Please **share** the metaphors you frequently use in your research. Take a few minutes to reflect on the metaphors you use and write them down (2) **Exchange** metaphors with a teammate and use their metaphors to describe your research and vice versa (3) **Report out**: See what interpretation they make of the metaphors you assigned to them (4) **Discuss**: How do you feel about their interpretation of your metaphor? Do you see similarities and differences in the usage of your metaphor? Does the meaning of your metaphor change for you when others use it? (5) What do you feel about the usage of your metaphor? Reflecting back, would you still use the metaphor in the same way?

We plan to analyze the collected data using *In-Vivo coding.* In-vivo coding is typically used when the researchers want to capture the verbatim meaning of words used by participants from a particular culture or who have experienced a particular phenomenon [48]. In our study, we intend to highlight metaphors used by EE researchers and derive the meaning of the metaphors directly from the participants' voices. Therefore, In-Vivo coding is suitable for capturing rich data from our participants' focus group interactions.

Conclusion

With this proposed study design, we will explore how metaphors are used in EER research, the meaning assigned to these metaphors, and the implications of these metaphors. The purpose of this paper is not to promote the use of one metaphor over another but to be creative and intentional in our metaphorical usage. It is the use of multiple metaphors that enables us to think critically and collaboratively by interrogating an idea from different perspectives [2]. Further, metaphors can reveal our values and beliefs on what is considered engineering knowledge and how it is produced or transmitted. Donna Riley's [12] eloquent words and apt metaphors sum up the motivation and goals of this paper:

"In academic contexts, rigor also connotes adherence to the protocols of a particular discipline, especially in methods and epistemology. Work is critiqued for lacking rigor if questions are not framed in particular ways, if certain tools are not employed, certain processes not followed, and certain modes of interpretation not applied. Rigor restricts us to certain ways of knowing, specific to a particular discipline. This is why authentic interdisciplinarity is the third rail of academia: if you cross disciplines on the level of epistemology and mix ways of knowing, you mix rules of rigor, and siloed heads explode."

With this work, we hope to draw new boundaries for research in engineering education. Metaphors can help us crystallize our epistemologies. Like prisms, our epistemologies reflect and refract a new spectrum of ideas and experiences. We believe this work will contribute to the research in engineering epistemologies listed in RAEE [9]. We also have much to learn from other disciplines (like humanities and languages) to expand our epistemological boundaries. Thus, our study will also contribute to strengthening interdisciplinary approaches in EER. With these broad aims, this WIP paper contributes to scholarship on how the language we use can influence the theory and practice in EER and the enactment of equity, culture, and social justice in education.

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