New Metaphors for New Understandings: Ontological Questions about Developing Grounded Theories in Engineering Education

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Abstract: Engineering education scholars have demonstrated an interest in broadening the scope of the field in multiple ways, including issues addressed and approaches employed. These scholars have argued the need to broaden the epistemological and methodological boundaries of the field. However, numerous challenges to such expansion exist, and they must be better understood if the potential of broadening the field's boundaries is to be fulfilled. To that end, this paper has three aims: 1) to demonstrate how new metaphors can contribute to grounded theory development, 2) to explain the significance of such approaches, and 3) to identify challenges of introducing grounded theories and new metaphors in engineering education research. The paper begins with a discussion of the methodological justification for developing grounded theories via new metaphors. An overview of one of our prior studies that attempted to develop a new metaphor-based grounded theory is then presented. Based on our experiences with that project, as well as other prior work, the challenges encountered in this type of work are then discussed. The discussion also raises larger questions about the nature of *theory* in engineering education research.

Introduction

Recently, engineering education scholars have demonstrated an interest in broadening the scope of the field in multiple ways, including issues addressed and approaches employed.[1-7] More specifically, these scholars have argued the need to broaden the epistemological and methodological boundaries of the field. Additionally, the stated aim of a recent guest editorial in *Journal of Engineering Education* was to increase "different perspectives of engineering education," including by studying faculty, departments, and institutions.[8] The same editorial also aimed to increase engagement with interdisciplinarity. In line with those objectives and trends, this paper discusses grounded theory development via metaphors, an approach that has not been widely engaged in engineering education, and highlights its challenges. In doing so, the paper also raises larger questions about *theory* in engineering education research. The aims of this article are threefold: 1) to demonstrate how new metaphors can contribute to grounded theory development, 2) to explain the significance of such approaches, and 3) to identify challenges of introducing grounded theories and new metaphors in engineering education research.

This paper follows others who have reflected on their own research studies,[9] and calls for increased reflexivity and reflectivity in engineering more broadly.[10] It begins with a discussion of the methodological justification for developing grounded theories via new metaphors. An overview of one of our prior studies that attempted to develop a new metaphor-based grounded theory is then presented. Based on our experiences with that project, as well as other prior work, the challenges encountered in this type of work are then discussed. The discussion also raises larger ontological and methodological questions about *theory* in engineering education research.

Methodological basis for grounded theories via new metaphors

Metaphors are used to understand or experience one thing in terms of something else that is more easily or clearly conceptualized.[11] Metaphors must be understood not merely as linguistic devices "but rather as cognitive units of categorical perception".[12] Explaining the general significance of metaphors, Lakoff and Johnson state that, "Our ordinary conceptual system, in terms of which we both think and act, is fundamentally metaphorical in nature. The concepts that govern our thought are not just matters of the intellect. They also govern our everyday functioning, down to the most mundane details".[13] In other words, metaphors structure both thought and action, particularly, in the context of this paper, in research.[14]

Research in cognitive science and Science and Technology Studies (STS) has demonstrated that metaphors are an integral part of research across a range of social, biological, and physical science fields.[15-19] In engineering specifically, Schön has discussed how *generative metaphors* guide design and engineering problem solving.[20] Of particular significance to this analysis, is that metaphors are particularly central to the development and changing of theories.[21-25] Therefore, the metaphors engaged in engineering education research warrant attention as they are of significance to the development of theory and methods.

While this body of prior research on metaphors often focuses on how people unconsciously use them in science, researchers can also deliberately employ metaphors to advance their research. Metaphors are rich and complex in ways that increase the theoretical significance of data.[26] More specifically, in social science research, metaphors can structure research and data analysis in several ways. They are *pattern-making devices* that situate or locate patterns within their larger social contexts; they are *decentering devices* that require moving "up a notch to a more inferential or analytical level;" and they connect findings to theory.[27] As Miles and Huberman (1994) explain:

> [T]he metaphor is halfway from the empirical facts to the conceptual *significance* of those facts; it gets you up and over the particulars en route to the basic social processes that give meaning to those particulars…In doing that, you're shifting from facts to *processes,* and those processes are likely to account for the phenomena being studied at the most inferential level.[28] [emphasis in original]

Consequently, metaphors both facilitate and necessitate analyses that require drawing inferences from other bodies of literature.

Metaphors can be particularly beneficial analytical tools in grounded theory research.[29] Grounded theory is a qualitative data analysis method, and it was recently identified as an emerging research methodology in engineering education research.[30] While there are numerous strands of grounded theory, they all share some common characteristics.[31-32] Grounded theory analysis begins by generating many early stage labels for words, phrases or other elements of the qualitative data; this is called *open coding,* or *initial coding,* and it is the initial step in which data are compared with other data and "we learn what our research participants view as problematic and begin to treat it analytically".[33] As these codes accumulate the researcher compares the codes to each other and across interviews (or other data source being used). After all data has gone

through open coding, or when the generation of open codes slows down, a second stage of detailed coding, called *focused coding*, begins. Here, many of the open codes are combined. The remaining codes are expanded and detailed. From these condensed and detailed codes, *theoretical coding* can be done, and a theory that explains the data can emerge. Theoretical codes "specify possible relationships between categories" developed in focused coding: they are integrative and "help you tell an analytic story that has coherence."[34] This theory is called *grounded* because it is grounded directly in the analyzed data. Grounded theories do not have to be universal and are initially context-specific, pointing to avenues through which they can be further developed.[35] Grounded theory analyses stand in contrast to analyses in which data are coded through a pre-existing lens or theory that *a priori* structures the codes.

There are numerous examples of grounded theory research that have effectively employed metaphors to increase "explanatory power".[36] Metaphors can serve as theoretical codes when, as Birks and Mills (2011) argue, "there is a sufficient fit between a metaphor and the grounded theory".[37] "Theoretical codes are advanced abstractions that provide a framework for enhancing the explanatory power of your storyline and its potential as theory".[38] In grounded theory research, theoretical coding is a stage of coding done late in the research process in order to move findings toward theory development.[39]

An example of grounded theory development via metaphor

Background

Female engineering faculty members remain underrepresented across the country despite decades of scholarship and interventions intended to address the problem.[40] One contributing factor is that, overall, women are denied tenure at higher rates than men and are more likely to leave the academy prior to tenure review.[41-46] The dominant metaphors in studies of STEM underrepresentation have been the *pipeline* and *chilly climate*; however these metaphors have been subject to critique.[47] However, these metaphors have been subject to critique. The pipeline in particular has been critiqued on numerous fronts. One leading critique relevant to this analysis is that it fails "to acknowledge the complexities of male advantage, gender power, and the gendered nature of organizational dynamics".[48-49] Despite such critiques, the pipeline persists prominently in structuring studies and initiatives aimed at addressing underrepresentation. Given: 1) growing interest in broadening methodological diversity in EER, 2) persistent underrepresentation of female faculty, 3) limitations of current metaphors, and 4) the significant structuring role that metaphors play in our thoughts, actions, and research, we wrote an article that put forth a new metaphor-based grounded theory and attempted to explain its significance for contributing new understandings of the careers of female engineering faculty members. We turn now to a brief overview of how we analyzed the data for that study, what we found, and how those findings led to a metaphor-based grounded theory analysis.

Data analysis: metaphors as theoretical codes

Data came from semi-structured interviews with male and female faculty members and administrators in engineering, technology, and science fields at a large, public research university in the Midwestern region of the United States. Recruitment and data collection

procedures have been described in detail elsewhere.[50-51] As discussed above, metaphors can serve as theoretical codes.[52] A prior analysis of a sub-set of four interviews had led to the development of a *foggy climate* metaphor to describe faculty experiences with tenure and promotion.[53] We therefore used the foggy climate metaphor as a theoretical code and coded the entire data set for instances of discussion related to ambiguity surrounding tenure and promotion. Consistent with grounded theory, relevant literature, in this case primarily from social psychology, was subsequently drawn in to contextualize the findings and explain the significance of the findings and emerging theory.

Findings

Ambiguity emerged as a leading theme throughout the interviews, in response to numerous different questions. When describing promotion and tenure processes, participants used adjectives that conveyed a lack of clarity and objectivity, including: "opaque," "confusing," "secretive," "subjective," "arbitrary," "blurry," and a "grey area." They experienced the ambiguity as "frustrating" and "stressful," as well as unnecessary. For example, when asked about requirements for tenure, one participant commented on the ambiguity:

> [T]hat was probably one of the least clear aspects. I was told anywhere from…that I'd need at least 12 publications to that I'd need a handful of publications. I would assume a handful being five, but [that's] to give you an idea of the lack of clarity…But that's a problem even there, because one high impact journal is equivalent to several low impact publications, but none of us know really what the equivalency rule is.

Another participant believed that promotions committees do have expectations for certain numbers of publications or grants, even though they will not articulate those expectations. She also believed those expectations should be specified so that faculty can make better-informed decisions about how to spend their time. She stated that:

> The review process [at this university] for promotion and tenure is absolutely dreadful and they are gutless in the extreme. They cannot and will not develop criteria by which you can measure whether or not you're being successful...[They] will sit there and go, "We can't write down criteria, everybody's got to be judged individually," and it's like oh come on, you can write stuff down. You can't tell me that after 50 years of being in academia…that you can't write down criteria for excellence or success.

She went on to explain she thinks that resistance to guideline specification stems from a fear of getting "boxed in" to having to keep someone they do not like, but that that is "absolutely ridiculous." Most participants wanted better, and more quantifiable, guidelines. Several described the expectations or requirements as a "moving target." Several participants also recognized that the ambiguity left room for biases and the likeability factors. For instance, one worried about the role of external letters, saying, "I don't know that I have any enemies in the field but perhaps there are people out there who don't like me or like my work and I was really scared that some of those people could write bad letters." This participant also said that the secrecy is "really frustrating… Especially from the perspective of a woman I think you worry about there being some kind of an old boys club. I had no evidence to say that was going be the

case but I think that's where I felt particularly vulnerable." Another faculty member also believed that votes were cast on the basis of likeability. Discussing how the publishing requirements were never made clear to her when she was hired, she believed the standards were "vague" intentionally so that "they can interpret it…the way they want and change it the way they want and a lot of it depends on how they feel about you." Similarly, an administrator recognized that the process is susceptible to "double standards" and is "all kind of relative in many ways" because "we're all people that have biases and we look at things all in different ways."

Discussion: developing a grounded theory of foggy climates

As seen in the findings presented above, which constitute a significantly shortened version of all the findings, ambiguity emerged as a leading theme in faculty members' and administrators' discussions. The findings therefore supported the further development of the foggy climate metaphor. Drawing on literature from social psychology allowed us to argue that ambiguity matters because of gender biases and contemporary prejudice, which we discuss in greater detail elsewhere.[54] Suffice it to note here that there is a large body of literature from social psychology, as well as other fields, that has documented the ways gender biases operate and that environments with ambiguous evaluation criteria promote prejudices while environments with concrete and objective evaluation criteria mitigate the operation of prejudices.[55-59]

Because metaphors are integral to research, shaping questions, methods, and findings, it is important that they be accurate, nuanced, and accountable to relevant bodies of knowledge. The dominant metaphors of pipeline and chilly climate are not: they are limited and oversimplified in problematic ways.[60] Our findings regarding ambiguity in T&P processes and decisions suggested that a foggy climate is an appropriate metaphor with which to conceptualize this career stage and from which to develop further research. This new metaphor overcomes critiques of pipeline by attending to gender (as opposed to women), power, and problematic facets of institutions. It overcomes limitations of chilly climate by accounting for variation and nuance across career stages and at specific points in career pathways. Invoking "fog" conveys the idea that there are aspects of faculty members' environments that are obscured, go unseen, are difficult to identify or locate, and make it difficult to see where they need to go. For voting committees, fog provides cover, promoting the operation of biases.

We were not suggesting that foggy climates alone account for women's underrepresentation in engineering departments. We were suggesting, as others have,[61] that ambiguity surrounding tenure and promotion is an understudied and under-discussed piece of the puzzle that warrants greater attention. By naming the foggy climate, our aim was to draw increased attention to it, to promote further studies on the ambiguity surrounding T&P, how it is experienced, and how its effects vary across racial groups and institutions. The new metaphor could prompt and guide new research on the foggy climate. Consistent with the aims of grounded theory, the new metaphor was intended to lead to be further developed in future studies to increase its theoretical significance, not to be an end in and of itself. Like all metaphors, it does not capture the entire range or all aspects of a phenomenon; instead, it highlights some while hiding others. This is not a limitation of the foggy climate metaphor: it is an inherent characteristic of *all* metaphors.[62-63]

Our findings on the foggy climate also led us to propose a related new metaphor of *microclimates* could contribute to more nuanced understandings. Examining and conceptualizing varying microclimates along career pathways would lead to better understandings of underrepresentation. Our data revealed that different challenges arose over the course of educational and career pathways, and the chilly climate metaphor alone does not account for such nuances or variations. Other scholars have similarly recognized the significance of developing new and more accurate metaphors in order to understand faculty careers and institutional contexts, including the specific challenges women face.[64-66]

It is important to note we are not arguing for the essential use of metaphors as alternative frameworks to dominant theoretical lenses. While this may have merit and deserves thoughtful attention, in this paper we address the *possibility* that metaphors may emerge from grounded theoretical analysis. These metaphors may also displace previous frameworks that are overly constraining. However, as an inductively developed theory there are rarely multiple (final) theories to evaluate, instead constantly returning to the data will support or push the researcher to a final theory that best aligns with the data.

Challenges and tensions

As discussed in the Methodological section, metaphors are significant because they shape research and theories and strengthen grounded theory analyses. We use the example study summarized above to provide entrée into a discussion of the use of grounded theory and theory in general in engineering education. Based on our experiences with this work, as well as other work, we have identified three distinct but interrelated challenges or tensions. These tensions arose when the study underwent peer review at an engineering education journal. They expand upon the authors' prior research exploring the nature of theory in engineering education research and peer review in engineering education.[67-70] It should be noted that the tensions identified do not cover the entirety of critiques reviewers had of the paper.

1. Disconnect between calls for greater methodological diversity and reality of what that entails

As noted, a handful of leading engineering education researchers have called for expanding the topics, theories, epistemologies, and methodologies addressed and used in EER. However, these expansionary interests are not necessarily held by all reviewers or editors for engineering education journals, leading to a paradox where those who answer the calls for new approaches encounter resistance during the review process. Some of the challenges have been identified by Douglas et al. (2010).[71] New methodologies and epistemologies in the research entail concomitant methodological and epistemological changes on the part of gatekeepers. How can we expect researchers to employ new approaches if they are not going to be able to publish the work from those new approaches in engineering education journals?

2. Grounded theory = open coding

It is not uncommon for engineering education researchers to label their data analysis methods as *grounded theory*. Many stop short, however, of moving to the final step of theory development. *Grounded theory* is thus used to refer to only one piece of the entire process, namely open

coding. This is not uncommon, and occurs in other fields as well, and grounded theory means different things in different research traditions.[72] "Theory generation continues to be the unfilled promise and potential of grounded theory. As Dan E. Miller (2000: 400) states, 'Although grounded theory (Glaser & Strauss, 1967) is often invoked as a methodological strategy, ironically too little grounded theory is actually done'".[73]

Therefore, using *grounded theory* as synonymous with *open coding* is not wrong, per se, but it does not fulfill the full potential of grounded theorizing. The fact that it is the dominant mode of grounded theory use in EER means that moving beyond the open coding to actually proposing a grounded theory is unusual. Reviewers and editors may not be accustomed to seeing how the theory grew out of the data and interpret it as it as merely made up on the whim of researchers, as not empirically derived. This, then, is one example of a necessary change referred to in Tension 1 above.

It highlights a methodological bias on the part of reviewers who think findings can only come from data in limited ways. Imagination and researcher creativity are an inherent part of full grounded theory, indeed one of the primary virtues of grounded theorizing (in the interpretative tradition). As Charmaz argues, "Grounded theory methods can provide a route to see beyond the obvious and a path to reach imaginative interpretations".[74] Likewise, metaphors can be thought of as *imaginative rationality*.[75] Thus, while grounded theorizing does not necessarily entail the development of new metaphors, as discussed above, it can benefit from doing so. As a new approach within EER, however, such imaginative rationality encounters resistance.

Resistance to new metaphors, stemming from concerns over how they were developed (with insufficient justification), harkens to concerns in the field over objectivity, which has been discussed elsewhere.[76-78] These concerns in turn are reflective of broader social concerns that Lakoff & Johnson term the *myth of objectivism*. They explain that "The fear of metaphor and rhetoric in the empiricist tradition is a fear of subjectivism – a fear of emotion and the imagination…In terms of real power in society – in science, law, government, business, and the media – the myth of objectivism reigns supreme".[79] New metaphors in particular encounter resistance precisely because they are seen as metaphors, in contrast to established metaphors, which are often simply taken as Truth and not even recognized as metaphors.[80] Reviews of our study highlighted concerns over objectivity.

3. theory vs. Theory

Prior research has warned about the risks of *concept matching* or using prepackaged theories.[81-84] Concept matching involves uncritically or unreflectively applying a theory to a particular phenomenon because of face similarity between the two, merely matching data onto terminology derived from the Theory. Application is one-way; that is, the theory is used to frame the phenomenon without: 1) reflection back on what the evidence collected implies for the theory, 2) wrestling with the complexities of the data and theory to realize the full power and potential of both, 3) being reflective about "how we think with theory as we undertake the analytical labors of research and writing", or 4) combining theories in novel ways.[85] In other words the theories' tenets are left unexamined (hence prepackaged), and theoretical development does not occur. Some examples of theories popular in EER that have been employed this way include self-

efficacy, social capital, and some identity theories. However, as Anyon and others have argued, to deeply understand the complexities of a given phenomenon, the evidence collected should also be contrasted with the theory (or theories) the researcher employs.[86-87] Concept matching as the dominant use of theory in engineering education is not unique: it reflects the dominant use of theory in education research more broadly.[88]

We are labeling this the distinction between uppercase *Theory* and lowercase *theory*. Theory is those well-known, well-established, packaged theories with specific, established names, such as *self-efficacy* or *social capital*. theory, on the other hand, is all the other ways in which theorizing is done and all the other perspectives that can be called theories. This tendency could help explain the limited use of feminist theory in engineering education,[89] because much feminist theory is theory, not Theory. Feminist theories are particularly attuned to feedback from the evidence in a study; however as Beddoes explains in her study of feminist scholarship in EER, many feel their contributions are not well-received or recognized in mainstream EER journals.[90] It should be emphasized that we are not against Theory, per se. Indeed, we have written elsewhere of the benefits that can come from Theory use.[91]

We encountered resistance by attempting a new approach outside the dominant mode of theorizing in EER, which is concept matching. There needs to be different appreciation for a wider understanding of the nature of theory – what it is, how it can be created – as opposed to Theory, if these approaches are going to be able to get published or influence the research landscape. Theory means different things in different research traditions.[92] In engineering education, it seems that theory is either not articulated[93] or packaged Theory; however even when it appears that theory is absent, research nonetheless contains covert or implicit theories.[94-95] We are suggesting that there needs to be a middle ground that expands the limited range of what counts as theory in EER. Allowing for different conceptualizations of what constitutes theory and theorizing will help facilitate the expansion of the methodological and epistemological boundaries of the field that has been called for. This is a second example of a necessary change refereed to in Tension 1 above.

Conclusion

For engineering education researchers interested in reading more about grounded theory, Charmaz (2006)[31] and Birks and Mills (2011)[52] provide practical introductions to the methodology. Graphical depictions of grounded theory exist,[96] but are typically over-simplified and fail to capture many of the iterative and inductive operations involved in developing a theory from the data. Our attempts to more fully capture the processes of grounded theory resulted in a graphic that required a lengthy explanation—thus we have chosen to rely on textual descriptions of grounded theory.

This paper was developed through critical reflection on one of our own research experiences in which we attempted to develop a metaphor-based grounded theory. The challenges and tensions identified through this experience build on prior observations we have made about the field of engineering education research. They raise questions for editorial boards, reviewers, authors, and others in fields such as engineering studies. As noted, the arguments for expanding the boundaries of the field have been decisively laid out; however, as this reflection suggests, there

remain serious questions about the nature of theory and the methodological beliefs of reviewers and editors, which may hinder the expansion of the field. In part, challenges likely stem from competing conceptualizations of theory. Definitions of theory vary across research traditions. For example, in positivist traditions, theory "seeks causes, favors deterministic explanations, and emphasizes generality and universality", where as in interpretive traditions, theory "calls for imaginative understanding of the studied phenomenon…assumes emergent, multiple realities" and indeterminacy.[97] In conclusion, we pose the following questions to the engineering education community in order to prompt reflection on the current state and future of the field: *What is theory? What ends does it currently serve in engineering education research, and what ends should is serve? What changes might be brought about by different dominant conceptualizations of theory and theorizing?*

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