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# Femininomenology: infusing feminist praxis into a descriptive phenomenological process. Methodology development: descriptive phenomenological research for engineering education contexts.

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# Tricks of the Trade (Methodology development): descriptive phenomenological research for engineering education contexts Femininomenology: infusing feminist praxis into a descriptive phenomenological process.

## Introduction

As graduate students learn to become independent researchers, they have to make many decisions for the first time. A critical decision for many new qualitative scholars is how to determine a methodology for their topic. This decision can often be the most daunting stage of designing a dissertation because the alignment of methods, theoretical framework, population, research questions, and implications of those elements is essential to a productive and convincing research project. Furthermore, this alignment takes place early in the process of designing a dissertation. I wish to present how I adapted a methodology for my specific project. I drew from existing strategies and methods, combining ontological influences from feminist theory [1], [2] to develop a method which is rare in engineering education literature [3], [4], [5].

I present here how I investigated the origins and applications of my chosen method, then modified and adapted it to fit my study context. I conclude this paper with a demonstration of how to leverage this method. I encourage other students to consider how they could tailor methods for their own study projects.

## Background

Many qualitative methodologies have similar primary components: data collection, data analysis, and ensuring interpretive validity [12], [13], [14], [15], [16], [17], [18], [19], [20]. Most Engineering Education programs have entire course sequences dedicated to effective qualitative methods. However, what if none of the established forms work for a study? This is where a distinction between methods and methodology is important. Methods are the techniques used within a research study, whereas methodology is the overarching approach, with inherent assumptions, techniques, and commonly leveraged elements.

## Effective Research Design (Methodology)

There are also entire publications on research methodologies, and how to select one for a study's purposes [6], [13], [13], [20], [20], [21], [22]. However, the major point drawn from these readings is the idea that any chosen approach must have alignment and consistency between the assumptions, the theoretical positioning, the object(s) being examined, the data being collected, the analysis for that data, and methods of communicating findings to the larger community.

Any study must have consistency in those elements, though any such element may be chosen first; the research design process, like senior design problems and paper writing, is a nonlinear iterative process.

My journey started with a definitive population and conceptual focus; I needed to find a methodology that would allow me to collect, analyze, and present data from my population that

answered my questions. Given that I was examining how a shared experience for a group existed, I landed on descriptive phenomenology [19], [23], [24].

## Phenomenology

Phenomenology is a study of some intangible phenomenon [1], [2], [3], often used to understand or research emotions, experiences, or ephemeral ideas. It relies upon gathering data from multiple sources (participants) who have some shared identity or relation to the phenomenon of investigation. Then, those individual understandings or experiences are examined, then overlaid to give a better description of the phenomenon itself. There are several primary schools of phenomenology, based upon what philosophical leaning the founder held.

Phenomenology as a methodology has a rich history, grounded in social science roots and philosophical underpinnings [4], [5]. Phenomenology is a qualitative method for determining the essence of an experience. That is, phenomenology looks at the nature of existence, and posits questions related to experiential moments, or looking at the interface of a person and an event, emotion, experience, or other interaction with an intangible something. Then phenomenology examines through those interfaces of people interacting with the thing, what the essence of the thing is.

The general method of proceeding through phenomenology is to gather participants' specific, individual description of an experience, concept, or "phenomenon." The researcher focuses upon determining what within the individual's experience of the phenomenon constituted the essential component of the experience, or what of the interaction with the phenomenon was integral to the phenomenon. Additionally, the researcher considers any interactions between those components of experiencing the phenomenon, seeking connections between those components for a more complete understanding of what it meant to experience the phenomenon. Then, making sure to center the phenomenon and the participant's description, the researcher compares multiple participants, and finds the core components of that phenomenon or experience. The primary goal of phenomenology as a method is to consider how a phenomenon unfolds and what is experienced by people who are interacting with said phenomenon [6], [7], [8], [9], [10].

## Methods

### Phenomenological Inquiry

A core component of phenomenology is a focus upon the participant, centering their description and their personal definition, as the researcher should not be applying any interpretation to the individual's construction of experiencing the phenomenon.

I started with an exploratory survey of phenomenology, namely how to collect data and conduct phenomenological analysis [7], [8], [9], [25], [26]. I focus my own research on developing definitions of the phenomenon of investigation, or what is called descriptive phenomenology. Phenomenology, particularly from the founding original Husserlian traditions, is more focused on philosophical nuances as opposed to operationalized usage of the findings. Further, most phenomenological analytic approaches are especially vague and highly contextual dependent. As such, I chose to adopt data collection from the Husserlian traditions [7], [10], and adopt analytic

techniques developed by other STEM scholars [8], [11]. Within Husserlian phenomenology there is a focus upon ‘bracketing’ or complete removal of the researcher’s personal bias to ensure validity. Given that I myself am part of my study population, I chose to forego bracketing in favor of the reflexive ‘bridling’ of another school of phenomenological inquiry, that of lifeworld research [11]. ‘Bridling’ focuses upon mitigating the researcher’s bias within the initial analytic stages while developing participant descriptions, yet then reintroduces that bias in the latter stages of analysis, particularly when the researcher is connecting findings to existing literature.

That is, I chose the methodology of descriptive phenomenology to answer my questions, but selected a different data collection and analysis methods than are common. I also modified the common practices designed to make the researcher more of an impartial observer, in favor of practices that would allow me to make use of the valuable insights I held as a member of my own study population, or an insider.

From these three components (data collection, data analysis, and bridling), I developed a detailed research design to investigate my dissertation project, drawing also from the lessons in feminist inquiry, namely how to incorporate humanizing elements to the interview process [1], [2].

Feminist inquiry encourages researchers to discard the assumptions of sterile environments, particularly when working with human subjects in what can be very vulnerable moments [1], [2], [27]. Rather than treating the researcher self as an objective instrument for data collection, instead this ontology calls for a departure from “the paradigm of the 'proper' interview appeals to such values as objectivity, detachment, hierarchy and 'science' as an important cultural activity which takes priority over people's more individualized concerns [1, p. 227].” That is, Feminist inquiry calls for an approach where “the goal of finding out about people through interviewing is best achieved when the relationship of interviewer and interviewee is non-hierarchical and when the interviewer is prepared to invest his or her own personal identity in the relationship [1, p. 229].” To put it another way, “one’s self can’t be left behind, it can only be omitted from discussions and written accounts of the research process [2, p. 161].” Researchers cannot set aside their humanness for a period of time; our personality and identity and experiences will naturally color our perceptions, views, and future experiences.

I chose to leverage data collection primarily through a semi-structured interview, with data triangulation via a pre-interview task and a post interview reflective narrative. The interview follows the guide for semi-structured interviews and aligns with the core of phenomenology in that it is entirely seeking the many different possible components in the phenomenon of examination, “learn engineering” or “learning engineering.” The pre-interview task is intended to allow for targeted personalized questions, as well as giving us a starting point as to this particular participant’s understanding of the phenomenon. The interview itself was semi-structured, following a rough protocol which leveraged a question bank for guidance, yet still adhered to the principles of open-ness and centering the core phenomenon of investigation; that is, a bank of questions was developed, but not expected to be fully leveraged. Instead, priority was given to following promising threads of conversation as the interviewer seeks to comprehend how the participant constructs, views, or considers the existence of the phenomenon in question. Further, the interview leveraged an activity (which participants were previously notified about) where they were asked to connect their knowledge of some topic with the techniques they would use to teach another person that topic. Finally, data collection concluded with a reflective narrative of a time they experienced the phenomenon.

## Data analysis

I chose to align with the protocols for psychological phenomenology. This data analysis process was the most defined, concrete, and descriptively detailed, as well as designed for similar concepts in social science research, which sits at the edge of human-facing investigations and disciplinary rigor, just like engineering education. After this data analysis, a cohesive definition of how the phenomenon is composed by the participants should emerge, as well as any unexpected findings which shook loose along the way. This is the point when my personal viewpoint is reintroduced, to allow for deeper analysis of the phenomenon.

So, in conclusion, I drew upon collection techniques from two different approaches, data analysis from a third, and methods of data validation from an additional two approaches. Given that each approach is a distinct methodological entity, I had to ensure ontological alignment of the underlying assumptions for each of them.

## Adapting Methods Together- not just a simple stitching

To check for internal congruence in the methodological components, I examined each of them in depth to determine what assumptions were made about the research done using that component.

Leveraging interviews as the primary source of data for phenomenological studies is well established [7], [24], [28], yet most such interviews leverage open interviewing, where the interviewer is guided solely by the subject, following trains of thought as they emerge. To facilitate interviews with a constrained and prescriptive protocol risks compromising the entire participant's data, predisposing the researcher toward expected lines of inquiry as opposed to engagement with the lines of inquiry which appear. However, when the phenomenon of consideration is one that the participants have (possibly) never considered, there is a risk of those inquiry lines stalling out. As such, a question bank can serve as a compromise [28], [29]. Phenomenological interviewing assumes that the participant can verbalize the phenomenon or attempt to grasp the elements therein. As well captured by Barlow and Brown, "while interviews are inherently limited by how the participant perceives their own reality and conceptualize the phenomenon being discussed, we suggest study of the personal, or particular, will, in time, help make sense of the whole [[30, p. 60]." A question bank requires the researcher to better understand probable lines of investigation for the phenomenon.

The interview may serve as the focus of the data collection, but given the highly interpretive nature of phenomenological inquiry, additional grounding points of data can be helpful. In this case, I chose to gather a preliminary definition for data triangulation [28], [31], as well as a personal narrative [7], [23], [32] after the interview. This allows me to center any findings from the interview analysis within the preliminary definition, and seek those same elements in the narrative itself. Narrative analysis is more commonly a technique of interpretive phenomenology, but these narratives can have powerful latent examples of components of the phenomenon. This is particularly important when the phenomenon is unintuitive [32], [33]. Thus, the multi-stage data collection from several distinct sources, analyzed separately, allows for a triangulation and emphasis on the phenomenon itself; any data example that emerges in all of the sources is even more likely to be important, while a data element that is present in one of the data sources but not the others is far less likely to be relevant to the final phenomenon structure. Personal definitions of the phenomenon of inquiry both gives the participant time to consider their answer, while also

providing their own words and framing for the direction taken for the phenomenon. In contrast, the narrative allows for explication and uncovering latent elements of the phenomenon which are experienced, but cannot be verbalized or were not presumed to be connected. Narratives assume that an experience does not have to be labeled and analyzed in a detailed manner to be an effective demonstration. Similarly personal definitions presume that ideas can be communicated through many different types of jargon; both require significant analysis by the researcher to distill out the salient components. This was also one of the primary places where feminist inquiry strongly informed my work: the interview itself. Feminist inquiry values the personal and human-ness of participants, which is extremely valuable in such a personal study where the researcher is also a viable participant. Being willing to answer my own questions, dispense with the 'clinical' approach to interviewing, and relate personally with the fellow human who was constructing the interview experience with me were all elements to the attitude I drew from feminist inquiry [11], [12], [13].

Phenomenology arose as a philosophical method of analysis, and many of the established phenomenological methods [6] still draw heavily upon those foundations. This can be a powerful tool, yet engineering is a STEM field, rather than a philosophical one. The majority of engineering concepts are based upon or describing physical phenomena.We chose to follow an established data analysis method as it is the most detailed and rigorous analytic method within descriptive phenomenology. Further, it aligns the ontological and theoretical elements of "hard science" with the philosophical attitude of phenomenology. "Phenomenology was initiated as a philosophy" and Husserl's method "was intended to be a philosophical one ([10, p. 87])." As such, I find Giorgi's adaptations to be relevant; his changes were "based upon scientific and psychological perspectives." This process is excellent at guiding a researcher through the numerous steps of analytic vagueness, or as well described by Barlow and Brown, explicating the "hermeneutic circle of interpretation that allows for meaning to be shared from participant, researcher, and reader: when prompted with an interview question, a participant makes meaning of it as they respond. The researcher makes meaning of their response through a careful series of analyses. Finally, you, the reader, make meaning of our interpretations presented in written word. This analysis allows us to present themes to answer the research question [30, p. 60]."

Within each of these paradigms (interviewing, narratives, data analysis) there is a presumption of objectivity by the user. In fact, this is a point grappled with through the entirety of Giorgi's book and process [10]- how to balance determining if something is significant while also remaining distant and objective. Given that I am an insider, a member of my own study population, I turn to feminist inquiry to address this tension. As well stated by Oakley, "The dilemma of a feminist interviewer interviewing women could be summarized by considering the practical application of some of the strategies recommended in the textbooks for meeting interviewees' questions [1, p. 235]" which means the ways you treat your interview subjects are both informed by your positioning and convey power relations about you, the study, and the eventual uses of the information discovered. As such, I embrace these approaches and their power equalization, given that I am a peer interviewing others about their experiences and views in graduate school, the shared space we are all inhabiting. I cannot, and do not want to, be objective; I value the personal, the unique and individual, and do not seek generalizability of my findings [34], [35], [36]. This also informs my data analysis: I sought to be true to my participants rather than find broadly applicable outcomes.

Though I do not seek generalizability of my findings, I do seek to describe the phenomenon, and as such need to ensure my research and inquiry are minimally biased. Though my personal viewpoint is an asset, it will naturally color my own analysis. In order to mitigate my analysis of the data with my own views, I chose to engage in "bridling" or constant and continuous reflexivity to be aware of and mitigate existent thoughts or biases [11]. This is distinct from the more common "bracketing" which assumes that the researcher can completely void their thoughts on the topic at hand to get a pure version of it [9], [28]. Bridling, contrastingly, draws on humanist perspectives that the personal cannot, and should not, be completely separated from the research process, but it can be held at bay for a brief time to attempt a more situated analysis of the participants view of the phenomenon, before re-introducing the researchers views in the analysis step. Thus, the first step in data collection is to pre-bridle existent personal assumptions of the phenomenon, related theories, external factors or inputs, and any related pre-conceptions explicitly into a journal to note existent biases. This allows the researcher, through constant efforts in reflexivity, to ensure that their analysis of the participant's phenomenon descriptions are as accurate as possible. After all the participant's descriptions have been composed,when the final stages of the analytic process are underway, then my perspective is un-bridled and my biases serve as a powerful analytic tool in refining the data. This also distinguishes my method from many others in phenomenology, leveraging the personal viewpoint of the researcher as a 'bonus participant', informed interpreter, and also human participant in the data collection process.

## Findings

I conclude with a practical example of this method. I present the data from one of my participants: how the data was collected, analyzed, and interpreted. Within this process, I am emphasizing the incorporation and influences of the research design to make this more concrete of a demonstration for the reader.

### Collection of Data

Data for this project was collected via three phases. All participants completed the full phase sequence prior to compensation, and all participating individuals chose to complete the sequence. This consisted of a pre-interview priming question, asking them to define in their own words the phenomenon of consideration. They were asked to "describe in your own words what you consider it means to "Learn Engineering." Participants were required to send this to me 12 hours before the interview, though 24 hours was requested. Participants were also informed in advance of an activity they would be requested to engage within during the interview, where they would describe how they planned to teach a specific population some specific topic. They got to choose the topic, population, area of focus, and were informed I would ask about their personal understanding of the topic, whether the learners were voluntary or mandated, and the level of the learner. All these follow-up questions were only used if the participant did not cover the information during their description of the context, importance, and teaching of the topic. I leveraged this because many of the PSF I work with are in the middle of a developmental phase within graduate school, and have had limited pedagogical opportunities by and large. These inquiries to teaching methods allowed me to triangulate their own views of learning with the (mis)aligned actions they would use to facilitate the learning of others.

These interviews were in-person or virtual, at the participant's discretion. During the interview, I planned to ask only 5 questions. The first was a request to orally repeat to me their definition of the phenomenon, what it means to 'learn engineering'. The second question was the aforementioned activity describing in detail how they would educate future students about some topic. The remaining three questions were dedicated and targeted follow-ups based on the pre-interview definition I had received, and thus varied widely for each participant. However, knowing my population and their widely ranging level of self-reflection or awareness of epistemological elements, I also developed a bank of 'likely to be effective guided reflection questions' to fall back upon should the open-interview process stall. These questions were developed from literature around semi-structured interviews in engineering, reflections by Pre-Service Teachers, and the common areas of focus for engineering or STEM centric pedagogical professional development.

That is, I had the 5 planned questions, and a desired goal to ask those five and then spend the remainder of the interview using emergent inquiry and my researcher instincts to develop lines of questioning toward emergent phrases. I did have a bank of questions should this process stall which were developed to target elements of epistemology, pedagogical knowledge, and scaffold the reflective insights I was seeking, which might be occurring in real-time with the participant. For at least three of my participants, this interview was the first time they had considered several of the questions, such as 'how do you know you've learned something' or 'how do you feel when you're learning' so the answers were often more raw than expected for a graduate student population.

After the interview, at least 24 hours later, I sent them a post-interview task. I asked them to detail a narrative of a time they distinctly recall experiencing the phenomenon, complete with emotions, reflective insights, and how they knew the phenomenon was occurring. I provided them an example narrative, of my own experience with the phenomenon of 'baking a pie' to give scaffolds as to the type of language, description, intentional reflection I was seeking, yet not pre-dispose them in any way for their own narrative.

I leveraged these three pieces of data as a mechanism for triangulating my analysis. Each participant thus contributed a pre-interview description, an interview with an educational activity, and a post-interview narrative to the data corpus.

## Analysis of an Interview

Within this analysis process, I chose to align to Giorgi's process for descriptive phenomenology, as it was the most detailed and rigorous method I identified. Further, given the method's development within analytic psychology, this method balances the well-structured nature of STEM with the intuitive and adaptive methods inherent to qualitative research, and especially within phenomenology.

Giorgi's method follows general protocols of phenomenology and is presented below.

A. Listen to each interview repeatedly.

B. Identify key elements or codes within the interview.

C. Only use the participant's words to define those codes.

D. Determine the organizations of those codes, or themes for the interview.

E. Organize the themes within a hierarchy for the phenomenon

F. Repeat this process for every interview, independent of other interviews.

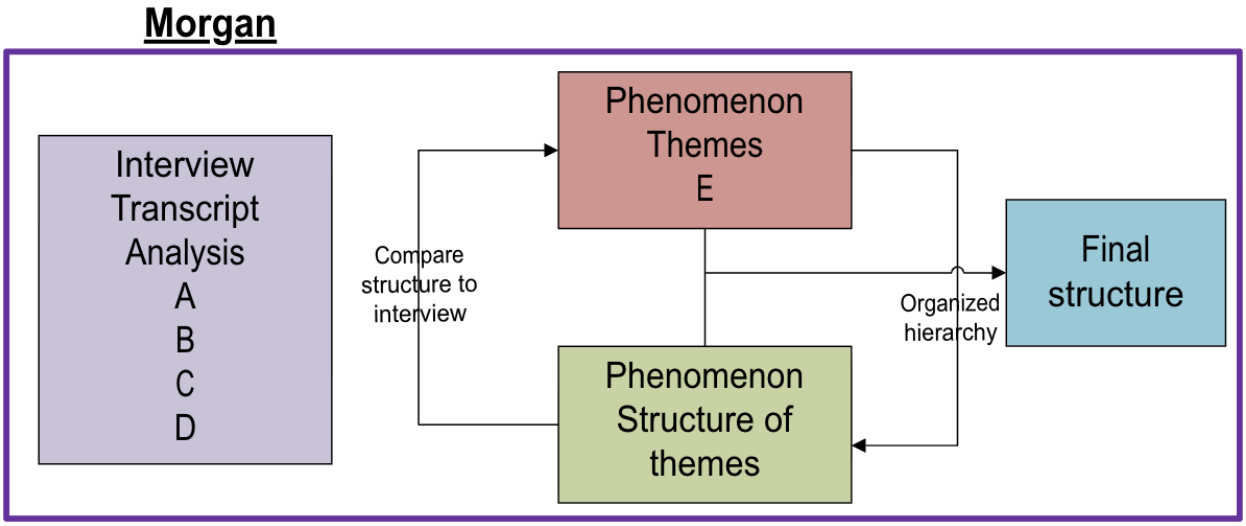
G. Look across all the interviews for consistent themes and hierarchical relations.

H. Determine which of those themes and relations are most important and essential to the phenomenon.

I. Develop the composite phenomenon via those essential themes and relationships. This should take the form of a hierarchy of themes.

Figure 1 below is a visual of this process for an individual participant. This analysis was conducted for each participant individually, then comparing those individual phenomenon structures to develop a composite hierarchy of consistent themes for the entire population.

Figure 1: Data Analysis for an individual participant (Morgan)




Analysis of Elizabeth Johnson's Interview

Elizabeth Johnson is a second year Biomedical Engineering PhD student who uses she/her pronouns, and identifies as caucasian. She has a previous bachelors degree in Biomedical Engineering from a domestic US university. I chose her to present her data because Elizabeht Johsnon was among the most reflective of my participants. I began by analyzing her pre-interview description; unlike many of my participants, her answer to the question 'What does it mean to be *Learning Engineering*?' was almost a page in length. This allowed me some very interesting follow up questions about that description, such as 'you can't manipulate a system until you define it, and this requires creativity. What step of defining? Why does it require creativity?' which prompted an entire 3 minute discussion about creativity as a component of learning engineering.

In my analysis, I leveraged a modified epistemological beliefs framework to guide my findings. This framework was composed from elements of epistemological beliefs [37], [38], [39], [40] as well as epistemic cognition [41], [42]. For more details on the composition of this framework, see previous work [43].

I analyzed Elizabeth Johnson's pre-interview task, her description of 'Learning Engineering,' and then the major elements from that became the list of expected codes for her interview transcript. I also looked in the interview transcript for moments of elaboration and statements she had made about important components of the learning process. Further, I referenced my notes from the interview itself to note when she had become more animated or exhibited non-verbal cues that an idea was important, as the interviews were only audio recorded. Once I had her final list of codes, I took them to her post-interview narrative where she was asked to provide 'a narrative, detailed description of a time you distinctly recall experiencing the phenomenon '*Learning Engineering'* in your life.' I used this list of codes to see which were present in the narrative, as well as any components of the narrative which were not captured by my existing list of codes. Any codes which were not in the narrative were more tentative, and any significant elements of the narrative which had not been coded were re-examined to see if there was part of the interview which aligned to them and had been missed.

After all that, I took my list of codes and sorted them into my worksheet, to elaborate her epistemological beliefs about the phenomenon of 'Learning Engineering.' This worksheet explicitly organized findings in terms of participants beliefs about:

1. Epistemic aims in learning
2. Epistemic values from learning
3. Certainty of knowledge
4. Structure of knowledge
5. Source of knowledge
6. Justification for knowledge
7. Process(es) for learning
8. Variance in process(es) for learning

Elizabeth Johnson (EJ)'s understanding of 'Learning Engineering'

EJ has a very detailed, nuanced, and sophisticated view of learning. She views failed experiments with excitement and the joy of discovery. She considers the distinction between engineering and science in detail and descriptive terms, as her field of research perches between the two.

EJ displayed a clear belief about the importance of the "joy and discovery of learning" alongside a need to connect to material to make a personal understanding. She also asserted that engineering learning must have an application, but that an engineer has to use their knowledge,

skills, and judgement effectively, which is part of learning engineering. Interestingly, she asserted that engineering and hobby are not learned similarly; singing is embodied and instinctual, engineering is intellectual.

EJ also believes that engineering learning requires the development of judgement, that engineering is a "systems approach and a mindset" and that to learn engineering requires a "direct connection to the application of the concept" which is a running theme.

EJ's core aim in learning is to "build judgement and expand" and "learn enough" so she is able "to manipulate systems to a desired outcome, leveraging baseline knowledge, for an application." That is, her main goals, along with "doing good," are to be able to build models which solve some issue, apply her knowledge for an outcome, and create something, since "scientists discover or create, while engineers apply discoveries to solve problems." EJ seeks to use her judgement and learn more, so she can craft better systems. Her view is that engineers create, and they should do good with that power. Interestingly, she makes the claim that "engineers can be scientists," but the reverse is harder.

She derives value for these aims from the ability to "peek behind the curtain" as "math is beautiful" and if you go deep enough, everything is "just mathematics." Similarly, engineering "is making something with knowledge" as engineers are always asking "what is the point of me if I'm just enacting someone else's work?" This is particularly true for graduate students, who EJ asserts should have "their own beliefs, judgement of good enough, and ideas on how to proceed." Thus, EJ seeks to increase her knowledge, increase her personal ability, and desires to have good expert judgement so she can be trusted as a knowledgeable engineer.
The value for her is 2-fold. Firstly, knowledge for its own sake, the insatiable curiosity. Secondly, to affirm and build on personal judgement for future usage in problem solving and doing good. These are both very nuanced epistemological beliefs, learning for its own sake alongside an ethical responsibility.

EJ displayed a belief that knowledge is highly uncertain and always shifting. She notes that "some things have a physical truth" or reality that we can see/compare against" (e.g. biology/physiology exists). We're (humans) always learning but we COULD fully define things that exist, such as biology or nature/plants, but we might not know enough yet. "You have to learn enough for your topic or context" and you have to "use the best knowledge of the time" to handle whatever research or learning or topic. "relationships between knowledge drive your understanding" of things and how realistic your simulation is. EJ notes that you use "scientific theories" and then "learn as much as those theories can teach you." Thus she believes in an objective truth, due to working in a physical reality, but our understanding of that truth is always evolving.

EJ also displays a clear and nuanced constructivist view of the structure of knowledge. EJ asserted this early on, her first statement of data was that "the more I tried to narrow in on engineering, the more it broadened out" as she discovered the epistemological difficulty of the nature of engineering.
EJ believes that "as you focus in on a definition of engineering, it broadens." She also asserts that "it's like a puzzle that clicks" when you cement learning of something. Knowledge helps you "make and manipulate a system" through the use of its internal characteristics or components. "Engineering requires creating" unlike science. Further, when "designing a model

you have to use trial and theories" to leverage your own learning but depart from the established models. EJ notes that most topics are related, and engineering is all about defining a system that becomes your puzzle to solve via topics, tricks, and specific techniques you have learned. She has sets of tools and tricks to manipulate models to try and replicate reality, but most topics are interconnected. This is a very cognitivist view which requires one to choose the most appropriate tool for each problem. EJ also notes that the objective of the project determines that problem.

EJ believes that the applications of knowledge give it context, that where you learn things "depends on your field" as you need "interpretations of theories" but that some portion of the source is self, as "you get to decide the system." Often engineers are modeling a physical system, "and can't describe it fully so we do all that we can now." Thus, the applications of knowledge give it context, the field in which the knowledge is centered gives it a baseline and then the specific knowledge is either gained from a source, but also partially figured or transferred to specific system. That is, knowledge source depends on the field- some is learned, some is discovered, some is interpreted for your context, and some is sought out from reliable sources. However, this element wasn't fully present. The portions of it show a nuanced understanding of the complex nature of knowledge and composing full understanding from a variety of sources. Notably, very few of those sources are authority figures. She frequently asserts that she is an equal participant in research and needs to be able to "tell my advisor when they're wrong about something I know more about."

To EJ, the belief in the justification for her knowledge is the "validity of the model, in context" by which the realistic nature of what is being tried to model gives validity. "Systems are puzzles that click" and "failure is a chance to learn" so a person understands when the model aligns with the object of replication. If the model is accurate enough, it is good. You as the engineer decide what is good enough and trust your personal judgement. If you fail, your job is to figure out how, why, and where, and improve the next approach. This is a highly nuanced view, justifications based on alignment with measured systems and quantities, but under personal judgement of close enough and which metrics to use. This belief is highly sophisticated and nuanced, and displays a high level of epistemological clarity.

EJ also had a clear belief about her own learning process that "I think I learn best when I have the chance to explore it myself" which EJ means she can "sit down, map out the concept" and then "backwards figure from the goal to the process I want to use to achieve that goal" through the usage of "visuals and descriptions." This is her personal process for learning, using some strategies to learn elements of some topic or process, and then using a visualization process to finalize her grasp, all the while keeping in mind WHY she is learning something. I would code this as 'backwards designed learning' given that she focuses on the application and context, then connects to the material or concept. An unexpected area of tension emerged when EJ considered how others might learn. EJ views that "you have to explore to learn" and that one must "focus on the core topics." She notes that "other people can learn in many different ways" but that always you have to ask yourself "what is my success criteria?" By this she means that there are many ways to learn, as the person defines what learning is for them. As EJ takes a backwards design approach to her own learning, she presumes others do as well, and thus assumes that their format, model, and approach will inherently vary. Her assumption that everyone follows the same backwards design learning approach means she assumes they learn identically to her,

because she learns differently every time. This was at odds with her views of engineering vs science.

## Implications

The goal of this work is to present a narrative, detailed example of how to do one of the most difficult tasks of the proposal stage of graduate school journeys: developing and tailoring a research paradigm. I hope this can allow other students to have an easier time crafting their own methodological approaches, and also present my approach as an available tool to be leveraged.

## Conclusions and Future Work

This work is the second portion of my dissertation work, so the final analysis is ongoing. I have combined all the participant details, refined the resulting model, and am in the final stages of publishing a more detailed manuscript of this work. Regardless, Elizabeth Johnson was one of the most reflective, engaging, and intentional participants. Many times in the interview we could both see she was thinking through a question, arriving at her actual answer after 2-3 minutes of talking around the idea she was pondering.

This work also shows the difficult, lengthy, and intensive process of data analysis. Even with a specific worksheet, a defined theoretical framework, and a comprehensive analytic method, I still had to perform over 6 rounds of specific data analysis for the above description. That is to say, qualitative research is intensive, but highly rewarding, and developing your own method to do this research even more so. I hope this work has been enlightening to at least one reader, easing their process of developing their own study design.

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