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Thinking as Argument: A Theoretical Framework for Studying how Faculty Arrive at Their Deeply-held Beliefs About Inequity in Engineering

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Abstract

When it comes to engaging with complex, social problems, it is important to be aware of not only what one believes, but also why one believes it. Plus, focusing on beliefs about the *cause* of a social phenomenon (e.g., what one believes causes inequitable participation of women in engineering) rather than just beliefs about the phenomena itself (e.g., what one believes about the extent to which gender inequity exists in engineering) is an important contribution to broadening participation because one's causal beliefs relate to their ideas about what needs to happen to make engineering more equitable. In this paper, we describe our use of Thinking as Argument (TaA) as a promising theoretical framework for exploring how engineering educators arrive at their beliefs about the cause of gender-based inequity in engineering. According to TaA, the type of robust argument that is desirable for one to commit to their beliefs about the cause of complex social phenomena includes five distinct components: causal theory, evidence, counterargument, counterevidence, and rebuttal. By conducting interviews about gender-based inequity using TaA, we can explore 1) the ways in which individuals articulate their causal beliefs as arguments of varying sophistication, and 2) the ways in which individuals use evidence to commit to their beliefs. In this contribution, we: describe TaA as a framework, document how we used TaA in a pilot study to inform our ongoing research on engineering faculty's causal beliefs, and provide initial evidence for TaA theory as a novel methodological contribution for studying beliefs related to equity in engineering. Specifically, our use of TaA revealed that while each participant offered a belief in a system-level cause of gender-based minoritization, there was considerable variation in the ways in which they used evidence to arrive at their beliefs and in their epistemological orientation toward gender-based inequities in engineering. We believe there is value in the use of TaA to study beliefs because ultimately, when we increase our explicit awareness of our commitment to our causal beliefs, we are better able to behave in ways that align with our beliefs and to develop agency to disrupt oppression.

1. Introduction

Broadening participation is needed in engineering. This includes a responsibility to equitably prepare a globally competent and diverse workforce, starting with students representing all social groups. Despite many engineering faculty's professed desire to behave in inclusive ways, the status quo for participation in engineering remains male and white. As part of broader efforts to make engineering more diverse and inclusive, our research team is focused on surfacing the deeply-held beliefs of engineering educators with majority gender- and race-based identities (e.g., white men, white women, and non-white men). Specifically, we are focused on contributing by developing ways to enable engineering educators with majority identities and in powerful positions to become aware of and reflect on their beliefs about the causes of gender- and race-based inequities in engineering. We see promise in using Thinking as Argument (TaA) [1] as a theoretical framework to inform our method of studying beliefs in a novel and productive way. TaA shifts the focus from trying to capture the content of one's beliefs about reality (e.g., to what extent do you believe there are gender-based inequities in engineering education?) to

revealing the ways in which one thinks about and uses evidence to commit to their beliefs about the *cause* of social phenomena (e.g., what causes gender-based inequities in engineering and how do you know?). This contribution provides a detailed overview of TaA theory, a description of how we translated TaA to our research context of studying the beliefs of engineering faculty with majority gender- or race-based identities, and initial evidence of the promising outcomes of using it in a pilot study with three engineering faculty (one white male, one non-white male, and one white female). Ultimately, we conclude that our findings demonstrate how TaA can be used to reach beyond the surface of what engineering faculty believe and uncover the variation in the ways they use evidence as well as their epistemological orientation toward gender inequity.

2. Background

Beliefs are an important research construct. The beliefs that we hold at an individual level serve as the foundation for how we understand our experiences, and they provide us with our explanations for how the world works [1]–[6]. Beliefs also play an important role in culture and social systems by serving as group norms and values, which are transmitted socially [2], [4]–[6]. Within the context of engineering education, significant work has been done by scholars to investigate what students believe about themselves (i.e., identity) [7]–[10], their own capabilities [11]–[16], engineering problem solving [17], engineering design decisions [18], [19], the nature of knowledge [20]–[22] and intelligence [23]–[26], and engineering more broadly [27], [28]. While the methods used in these studies vary, they tend to focus on the *content* of student beliefs in the context of engineering.

However, looking at the content of beliefs only scratches the surface; beliefs must be investigated with greater depth. Beliefs are difficult to operationalize and study because they are a complex research construct and because they are not necessarily coherent or internally consistent [2], [3], [6]. Plus, studying beliefs requires greater depth because while beliefs may be explicitly known and articulated, they also frequently operate outside of our conscious awareness [2], [6]. In fact, the beliefs that are held implicitly or subconsciously are dominant when it comes to complex, social phenomena such as inequity [3], [6]. Therefore, accessing deeply-held beliefs is an important piece of our collective efforts to broaden participation.

Specific to our interest in increasing equity in engineering, it is important to study engineering faculty's deeply-held beliefs about what causes inequity in engineering. We know that non-male and non-white individuals do not participate equitably in engineering [29], [30]; this reality is no longer debatable. Therefore, it makes sense to shift to exploring people's beliefs about *why* this reality persists, or the cause of inequity, which is far more complex and dynamic and relates directly to their ideas about what actions are needed to increase equity in engineering. For example, in the case of gender, if one believes that women do not stay in engineering because no one encourages them, they may try to offer extra encouragement to their own female students. On the other hand, if one believes that women do not stay in engineering because policies that govern student participation are sexist, they may work to change those policies. Additionally, looking at the ways in which engineering faculty use evidence to arrive at their beliefs is important because we know that belief formation does not require evidence or explicit reflection; instead, it is often based on personal experience and evolves over time [2], [5], [6]. This means that without awareness of how we commit to our beliefs, we are at risk of unintentionally relying

on our passive socialization to explain to ourselves why inequity remains the status quo in engineering. This potential reliance on our passive socialization is problematic because in the United States, we are socialized in a society that is fundamentally racist and sexist [31]. Therefore, we (especially those of us with majority identities) must do the work to recognize the ways in which our socialization informs what we believe about the causes of inequities in engineering and why we believe it. An explicit awareness of what we believe and why we believe it enables us to be reflexive, disrupt the problematic aspects of our socialization, and gain agency as change agents for equity in engineering.

In pursuit of a theoretical framework to study deeply-held beliefs about complex social phenomena in a novel and useful way, we discovered Kuhn's framework: TaA. We decided that this framework had great potential to study engineering faculty's deeply-held beliefs about inequity in engineering, especially with its focus on how people think and reason about the cause of common yet complex social phenomena. Therefore, in this paper we describe Kuhn's TaA theoretical framework, show how we translated it to our research context of studying the ways that engineering faculty commit to their beliefs about inequities in engineering, and present our initial evidence from a pilot study for how the use of TaA can lead to new and useful knowledge to support our broader goal of disrupting the inequitable status quo for participation in engineering.

3. Description of Kuhn's Theoretical Framework: Thinking as Argument (TaA)

Deanna Kuhn [1] proposed that rhetorical argument—informal reasoning conducted in one's own head—can be used to "examine people's mastery of argumentative reasoning skills." This allows individuals to reflect on their own thinking. If an individual is unable to reflect on their beliefs, they cannot justify them, nor can they control them. However, rhetorical argument typically ignores a significant piece of argumentation: the other side. As a result, Kuhn argues that proper rhetorical argument must borrow from dialogic argument, a style of argument between two or more people. In this proposed form of rhetorical argument, an individual is not only responsible for stating and defending their own position but also imagining and defending someone else's position. This process allows for more critical reflection of one's own commitment to a belief because it requires understanding and consideration of an alternative belief, to which one is not committed. Furthermore, constructing this form of rhetorical argument provides a window into how individuals use evidence to commit to their beliefs. This section provides a detailed overview of TaA theory.

To facilitate a rhetorical argument for research purposes, and based on Kuhn's own empirical research, she proposes the Thinking as Argument (TaA) theoretical framework, which consists of five distinct components: causal theory, evidence, counterargument, counterevidence, and rebuttal. An interview protocol informed by TaA starts with a question regarding the cause of a complex, social phenomenon. For example, Kuhn used TaA to investigate the public's beliefs about the causes of the following:

- Prisoners returning to crime after being released
- Students failing out of school
- Unemployment

Kuhn asked her participants to discuss their thoughts on the cause of these phenomena with the goal of unpacking not just the content of their beliefs, but really the thinking process (i.e., use of different forms of evidence) behind their commitment to their belief. For instance, if a participant were asked "what causes prisoners to return to crime after they are released?", they might argue that a lack of education would result in the inability to get a job, which necessitates a return to crime.

The participant would then be prompted to generate some evidence to support their causal theory. According to Kuhn, there are three main categories of evidence: genuine evidence, pseudoevidence, and nonevidence. While Kuhn goes to great lengths to explain these terms, we have chosen to relabel the terms for the purpose of our work as direct evidence, indirect evidence, and nonevidence, respectively, for clarity. Specifically, we relabeled them to focus more on the ways in which the evidence is *used*, which is foundational to the theory. Also, we believe this adjustment in language is needed given the abundance of researchers who have called out the ways in which particular ways of knowing are unjustly privileged in engineering spaces [32], [33]. As a result, Table 1 lists all three categories using Kuhn's terminology alongside our modified terminology.

Kuhn called the first type of evidence "genuine evidence" (see 1 in Table 1). By genuine, she was not focused on the type of evidence provided, but rather the way in which the evidence was used within the argument. Genuine evidence is defined as evidence that shows a *direct* connection—either qualified or quantified—between the participant's causal theory (e.g., a lack of education) and the social phenomenon (e.g., a return to crime). An example of genuine evidence for the lack of education causal theory would be to look at the education level of prisoners. The goal would be to demonstrate a causal relationship between education level and a return to crime.

According to Kuhn, genuine evidence is rare in interviews. It is more common for participants to generate what she referred to as "pseudoevidence" (see 2 in Table 1), which demonstrates an *indirect* connection between the causal theory (e.g., a lack of education) and the phenomenon (e.g., a return to crime). Or as Kuhn [1] would describe it, "evidence by illustration." In other words, rather than describing how the causal theory and piece of evidence are connected, the participant would describe an instance of how the causal theory might occur. In the returning to crime example, a participant might use the example of one of their friends who dropped out of school and has been in and out of jail ever since as evidence to support their causal theory that it is the lack of education that causes people to return to crime after being released from incarceration.

There is one final category to classify evidence in the TaA framework: nonevidence (see 3 in Table 1). Through nonevidence, participants may argue that evidence is unnecessary, provide evidence that is unconnected to their causal theory, or provide the effect itself as evidence of the cause. For the lack of education causal theory, the participant might argue that returning to crime is evidence of a lack of education (i.e., the social phenomenon itself is restated as evidence).

Table 1: Evidence Classification in TaA Theory

Original TaA Evidence Type	**Modified TaA Evidence Type**	**Definition**	**Example Subcategories**
(1) Genuine Evidence	(1) Direct Evidence	Any evidence that demonstrates a direct connection between the causal theory and the social phenomenon (e.g., unemployment)	• Correspondence • Covariation • Correlated Change • External Evidence • Analogy • Assumption • Discounting • Partial Discounting
(2) Pseudoevidence	(2) Indirect Evidence	Any evidence that demonstrates an indirect connection between the causal theory and the social phenomenon	• Generalized Scripts • Specific Instances • Illustrations
(3) Nonevidence	(3) Nonevidence	Any evidence that does not fit the other two categories	• Evidence as Unnecessary • Unconnected Evidence • Effect as Evidence

Once participants have generated evidence or exhausted the prompts for describing evidence for their causal theory, participants are then asked to imagine an alternative theory—one of disagreement with their own causal belief. To kick off this discussion, participants are first asked to falsify their own position. In other words, can they generate a counterargument for their causal theory? In the process of creating a counterargument, participants may generate an alternative theory. Given our example of prisoners returning to crime, an alternative theory might be that the criminal justice system fails to provide a deterrent to crime. However, an alternative theory on its own is not a counterargument, so participants are asked to provide evidence that falsifies their own causal theory. For example, a participant might back up their alternative theory by providing indirect evidence: "I know someone who would prefer to be in jail than out on the streets." However, this would not necessarily falsify the original causal theory that people return to crime due to a lack of education. Regardless of their ability to generate a counterargument, participants will be asked to generate an alternative theory, if one is not already generated. If one cannot be generated, one is provided by the interviewer. Finally, the participant is asked to provide a rebuttal to the counterargument, or more simply, they are asked to recommit to their causal theory by saying how they can show that the alternative belief is incorrect.

Throughout the entire interview process up to this point, participants are responsible for generating their own argument. In other words, nothing is provided for them unless it is necessary to further the interview. This section of the interview is what is used to understand the

participants' ability to reason through different possible causes for a complex social phenomenon and how they use evidence to commit to their own causal belief. Following the argumentation portion of the interview, participants are provided with cases that contain two types of evidence, underdetermined and overdetermined, which they are expected to evaluate. In underdetermined evidence, the participant is provided with an example of someone who experienced the social phenomenon in question (e.g., return to crime). This example is crafted in such a way that no explicit causes of the phenomenon are listed. The purpose is to see if the participant recognizes the case as lacking direct evidence about the cause of the social phenomenon. Failure to do so is typically demonstrated through projection of the participant's own causal theory. The case that contains overdetermined evidence is the opposite. Rather than providing no evidence, overdetermined evidence provides several correlations that could be causes for the social phenomenon. However, no causal information is provided. Therefore, the purpose is to see if the participant recognizes the uncertainty of the cause of the phenomenon given the evidence. In this section of the interview framed by TaA, participants are likely to demonstrate some level of certainty in a portion of the evidence that most closely aligns with their own causal theory.

4. Translating Thinking as Argument to our Study of Beliefs about Inequity in Engineering

TaA was originally developed using several social phenomena that could be discussed without a lot of technical knowledge. In other words, these phenomena are everyday parts of reality and therefore regardless of expertise, lived experience, or positionality, people are likely to hold beliefs about how it works and why it occurs and feel able to talk about the topics. We see a parallel with issues of gender- and race-based inequities in engineering. Regardless of our training or expertise, discussions around diversity are a part of our professional spaces, to some degree, and we have all been socialized in ways that embed foundational beliefs about how race and gender matter (or not) in society. Therefore, translating TaA to the context of engineering education is appropriate given the likelihood that engineering educators, regardless of their expertise, have ideas about the cause of gender- and race-based minoritization in engineering. Our resulting interview protocol based on TaA is provided in full in Appendix A. Several considerations were made in the process of this translation.

In terms of topic focus, we decided to adapt TaA for gender-based minoritization first. However, given the system-level connotation of minoritization, we did not want to use language that could suggest the nature of the cause when engaging with our participants. As a result, we chose to use the language of gender-based "inequities" rather than "minoritization" (the term used in the title of the overarching research project).

In terms of question design, we largely borrowed from TaA directly. For example, many of the argumentation questions fell from TaA (questions 2-11) with the addition of a brief introduction question (question 1). Meanwhile, the instrumental reasoning section was modified to include questions that scoped down from ways to address gender inequity broadly down to ways the participant could address gender inequity directly (questions 12-14). In the following question (question 15), we added an opportunity for the participant to explore topics not previously discussed. Then, we completed the instrumental reasoning section by asking participants to describe their role in resolving gender inequity through an analogy (question 16). Meanwhile, in

the evaluation of evidence section, we constructed our own cases that targeted issues related to gender-based inequities in engineering (questions 17-18). To conclude the interview, we ask participants to summarize their impression of what has been discussed as well as any insights or ideas they may have (question 20). Due to the overall length of the interview, we excluded the explicit questions around epistemological reasoning in TaA, as these questions were not the focus of our study.

While most of the interview protocol falls directly from TaA, there was one line of questioning that we added (question 19). It asks the participant to think about someone (real or fictional) who represents their "hero" or "ideal" engineering faculty, staff, or administrator when it comes to promoting gender equity. We added this section in addition to the portions of the interview based on TaA because a cultural hero is defined as a symbol of the ideal of a people or group [34], and we decided this would provide insight into what our participants believe is needed to advance gender equity in engineering, rounding out the picture of not only what they believe the cause to be and why they believe it, but also how they think about what can or should be done to advance equity. We believe this question is telling in an important way because in literature, heroes are considered a reflection of culture and a window into the values that are admired or emulated within a cultural group [35]. Researchers in medical education have concluded that role models are a key part of a professional's identity and socialization [36]. In the next section, we present our initial evidence for how these interviews using TaA show promise as a way to study beliefs about equity in engineering based on three pilot interviews and our preliminary data analysis.

5. Methods: Pilot Interviews

To understand how our interview protocol designed based on TaA would work with our target of engineering faculty, staff, or administrators, we conducted three pilot interviews. Our pilot participants were recruited and selected by members of our research team based on our own view that they represent exemplars when it comes to being inclusive engineering educators. We also chose one pilot participant to represent each of the three intersectional demographic groups (race and gender) of the larger study: white male, white female, and non-white male. Interviewer and interviewee were paired based on their racial and gender identities (i.e., white female researcher interviewed the white female participant, white male researcher interviewed the white male participant, and non-white male researcher interviewed the non-white male participant). This pairing was done intentionally based on prior evidence that matching social identities of the interviewer and interviewee can lead to more authentic data [37], which we see as especially important given our inquiry around topics that are highly politicized, built on deeply-held beliefs, and potentially communicated via some level of shared understanding withing a given group. The interviews lasted around two hours and were conducted using the Zoom video-conferencing application. Following the interviews, participants were asked for their pseudonyms. For participants who did not provide a pseudonym, they were assigned one by the first author.

The data analysis process started with the authors reviewing the raw transcripts generated by Zoom. Each author read and/or listened to each pilot interview and coded each transcript based on the framework of TaA. Specifically, each author was tasked with individually identifying each participant's causal belief, evidence, counterargument, counterevidence, and rebuttal. We also independently classified each piece of evidence used in the interviews as direct, indirect, or

nonevidence (using Table 1). The results of our independent coding were organized into tables, collectively discussed to resolve inconsistencies, and finalized. One member of the research team also generated Table 3 using Kuhn's [1] description of epistemological reasoning. This table was then used to classify each participant's epistemological orientation, which was determined by a single member of the research team and the results were reviewed by the other two authors and discussed until consensus was met.

6. Findings: Initial Evidence for TaA as Novel Contribution for Studying Beliefs Related to Equity in Engineering

What we found most promising was that while all three participants offered similar systems-level causal theories for gender-based inequities in engineering, our use of TaA revealed considerable variation in 1) how they described using evidence to arrive at their causal belief, and 2) their epistemological orientations. In the following subsections, we detail both findings from our initial evidence using quotes that were modified for readability.

6.1. Variation in How Participants Used Evidence to Arrive at their Causal Beliefs

We found that this protocol does an excellent job of illustrating how people arrive at their beliefs about the cause of gender-based inequities in engineering, extending extant work in the space of beliefs and equity in engineering. To demonstrate this, we show next the results of our preliminary analysis to show how each participant described arriving at their beliefs. Participants are presented in order of the cumulative strength of their evidence from weakest to strongest, based on Kuhn's definition of a robust rhetorical argument, where strength is determined by the dominant type of evidence used in the interview as a whole. A summary of these results can be seen in Table 2.

Table 2: Summary of Evidence Classification by Participant

Participant	**Race**	**Gender**	**Causal Theory**	**Evidence**	**Evidence Classification**
Trent	Black	Male	Historical Systemic Bias	(1) Existing Research (2) Observations (3) Personal Experience	(1) Nonevidence (2) Nonevidence (3) Direct
Flynn	White	Male	Momentum of the Dominant Group (Men)	(1) Example Narrative (2) Classroom Poll (3) Personal Experience (4) Intuitive Argument	(1) Direct (2) Direct (3) Nonevidence (4) Nonevidence

Ellen	White	Female	Cultural & Structural Messaging	(1) Existing Research (2) Observations (3) Personal Experience (4) Personal Experience	(1) Direct (2) Direct (3) Direct (4) Indirect

6.1.1. Trent

Our first participant, Trent, is a Black male engineering faculty member. In the interview, he argued that the cause of gender-based inequities in engineering was "historical systemic bias" in terms of "attitudes, traditions, and processes." Trent provided a mix of direct evidence and nonevidence to support his causal theory; nonevidence was what he used most in the interview. Of the participants, Trent provided the weakest mix of evidence because the evidence he offered was mostly not directly connected to his causal theory.

In terms of nonevidence, Trent provided two examples. First, Trent pointed to existing research to back up his causal theory (see 1 in Table 2):

> "...you need to convince people that there's systemic bias along the entire length of the engineering pipeline. I'm probably going to go get data."

It is unclear exactly what research Trent was referencing here. When pushed to provide more detail, Trent referenced concepts like persistence and retention which are associated with the social phenomenon itself, not his causal theory. As a result, we classified it as nonevidence.

Also, Trent leaned into classroom observations as evidence (see 2 in Table 2):

> "I guess if I wanted to be dramatic about it, I could send you a picture of my classroom."

Here, it is unclear from Trent's transcript how observing the phenomenon of gender inequity in the classroom relates to his causal theory of historical systemic bias. Instead, it appears to provide evidence of the phenomenon. In other words, Trent used the fact that gender inequity shows up as fewer females in engineering classrooms as evidence of his causal theory. Therefore, we also categorized this use of observations as nonevidence.

In terms of direct evidence, Trent provided one example. Specifically, he used his own personal experience as being a person of color as an analogy to what women might experience in engineering (see 3 in Table 2):

> "You know, leveraging lived experience, if I sit here long enough, I can identify points of discrimination inequity. Looking for another word...bias...ironically, effectively along each point of my professional journey."

Because Trent used his personal experience to draw an analogy between the experiences of women and people of color, we categorized this piece of evidence as direct evidence.

6.1.2. Flynn

Our second participant, Flynn, is a white male engineering faculty member. In the interview, he claimed that the cause of gender-based inequities in engineering was the "momentum of the dominant group"—in this case, men. When asked to justify this claim, Flynn provided a mix of direct evidence and nonevidence. Of the participants, Flynn fit somewhere in the middle in terms of strength of evidence.

In terms of direct evidence, Flynn provided two examples. First, Flynn illustrated how the momentum of the dominant group could occur through an example narrative (see 1 in Table 2):

> "And so, when I think about that dominant momentum thing, I try to picture somebody who grew up in a family who didn't have [a mother and older sister with advanced degrees in STEM], right? And if it's way more common that you have a father who's an engineer and way less common to have a mother that's an engineer, I do think that starts to shape how we envision ourselves and the people we look up to."

Flynn used this narrative to show that gender inequity is a function of who the engineer is in the family. If men are usually the engineers, then it follows that men will continue to dominate engineering. Therefore, there is a direct link between the evidence he is articulating and the causal theory he offered; he did not just offer the evidence as an example of how the causal theory might occur (i.e., indirect evidence), but instead as a correspondence between the phenomenon and the causal theory (i.e., direct evidence).

Flynn also referenced a poll that he administers in his courses (see 2 in Table 2):

> "I can also point to the fact that when I poll my classes about why they decided to be in the first-year engineering course, why they decided to be engineering majors, one of the most common responses is because that's what my 'blank' does...my father, my mother, whatever."

Flynn's poll story is another example of what is classified as direct evidence within TaA. Specifically, he showed the connection between male dominance and gender inequity by reinforcing the previous idea that family plays a role in students' choices to participate in engineering. However, the connection is not as explicit as in the example narrative.

In terms of nonevidence, Flynn provided two examples. First, he drew on his relationship with his mother and sister who stand in stark contrast with reality (see 3 in Table 2):

> "One of the things that comes into my mind is that I grew up in a household where my mom had a PhD. She was a professor. […] And so, the momentum thing is one of the things that I point to because, I think there were points in my life [his own higher education in STEM] where I was baffled by the fact that I wasn't seeing more women."

We classified Flynn's relationship with his family as nonevidence because he cites the phenomenon (i.e., gender inequity in engineering) as evidence for his causal theory (i.e., the moment of the dominant group). His experience demonstrated that gender inequity is unjust, but it was unclear how he connected that experience directly to his causal theory for the social phenomenon.

Also, Flynn closed out his argument by stating that he believes there really is no evidence needed to back up his causal theory (see 4 in Table 2):

> "So, I just think there's like an intuitive argument there that doesn't need evidence."

Much like Flynn's personal experience, this is another example of nonevidence—this time conveyed a bit more explicitly by the participant.

6.1.3. Ellen

Our last participant, Ellen, is a white female engineering education faculty member. In the interview, she argued that the cause of the gender-based inequities in engineering was "cultural and structural messaging." When asked to justify this claim, Ellen provided mostly direct evidence with one piece of indirect evidence. Of the participants, Ellen provided the strongest mix of evidence according to the theory of TaA.

In terms of direct evidence, Ellen provided three examples. First, she leaned into the research (see 1 in Table 2):

> "I have read quite a bit about these topics, both through my master's degree work."

Ellen's interview explicitly outlined the types of research that she refers to here and how it is connected to her causal theory. For example, she offered the name of a specific book that she read while earning her master's degree and articulated how the content of that book directly supports her own causal belief. She also mentioned how she has an on-going practice of reading current research related to gender-based inequities in STEM in order to identify current materials to share with students when she teaches her course. As a result, we classified her description of her extensive knowledge of the research related to gender-based inequity as direct evidence.

Second, Ellen leaned into her own observations (see 2 in Table 2) as evidence for her causal theory. For example, she argued that while she believed cultural messaging was the dominant cause, she was aware of instances where people had switched fields based on their own preferences and agency. Specifically, she stated the following:

> "We know that about 40% of those women will not persist and stay in engineering. And we know that part of that is due to the fact that sometimes they just get interested in other jobs. My good friend is now a project manager for [a large engineering company] instead of an electrical engineer because she was more interested in that work. But we also know part of that is due to the culture of engineering."

Here, Ellen demonstrated an understanding of the complexities of gender-based inequities by acknowledging that while women have agency to make decisions based on their interests, the cultural messaging still matters in their experience and decisions to leave engineering. She explained her belief that some women leave engineering due to a lack of interest while others are drawn away by the culture. Because this is a "partial discounting" [2, pp. 63-65] of an alternative theory, we classified it as direct evidence.

Third, Ellen further drove home the messaging argument by providing an anecdote about her daughter (see 4 in Table 2):

> "My daughter recently told me that her butt was fat. Which was really upsetting because, of course, I never talked about my body. I mean if we talk about bodies, we talked about...there's different shapes and sizes of bodies and they're all good. And there are others, you know, we want to move our bodies in a healthy way. But she got that message from somewhere."

While this appears to be an example of how cultural and structural messaging occurs, a subtle distinction arises through Ellen's use of "correlated change" [2, p. 50-54]. In other words, she described how her daughter could not have received those messages from her and therefore must have received them elsewhere. As a result, we classified this example as direct evidence because she links it to her causal theory directly.

In terms of indirect evidence, Ellen provided a single example. Specifically, Ellen referred to some of her personal experience as evidence (see 3 in Table 2):

> "I think that we all know anecdotally, or we've had conversations with people where we've seen this happen. And we've experienced this, we felt this, you know. I've been sexually harassed at work. You know, like these things happen to us. They happen to our colleagues, and when you see it matching what you've read in the research, it really makes it more real."

In this example, Ellen illustrated how her "cultural and structural messaging" causal theory might occur through a personal anecdote, but she does not directly show how this leads to gender inequity in engineering. As a result, we classified it as indirect evidence.

Generally, all three participants present diverse sets of evidence. However, we noticed that these participants vary in the *strength* of the evidence provided, as understood through the lens of TaA. While Flynn and Trent provided experiences that show a direct connection between their causal theory and the phenomenon, they both relied predominantly on evidence that they did not explicitly connect to their causal theories and arguments of intuition. Meanwhile, Ellen provided almost explicitly direct evidence. Therefore, we believe that by classifying the evidence that faculty describe using to arrive at their causal belief, we can uncover a new level of depth (and in this case, variation) than previous approaches to investigating beliefs and inequity in engineering. While each of our three participants offer a similar (structural-level) causal theory, the fact that only one participant was able to articulate how she arrived at that theory based on

evidence with direct links to her theory shows that by just asking faculty members about the content of their beliefs is incomplete and may include problematic assumptions when it comes to the faculty members' ability to be change agents. This supports our use of TaA to study beliefs and inequity in engineering.

6.2. Epistemological Reasoning

While pragmatic considerations around the length of the interview protocol drove us to exclude the explicit epistemological reasoning questions from Kuhn's TaA, we still believe that our current protocol provides enough data to broadly interpret participants' epistemological orientation when reasoning about the cause of gender-based inequities in engineering (i.e., what does it mean to *know* the cause of gender-based inequities in engineering?). In particular, we argue that epistemological orientation can be extracted through a participant's ability to generate a complete argument. For example, the inability to generate a counterargument to their causal theory would likely indicate, as Kuhn would categorize it, an absolutist position. Likewise, we believe further information can be obtained through any question that requires the participant to grapple with the concept of "proof." Kuhn [1, p. 172] provides some support for this observation by stating that "responses to the questions about proof that occur in the main body of the interview […] also shed some light on epistemological beliefs." However, Kuhn argues that their taxonomy for epistemological reasoning, as seen in Table 3, is also a function of the participants' trust in expertise, which we did not directly access in our interview protocol. As a result, our categorizations of participants' epistemological orientation when thinking about the cause of gender-based inequity in engineering can only be made indirectly through the behaviors that participants exhibit during the interview. Additionally, some behaviors (e.g., describes the phenomenon as having "too many factors") are associated with multiple epistemological orientations, which means that these orientations are not truly clear cut or bounded in the ways used to describe them theoretically. In the remainder of this section, we will present the epistemological orientations that we assigned to each participant with supporting evidence from our preliminary analysis. As with the evidence section, we will present participants in order of the epistemological orientation spectrum seen in Table *3*.

Table 3: Epistemological Orientations as adapted from Kuhn [1]

Epistemological Orientation	**Criteria**	**Related Behaviors**
Absolutist	(1) Accept that experts know, with certainty, the cause of gender-based inequity in engineering [1, pp. 173–174]	(1) Believes knowledge is certain and absolute [2, p. 174] (2) Appeals to facts and authorities [2, p. 174] (3) Remains rigid in beliefs; "unsusceptible to challenge" [2, p. 175] (4) Believes certainty is tied to personal commitment [2, p. 175] (5) Claims high certainty but acknowledges other viewpoints could be correct [2, p. 176]

		(6) Imposes viewpoint in attempt to persuade [2, p. 177]
Multiplist	**(**1) Deny the possibility that experts know, with certainty, the cause of gender-based inequity in engineering [2, p. 180] (2) Claim equivalent or greater certainty in the cause of gender-based inequity in engineering than experts [2, p. 180]	(1) Exhibits certainty in beliefs [2, p. 181] (2) Acknowledges subjectivity in beliefs [2, p. 181] (3) Denies the ability to prove anything [2, p. 181] (4) Ties beliefs to personal experience [2, p. 182] (5) Believes everyone is entitled to their opinion [2, p. 182] (6) Describes the phenomenon as having "too many factors" [2, p. 188]
Evaluative	(1) Deny the possibility that experts know, with certainty, the cause of gender-based inequity in engineering [2, p. 187] (2) Claim lesser certainty in the cause of gender-based inequity in engineering than experts [2, p. 187]	(1) Describes the phenomenon as having "too many factors" [2, p. 188] (2) Believes absolute certainty is impossible, so knowledge is based on judgment [2, p. 189] (3) Demonstrate an openness to modifying their beliefs [2, p. 190] (4) Uses argument as a method of convincing others [2, p. 191]

However, before we provide categorizations for each participant, we must note that categories like absolutism and multiplism should not be interpreted as our indictment of these faculty members. Indeed, there are different ways of knowing that are valuable despite being minimized within the "scientific" or post-positivistic orientation that undergirds engineering culture [32], [33]. We believe that the epistemological theories are context dependent and therefore cannot be assumed to map to our participants' epistemological orientations in other aspects of their lives or as experts in their profession. In fact, we would argue that faculty members almost certainly demonstrate an evaluative epistemology in their work where they have academic expertise.

6.2.1. Trent: Multiplism

We argue that our first participant, Trent, exhibited the strongest multiplistic orientation toward gender inequity. Specifically, he exhibited a mix of behaviors that suggest a multiplistic epistemology as seen in Table 4:

Table 4: Trent's Epistemological Behaviors

Behaviors	**Epistemology**
(1) Claims high certainty	Absolutism (5) or Multiplism (1)
(2) Ties beliefs to personal experience	Multiplism (4)
(3) Denies the ability to prove anything	Multiplism (3)

(4) Demonstrates an openness to modifying their beliefs	Evaluative (3)

In terms of multiplistic behaviors, Trent exhibited three. First, as shown in the evidence section, Trent claimed high certainty in his causal theory about historical systemic bias by leaning into the intuitive argument:

> "[Historical systemic bias] is just something that intuitively strikes me as the truth."

This degree of certainty without evidence of the fact is characteristic of the absolutist and multiplist epistemologies (see 1 in Table 4).

Second, Trent then relied heavily on personal experience to justify his causal theory (see 2 in Table 4):

> "I guess I could probably use myself as a data point, you know, because I can extend some of the things that I encountered. Yeah, even as an African American male, I would extend to other minorities within the space in entirely different ways, but perhaps no less detrimental."

When pressed to provide further evidence beyond personal experience, Trent provided vague references to "data":

> "And for others, I would go grab the most recent copy of the numbers and just show the disparity at all levels, you know. That data is there."

We believe this further solidifies Trent's position in the multiplist epistemology because, as Kuhn [1] would argue, he "inadequately distance[d]" himself from his own causal theory. Only when he was pressed to define "data" did he reference the phenomenon itself using terms like "persistence" and "retention".

Third, Trent denied the ability to prove anything by arguing that data can be used to advance any argument. Therefore, nothing can be proved (see 3 in Table 4).

> "You may not be able to prove the person wrong, right? Well, there's this data [that you provide me]. What do [I] do? Now, [I] got to go back and get more data or illustrate where there may be some bias in the data that you're giving me."

In fact, Trent argued several times that it is possible to cherry pick data to suit the needs of any causal theory. If the evaluative epistemological orientation bases knowledge on reasoned argument, this seems slightly less sophisticated. In other words, is there no way to differentiate good evidence from bad evidence? If not, Trent likely falls more into the multiplism category.

Despite Trent predominantly demonstrating multiplistic behaviors, he did exhibit at least one instance of behavior indicative of an evaluative epistemological orientation. When asked if there

was evidence that would prove his theory wrong, Trent demonstrated a willingness to have his mind changed (see 4 in Table 4):

> "Like, I'm sure, there could be [evidence to prove me wrong]. I would love for there to be."

However, Trent did little to demonstrate this willingness to change through examples of what this evidence would have to look like. As a result, we believe Trent more closely aligns with the multiplism orientation.

6.2.2. Flynn: Multiplism

We argue that our second participant, Flynn, fits somewhere in the middle of our three participants in terms of epistemological orientation. While overall we believe he aligns most closely with the multiplism epistemology, he did exhibit a mix of behaviors that position him closer to the evaluative orientation than the absolutist orientation as seen in Table 5.

Table 5: Flynn's Epistemological Behaviors

Behaviors	**Epistemology**
(1) Claims high certainty	Absolutism (5) or Multiplism (1)
(2) Describes the phenomenon as having "too many factors"	Multiplism (6) or Evaluative (1)
(3) Demonstrates an openness to modifying their beliefs	Evaluative (3)
(4) Uses argument as a method of convincing others	Evaluative (4)

In terms of multiplistic behaviors, Flynn demonstrated two. First, like Trent, Flynn claimed high certainty of his causal theory:

> "So, I just think there's an intuitive argument there that doesn't need evidence."

Again, displaying high levels of certainty are traits of both absolutism and multiplism (see 1 in Table 5).

Second, despite arguing how intuitive his causal theory was, Flynn was not eager to commit to that viewpoint, citing too many factors as the culprit (see 2 in Table 5):

> "It's so hard, right? There are so many things. I don't even know where to begin. I really don't."

Recognizing that a problem is multifaceted is a quintessential characteristic of progression into the multiplist and evaluative epistemologies.

In terms of evaluative behaviors, Flynn demonstrated two as well. First, Flynn seems to have no problem reconciling diverging viewpoints. For example, Flynn mentioned that there are possible alternative theories such as explicit bias (e.g., choosing men over women in hiring instructors) or

natural causes (e.g., men and women are fundamentally different). Rather than doubling down on his position, Flynn quickly integrated these ideas into his own causal theory:

> "I think, honestly, if I was having that conversation, I would agree with them. I wouldn't push back because I do believe that [explicit bias] is an important piece of it."

This type of argument seems to suggest more of an evaluative (see 3 in Table 5*)* position as it demonstrates an openness to change of belief. In other words, Flynn amended his position by arguing that these alternative theories are not necessarily wrong but are small factors in a greater whole—or potentially even artifacts of the causal theory itself.

Flynn successfully reconciled multiple viewpoints by conceding that men and women may be biologically different, but that does not mean that women cannot be engineers. In fact, Flynn argued that the skills women demonstrate as children (e.g., attention to detail and teamwork) might be more valuable in engineering:

> "I might say, 'so what?' My niece likes to put shoes on her Playmobil. That doesn't mean she can't be an engineer if later on in her life she decides that's what she's interested in. Or, you know, I might say that is an exceptionally interesting level of attention to detail that she is exhibiting. And that is one of the fundamental skills or like natural abilities we might look for in an engineer."

Second, Flynn leveraged argument as a method of convincing others (see 4 in Table 5). For example, when asked to rebut the idea of explicit bias as the dominant cause, Flynn reduced the impact of the explicit bias argument by stating that reducing the momentum of the dominant group by increasing representation of women would solve explicit bias as well.

Despite Flynn exhibiting a mix of multiplistic and evaluative behaviors, we hesitate to classify him in the evaluative epistemology because he never successfully entertains an alternative theory, which is seen as a less sophisticated argument construction. According to Kuhn [1, p. 101], to successfully generate an alternative theory, the participant must propose an alternative position that contrasts with the dominant cause, and they must recognize it as an opposing position—not one that can be integrated into the dominant cause. In this case, Flynn appears to have integrated both alternative theories into his own causal theory. Kuhn [1, p. 102] would argue that this type of argument does not reflect a "sophisticated understanding, but a serious lack of understanding." Kuhn backs this claim by arguing that the inability to conceive of alternatives suggests that the participant cannot imagine being wrong. Therefore, their ability "to analyze or evaluate the causal complex that is advocated is limited at best" [1, pp. 102–103]. In other words, despite displaying many of the behaviors of the evaluative epistemology, Flynn did not appear to evaluate alternative perspectives at all, which suggests a multiplistic epistemology.

6.2.3. Ellen: Evaluative

We argue that our last participant, Ellen, approaches the subject of gender-based inequities with the strongest evaluative orientation of the three participants. Overall, we classify her in the

evaluative epistemology—though, like all participants, she exhibits behaviors in multiple categories as seen in Table 6.

Table 6: Ellen's Epistemological Behaviors

Behaviors	**Epistemology**
(1) Describes the phenomenon as having "too many factors"	Multiplism (6) or Evaluative (1)
(2) Demonstrates an openness to modifying their beliefs	Evaluative (3)
(3) Uses argument as a method of convincing others	Evaluative (4)

In terms of evaluative behaviors, Ellen demonstrated three. First, when asked to describe the cause of gender-based inequities in engineering, Ellen argued that it was cultural and structural messaging. However, like Flynn, Ellen did not believe there was a singular cause. Over the course of ten minutes, Ellen mentioned several causes ranging from socialization and social messages to cultural and structural messages. When pressed for a dominant cause, Ellen said:

> "Oh god, can I simplify it? I don't know if I can. I find it really hard to separate out the structural from the cultural."

As with Flynn, Ellen's recognition of multiple factors seems to indicate either a multiplistic or an evaluative epistemological orientation (see 1 in Table 6).

Second, Ellen offered an openness to change her viewpoint which aligns with the evaluative epistemology (see 2 in Table 6):

> "It would be hard [to convince me] because my perspective is informed by so much research and so much time with this, so it would be very challenging. It would have to be a very robust and compelling meta-analysis, like all this work to show that it was a different factor to really find it even worthy of my attention."

Third, in this same quote, Ellen reiterated that debate is the only way she could be convinced which is another evaluative trait (see 3 in Table 6).

While Ellen predominantly demonstrated evaluative behaviors, we feel it is necessary to contrast her argument with Flynn's to show how they differ. For example, when asked to provide evidence of her causal theory, Ellen detached herself a bit from the phenomenon and instead leaned into existing research. For example, she referenced a book, Delusions of Gender by Cordelia Fine [38], which she used as evidence against the biology argument:

> "It's a science writing book where [Fine] was consolidating and condensing a bunch of research, but that's where I'm really definitely getting away from the idea that [gender inequity] is a biological difference, interest or something because she does a lot to explain how socialization happens at each of those phases."

Interestingly, Ellen provided this response prior to being prompted for an alternative theory, suggesting that she had spent some time thinking about this topic. While this is not a behavior explicitly outlined in Table 6, we noticed that this stood in contrast with the way that Flynn engaged with alternative theories, which suggests more of an evaluative epistemology for Ellen.

Likewise, when prompted to imagine a counterargument, Ellen talked about how Americans tend to subscribe to rugged individualism which, ironically, makes them believe that they are not susceptible to cultural influences:

> "I think that arguments against the structural and the cultural arguments tend to be about the individual and tend to be about exceptionalism. Like, that's just one math teacher who did that. That's just one person that you work with who did that."

Again, this alternative theory stands in contrast to the one provided by Flynn because Ellen has no problem engaging with it as an opposing viewpoint.

Ultimately, we classify Ellen as having an evaluative epistemology because she reflected behaviors of someone in the multiplism and evaluative categories with more weight on the latter.

In general, all three participants demonstrated at least a multiplistic orientation toward gender inequity in engineering. However, the three participants varied in their dominant orientation with Trent most closely aligning with multiplism, Ellen most closely aligning with evaluative, and Flynn somewhere in the middle. As with the findings surrounding evidence classification, we believe that classifying the epistemological orientation of faculty demonstrates a new level of depth that has not been seen in previous methods of investigating beliefs about inequity in engineering. Again, while all three participants share a similar causal theory, only one participant was able to approach the issue of gender inequity from an evaluate orientation. This finding shows that asking participants about their beliefs about gender inequity directly ignores the underlying reasoning, or lack thereof, that goes into justifying their beliefs. Therefore, focusing on the content of beliefs may include problematic assumptions when it comes to the faculty members' ability to be change agents, which supports our use of TaA to study beliefs and inequity in engineering.

7. Implications and Recommendations

After applying TaA to our context, we found that all participants shared a causal theory that was systemic in nature, but there was considerable variation in how they described committing to those causal theories. This finding is important because it demonstrates the value of TaA compared to other methods for understanding beliefs. Had we asked participants for their beliefs about gender inequity directly, we may have concluded that faculty are highly knowledgeable of the phenomenon. Instead, we found that the strength of evidence and the epistemological orientation for each participant varied. Furthermore, the ways in which faculty used evidence to support their causal theory seemed to align with their epistemological orientations for all three pilot participants. In other words, the participants with the weakest evidence also seemed to align more closely to a multiplistic orientation toward gender inequity. We would not have been able to uncover these findings with a focus just on the content of their beliefs.

In terms of personal development, we believe TaA can be used as a tool for individuals who want to grow as inclusive engineering educators. Even for faculty who adhere to the modern understanding of sexism (i.e., systemic oppression), we have provided empirical evidence via TaA that the ways in which they arrive at those beliefs is varied, and for the two participants who most closely reflect a traditional engineering faculty member (male, educated in STEM), they draw on evidence that is mostly indirectly connected to their causal theory. Without the ability to directly link evidence and one's causal theory, beliefs and related behaviors are likely to remain unclear. As a result, we encourage engineering educators to try to answer the questions in our interview protocol themselves as a way to enable critical reflection, which increases their likelihood of being change agents [1].

In terms of professional development, we believe TaA can be used to identify new approaches that can offer a paradigmatic shift in how we try to enable change through diversity, equity, and inclusion initiatives. In our experience, professional development often provides evidence of gender inequity (e.g., shows statistics to convey how underrepresented women are in engineering) or offers a causal theory to participants (e.g., teaches about microaggressions or implicit bias). While these approaches may be considered effective in that each of our participants offered systemic causal theories, we think a more effective approach would be to provide engineering educators with opportunities to make explicit their own causal beliefs and help them link the evidence they are familiar with to their own causal theories in order to strengthen and clarify their thinking in this space. As Kuhn [1] argues, people are not necessarily consciously aware of their beliefs. TaA allows us to learn what types of evidence engineering faculty, staff, and administrators use to commit to their beliefs about the cause of gender- and race-based inequities in engineering. Plus, exercises to make connections between how evidence can be used to refute alternative theories can enable faculty to be change agents in their interactions with others because they will be more prepared to articulate and justify their own beliefs. Further, we have shown that TaA can surface epistemological orientations. We interpret any divergence between what faculty believe constitutes knowledge in their professional domains (if other than gender inequity) and in gender inequity to be an opportunity for professional development. In other words, we believe our findings are indicative of the investment that is needed to provide engineering faculty with the time and support to develop expertise in the space of equity, which draws on the expertise of those in fields like sociology, cultural anthropology, history, or educational psychology.

Finally, in terms of research on beliefs and equity in engineering, we believe TaA provides a novel and productive theoretical framework for studying deeply-held beliefs about various social phenomenon in engineering education. Our empirical evidence shows how TaA can be used to identify and classify evidence as well as epistemological orientation in the context of gender equity. The framework can easily be translated to other complex social phenomena important to understand in engineering education.

8. Conclusion and Future Work

Despite being inextricable from our experiences and behavior, beliefs remain a messy and complex research construct. Therefore, beliefs remain difficult to study, understand, and

ultimately change. We are excited by the potential of using TaA as a framework to study not just the content of individuals' beliefs, but the ways in which they are aware (or not) of how they came to arrive at their beliefs about how the world works. This paper has provided an overview of the framework and shared preliminary evidence for the efficacy of its use to study engineering faculty members' beliefs related to gender-based inequities in engineering. Specifically, we have showcased the variation in the ways that inclusive engineering educators use evidence to arrive at their beliefs about gender-based minoritization in engineering as well as in their epistemological orientations when reasoning about gender-based minoritization in engineering. Our future work in this space includes translating TaA to an interview protocol to explore the beliefs that engineering faculty, staff and administrators hold about race-based minoritization in engineering and ongoing data analysis. The larger project in which we are using TaA will also include data collection on participants' lived experiences via narrative-style interviews and participation in sense-making and action for change engagement. We are eager to leverage this framework to continue to explore this space and make sense of our data in ways that can inform our collective efforts to broaden participation in engineering.

Appendix A: Gender Interview Protocol

BACKGROUND INFORMATION

Our goal today is to explore your beliefs about the causes of gender-based inequities in engineering. As you know, this project is investigating beliefs about both gender- and race-based inequities, but today we will focus on gender. Gender inequity can be a tough topic to talk about openly, so we may fumble at times, and that's okay. I want to assure you that the goal of this project is NOT to pass any judgement on our participants or to determine if you are 'sexist.' In fact, the members of our research team adhere to the modern understanding that an individual is never really 'sexist' or 'not sexist.' Instead, we are focused on the fact that we are all socialized in a society that is fundamentally organized around gender. Furthermore, there is no 'correct' belief or set of beliefs for what we will be discussing, so I hope you won't worry about saying the 'right thing.'

Our goal is to understand the way that engineering faculty, staff, and administrators THINK about the cause or causes of gender-based inequities. We are doing this work because we want to learn from you and eventually design meaningful ways for other engineering educators to contribute to broadening participation in engineering. Also, please remember that we have selected you to participate in this study because you have already been endorsed as an inclusive engineering educator by [a student, colleague, award]. While we know that everyone has room to learn and develop in their ability to act inclusively, we do want to learn from you specifically as someone who has been identified as an exemplar. So, I encourage you to be as honest as possible, and of course feel free to elaborate or ask questions at any time during this interview. Any questions so far?

Ok, so just a bit of background before we begin the interview. For this project, we are defining 'gender-based inequities' broadly as anything that results in the inequitable participation of individuals who self-identifies as non-male. As a collective group, individuals who identify as non-male obviously possesses a great deal of diversity, including differences in racial-identity, nation of origin, sexual orientation, gender expression, and so on. Just want to note that we do use the men/women dichotomy as a way to talk about these things for the sake of discussion. As you are likely aware, in the U.S., women remain underrepresented in engineering compared to their presence in the population. Furthermore, research is largely conclusive that when women do participate in engineering, they face gender-based inequities. With that said, you have already consented to participating in this research project. Do you have any questions before we begin the interview?

[researcher START RECORDING]

ORIENTATION

1. Before we dive into our discussion of what you believe to be the cause of gender-based inequities in engineering, please tell me a little about yourself.
    a. Background, social identities
    b. Current role

ARGUMENTATION AS THINKING

[Researcher remember to explore/clarify throughout:

- *What do you mean by that?*
- *Why do you say that?*
- *What would this show?*
- *What would you expect to find out?]*

Causal Belief with Justification

2. What causes gender-based inequities in engineering?
   a. (*Probe when subject completes initial response*) Anything else?
   b. (*If multiple causes mentioned*) Which of these would you say is the dominant cause of gender-based inequities in engineering?
3. How do you know that this is the cause?
   a. (*Probe, if necessary*) Just to be sure I understand, can you explain exactly how this shows that this is the cause?
4. If you were trying to convince someone else that your view (that this is the cause) is right, what evidence would you give to try to show this?
   a. (*Probe, if necessary*) Can you be very specific, and tell me some particular facts you could mention to try to convince the person?
   b. Is there anything further you could say to help show that what you've said is correct?
   c. Is there anything someone could say or do to prove that this is what causes gender-based inequities in engineering?
5. Can you remember when you began to hold this view?
   a. *(If no)* Have you believed it for as long as you can remember?
   b. *(If yes)* Can you remember what it was that led you to believe that this is the cause?

Alternative Belief with Justification and Rebuttal

6. Suppose now that someone disagreed with your view that this is the cause. What might they say to show that you were wrong?
7. What evidence might this person give to try to show that you were wrong?
   a. (*Probe, if necessary*) Just to be sure that I understand, can you explain exactly how this would show that you were wrong?
   b. (*If not already indicated*) Is there any fact or evidence which, if it were true, would show your view to be wrong?
   c. Could someone prove that you were wrong?
8. (*Omit if alternative theory already generated*) A person like we've been talking about whose view is very different from yours—what might they say is the major cause?
9. (*Include if no alternative theory generated*) Suppose that someone disagreed with you and said that [*interviewer provide alternative theory*] was the cause. What could you say to show that this other person was wrong?
   a. (*Probe, if necessary*) Just to be sure I understand, can you explain how this would show the person was wrong?

Rebuttal

10. Would you be able to prove this person wrong?
11. (*If not already indicated*) What could you say to show that your own view is the correct one?

Instrumental Reasoning

12. Is there any one important thing which, if it could be done, would reduce gender-based inequities in engineering?
    a. Why would it improve it?
13. Is there any one important thing which, if it could be done at your institution, would reduce gender-based inequities in engineering?
    a. Why would it improve it?
14. Is there any one important thing that you could do to reduce gender-based inequities in engineering?
    a. Why would it improve it?
15. So, you are mentioning things mostly aimed at _____. I'd like to open it up to ideas you have about how to reduce gender-based inequities that are focused on [*Interviewer offer follow ups below if not a part of answer to 12-14*]:
    a. Engineering Students? (male or female)
    b. Engineering faculty? Staff? Administrators? (male or female)
    c. Engineering education systems (e.g., policies or processes)?
    d. Societal-level systems (e.g., policies or processes)?
16. Ultimately, what role do you perceive you have as an engineering faculty, staff, or administrator in addressing gender inequities in engineering? Can you provide an analogy for the role?

CHECK IN

Awesome, thank you so much. That is the end of the section of the interview to explore your beliefs and reasoning about why gender-inequities remain a part of engineering. The next part is a little different. I have two "cases" that I'd like to share with you with some follow-up questions about each and then a final question about the idea of "heroes" before we wrap up. It will probably take at least another 30 minutes or so. Are you alright to continue? If so, could you use a break?

EVALUATION OF EVIDENCE: UNDERDETERMINED

17. Alright, now I'm going to offer you a "case" and then ask your take on it. Here's the case [*interviewer share text so participant can follow along*]:

Ella Haris first grew interested in engineering as a young child after her 3rd grade classroom participated in a local science fair. At that fair, Ella heard one of her classmate's parents talk about how engineers make the world a better place, and that sounded like something she thought she would be good at. Ella maintained her interest in becoming an engineer through middle school and high school, but math and science weren't her strongest subjects. Ella picked up that engineering does require math and science skills, so she worked hard in these classes, earning mostly B's. Ella heard her teachers encourage the 'A' students to consider engineering as a career path, but no one ever provided her with such encouragement. Ella completed all the high school classes required for an engineering pathway, and she noticed along the way that she was often among only a handful of girls in those spaces. By the time she began applying to colleges, she knew she didn't have the GPA necessary to be admitted to her desired engineering major at her target school, so she decided to pursue a degree in education instead. Since completing her degree, Ella says that she's satisfied with her decision.

Okay, so I'd like to know:

a. What do you think is the cause of Ella's exit from an engineering pathway?
    i. Why do you think this is the cause?
b. How sure are you that this is the cause of Ella's exit from an engineering pathway?
    i. (if sure) What makes you sure?
    ii. (if not sure) What makes you unsure?
c. Are there any other possibilities?
    i. (if yes) Is it possible to choose among these different possibilities to say what caused Ella to exit from an engineering pathway?
        1. (if yes) Is it possible to choose based on the information we have here? Why? Why not?

<u>EVALUATION OF EVIDENCE: OVERDETERMINED</u>

18. Now, we'll take a look at a different case followed by a few questions. Here's the case [*interviewer share text so participant can follow along*]:

A multi-part study was conducted by three different researchers to understand the experiences of 25 women who had, at that time, decided to exit undergraduate engineering programs:

- A social science researcher conducted one-on-one interviews with the women, which revealed that many of them, especially the ones who had children, reported that unsupportive environments and systemic barriers contributed most to their decision to change their major. Within the same group, married women and those with the highest academic performance were likely to cite a lack of motivation when asked about their decision to leave. Finally, the interviews also revealed that many of the women felt at risk of conforming to gender-based stereotypes so much that it affected their performance.
- A different researcher conducted extended ethnographic observations of the participants within their school settings and concluded that they were all subject to different forms of gender-based inequities. Some women experienced gender-based microaggressions; others outright sexism.
- A final researcher investigated the women's academic performance and concluded that they performed roughly the same as the men.

    a. What does this study suggest about the cause of gender-based inequities in engineering?
    b. Does this study prove that this is the cause?
    c. Does this study suggest anything else about the cause of gender-based inequity in engineering?
    d. Does anything from this study influence your own thinking about what causes gender-based inequities in engineering?
    e. Do you have any doubts about what this study suggests?

<u>HERO</u>

19. I want you to imagine a person who works in engineering education (could be faculty, staff, or administrator) and is a 'hero' for gender equity. This person is your *ideal* example for what it looks like to contribute to gender equity in engineering. With that person in mind (fictional or real), tell me...

a. What are they like?
b. What matters most to them?
c. What motivates them?
d. How do they spend their time?
e. How do they behave on a day-to-day basis?
f. What sorts of things have they accomplished over time?
g. What is it about them and their life that makes them a hero?

CLOSING

20. Now that we've been through this interview...I just want to open it up to any closing thoughts you might have.
a. How would you summarize what we've discussed?
b. Have you gained any insights through this process?
c. Additional thoughts or ideas? Things we left out?
21. How would you like your interview to be identified? We can use your name, or we can provide you with a pseudonym starting with the letter [*interviewer provide next letter in alphabet*].
22. At this point, we've completed the portion of this study with a focus on gender-based inequity. Thank you so much for sharing your time and perspective with us. I'd just like to confirm that it is alright for us to reach out to you if we have any questions about this interview as well as to schedule the next interview about race-based inequities sometime in the next semester or two. Is [*interviewer list email we have on file as contact*] still the best way to reach you?
23. Finally, we're interested in expanding our research to institutions beyond The Ohio State University. Do you have anyone in your network outside of [home university] that you think is an inclusive engineering educator that might be a good addition to this study and interested in participating? [*interviewer collect name, contact info as appropriate and/or offer to email referral survey*].
24. As a small token of our appreciation for your time, we will be providing you with a $50 Amazon Gift Card claim code through email within the next week or so. If you do not receive it for some reason, please reach out to a member of our research team and let us know!

[*researcher STOP RECORDING*]

References

[1] D. Kuhn, *The Skills of Argument*. Cambridge University Press, 1991.

[2] M. H. Connors and P. W. Halligan, "A cognitive account of belief: a tentative road map," *Front. Psychol.*, vol. 5, 2015, doi: 10.3389/fpsyg.2014.01588.

[3] J. Nespor, "The role of beliefs in the practice of teaching," *J. Curric. Stud.*, vol. 19, no. 4, pp. 317–328, Jul. 1987, doi: 10.1080/0022027870190403.

[4] M. F. Pajares, "Teachers' Beliefs and Educational Research: Cleaning Up a Messy Construct," *Rev. Educ. Res.*, vol. 62, no. 3, pp. 307–332, Sep. 1992, doi: 10.3102/00346543062003307.

[5] S. Sloman and P. Fernbach, *The Knowledge Illusion: Why We Never Think Alone*. Penguin, 2018.

[6] A. C. T. Smith, *Cognitive Mechanisms of Belief Change*. Springer, 2016.

[7] M. Eliot and J. Turns, "Constructing Professional Portfolios: Sense-Making and Professional Identity Development for Engineering Undergraduates," *J. Eng. Educ.*, vol. 100, no. 4, pp. 630–654, 2011, doi: https://doi.org/10.1002/j.2168-9830.2011.tb00030.x.

[8] J. Jorgenson, "Engineering Selves: Negotiating Gender and Identity in Technical Work," *Manag. Commun. Q.*, vol. 15, no. 3, pp. 350–380, Feb. 2002, doi: 10.1177/0893318902153002.

[9] O. Pierrakos, T. K. Beam, J. Constantz, A. Johri, and R. Anderson, "On the development of a professional identity: engineering persisters vs engineering switchers," in *2009 39th IEEE Frontiers in Education Conference*, Oct. 2009, pp. 1–6. doi: 10.1109/FIE.2009.5350571.

[10] K. L. Tonso, "Teams that Work: Campus Culture, Engineer Identity, and Social Interactions," *J. Eng. Educ.*, vol. 95, no. 1, pp. 25–37, 2006, doi: https://doi.org/10.1002/j.2168-9830.2006.tb00875.x.

[11] M. A. Hutchison-Green, D. K. Follman, and G. M. Bodner, "Providing a Voice: Qualitative Investigation of the Impact of a First-Year Engineering Experience on Students' Efficacy Beliefs," *J. Eng. Educ.*, vol. 97, no. 2, pp. 177–190, 2008, doi: https://doi.org/10.1002/j.2168-9830.2008.tb00966.x.

[12] R. W. Lent, S. D. Brown, and K. C. Larkin, "Self-efficacy in the prediction of academic performance and perceived career options," *J. Couns. Psychol.*, vol. 33, no. 3, pp. 265–269, 1986, doi: 10.1037/0022-0167.33.3.265.

[13] R. W. Lent, H.-B. Sheu, D. Singley, J. A. Schmidt, L. C. Schmidt, and C. S. Gloster, "Longitudinal relations of self-efficacy to outcome expectations, interests, and major choice goals in engineering students," *J. Vocat. Behav.*, vol. 73, no. 2, pp. 328–335, Oct. 2008, doi: 10.1016/j.jvb.2008.07.005.

[14] R. M. Marra, K. A. Rodgers, D. Shen, and B. Bogue, "Women Engineering Students and Self-Efficacy: A Multi-Year, Multi-Institution Study of Women Engineering Student Self-Efficacy," *J. Eng. Educ.*, vol. 98, no. 1, pp. 27–38, 2009, doi: https://doi.org/10.1002/j.2168-9830.2009.tb01003.x.

[15] J. Michael, J. Booth, and T. E. Doyle, "Importance of First-Year Engineering Design Projects to Self-Efficacy: Do First-Year Students Feel Like Engineers?," *Proc. Can. Eng. Educ. Assoc. CEEA*, Jun. 2012, doi: 10.24908/pceea.v0i0.4650.

[16] Ş. Purzer, "The Relationship Between Team Discourse, Self-Efficacy, and Individual Achievement: A Sequential Mixed-Methods Study," *J. Eng. Educ.*, vol. 100, no. 4, pp. 655–679, 2011, doi: https://doi.org/10.1002/j.2168-9830.2011.tb00031.x.

[17] N. J. McNeill, E. P. Douglas, M. Koro-Ljungberg, D. J. Therriault, and I. Krause, "Undergraduate Students' Beliefs about Engineering Problem Solving," *J. Eng. Educ.*, vol. 105, no. 4, pp. 560–584, 2016, doi: https://doi.org/10.1002/jee.20150.
[18] E. Dringenberg, G. Guanes, and A. Leonard, "Beliefs about Diverse Approaches to Engineering Design Decisions: Students vs. Faculty," *Stud. Eng. Educ.*, Under Review.
[19] G. Guanes, L. Wang, D. Delaine, and E. Dringenberg, "Engineering Students' Beliefs About and Use of Empathic Approaches in Capstone Design Projects," *Eur. J. Eng. Educ.*, 2021.
[20] C. Faber and L. C. Benson, "Engineering Students' Epistemic Cognition in the Context of Problem Solving," *J. Eng. Educ.*, vol. 106, no. 4, pp. 677–709, 2017, doi: https://doi.org/10.1002/jee.20183.
[21] M. J. Pavelich and W. S. Moore, "Measuring the Effect of Experiential Education Using the Perry Model," *J. Eng. Educ.*, vol. 85, no. 4, pp. 287–292, 1996, doi: https://doi.org/10.1002/j.2168-9830.1996.tb00247.x.
[22] M. J. Pavelich and W. S. Moore, "Measuring maturing rates of engineering students using the Perry model," in *Proceedings of IEEE Frontiers in Education Conference - FIE '93*, Nov. 1993, pp. 451–455. doi: 10.1109/FIE.1993.405483.
[23] E. Dringenberg, A. Shermadou, and A. Betz, "Reactions from First-year Engineering Students to an In-depth Growth Mindset Intervention," in *2018 ASEE Annual Conference & Exposition Proceedings*, Salt Lake City, Utah, Jun. 2018, p. 30917. doi: 10.18260/1-2--30917.
[24] E. Dringenberg and A. Kramer, "The influence of both a basic and an in-depth introduction of growth mindset on first-year engineering students' intelligence beliefs," *Int. J. Eng. Educ.*, vol. 35, no. 4, pp. 1052–1063, 2019.
[25] K. J. Reid and D. M. Ferguson, "Do design experiences in engineering build a 'growth mindset' in students?," in *2014 IEEE Integrated STEM Education Conference*, Mar. 2014, pp. 1–5. doi: 10.1109/ISECon.2014.6891046.
[26] G. S. Stump, J. Husman, and M. Corby, "Engineering Students' Intelligence Beliefs and Learning," *J. Eng. Educ.*, vol. 103, no. 3, pp. 369–387, 2014, doi: https://doi.org/10.1002/jee.20051.
[27] E. Godfrey and L. Parker, "Mapping the Cultural Landscape in Engineering Education," *J. Eng. Educ.*, vol. 99, no. 1, pp. 5–22, 2010, doi: 10.1002/j.2168-9830.2010.tb01038.x.
[28] R. Stevens, D. M. Amos, L. Garrison, A. Jocuns, M. Jones, and H. G. Loshbaugh, "Engineering as Lifestyle and a Meritocracy of Difficulty: Two Pervasive Beliefs Among Engineering Students and Their Possible Effects," presented at the American Society for Engineering Education Annual Conference, Honolulu, HI, 2007.
[29] G. Lichtenstein, H. L. Chen, K. A. Smith, and T. A. Maldonado, "Retention and persistence of women and minorities along the engineering pathway in the United States," *Camb. Handb. Eng. Educ. Res.*, pp. 311–334, 2014.
[30] M. J. Chang, J. Sharkness, S. Hurtado, and C. B. Newman, "What matters in college for retaining aspiring scientists and engineers from underrepresented racial groups," *J. Res. Sci. Teach.*, vol. 51, no. 5, pp. 555–580, 2014, doi: https://doi.org/10.1002/tea.21146.
[31] P. T. Reid, "Racism and Sexism," in *Eliminating Racism: Profiles in Controversy*, P. A. Katz and D. A. Taylor, Eds. Boston, MA: Springer US, 1988, pp. 203–221. doi: 10.1007/978-1-4899-0818-6_10.

[32] A. Wilson-Lopez, J. A. Mejia, I. M. Hasbún, and G. S. Kasun, “Latina/o adolescents’ funds of knowledge related to engineering,” *J. Eng. Educ.*, vol. 105, no. 2, pp. 278–311, 2016.
[33] E. A. Cech, “Culture of disengagement in engineering education?,” *Sci. Technol. Hum. Values*, vol. 39, no. 1, pp. 42–72, 2014.
[34] “Definition of CULTURE HERO.” https://www.merriam-webster.com/dictionary/culture+hero (accessed Mar. 30, 2021).
[35] Medievalists.net, “The Hero as a Reflection of Culture,” *Medievalists.net*, Mar. 27, 2012. https://www.medievalists.net/2012/03/the-hero-as-a-reflection-of-culture/ (accessed Mar. 30, 2021).
[36] K. Foster and C. Roberts, “The Heroic and the Villainous: a qualitative study characterising the role models that shaped senior doctors’ professional identity,” *BMC Med. Educ.*, vol. 16, no. 1, p. 206, Aug. 2016, doi: 10.1186/s12909-016-0731-0.
[37] M. Song and D. Parker, “Commonality, difference and the dynamics of disclosure in in-depth interviewing,” *Sociology*, vol. 29, no. 2, pp. 241–256, 1995.
[38] C. Fine, *Delusions of Gender: How Our Minds, Society, and Neurosexism Create Difference*. W. W. Norton & Company, 2010.