Complexity of Engineering Identity: A Study of Freshmen Engineering Students

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Thesis submitted to the faculty of the Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of

Master of Science
In
Computer Science & Application

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June 10, 2019
Blacksburg, VA

Keywords: Human Computer Interaction, engineering identity, engineering education, narrative, contextual inquiry

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ABSTRACT

The General Engineering Program exists at Virginia Tech to provide curriculums that engage, challenge and support entry-level engineers. One important part of this initiative is helping students identify with a specific engineering branch, and overtime develop an identity within it. Yet, there exists little research on what entry-level engineers believe it means to be an engineer, especially during these stages of early formation and continual shifting. In order to generate insight on this topic we developed a contextual inquiry method to help inquire into engineering identity. Two participants were placed in an online chatroom and allowed to talk for ten minutes, with one trying to answer the question 'Am I talking to an engineer or not?' and asked to give their reasoning. Comparisons allow entry-level engineering students to articulate their beliefs on what characteristics, behaviors and personalities make up their cohort -- thus exposing their ideas about identity. Moreover, this methodology also provides opportunities for participants to critique their own bias and further develop and expose their opinions on identity. Additionally, our findings showcase the complexity around student's perceptions of engineers. For example, participants' responses pointed to: many sources that inform identity, the difficulty of identifying what is uniquely engineering, how identity is impacted by the ideal image of an engineer, that identity is a spectrum, and that identity varies with respect to associations and time. As a result, through our inquiry and representation of results we demonstrate the validity of our methodology as a HCI research tool along with the power of narrative forms of representation.

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GENERAL AUDIENCE ABSTRACT

The General Engineering Program exists at Virginia Tech to provide curriculums that engage, challenge and support entry-level engineers. One important part of this initiative is helping students identify with a specific type of engineering, and overtime develop an identity within it. Yet, there exists little research on what entry-level engineers believe it means to be an engineer, especially during their freshmen year of college when they are still forming and changing their ideas about engineering identity. In order to generate insight on this topic we developed a methodology to help inquire into engineering identity. Two participants at a time were placed in an online chatroom and allowed to talk for ten minutes, with one trying to answer the question 'Am I talking to an engineer or not?' and asked to give their reasoning. Comparisons allow entry-level engineering students to articulate their beliefs on what characteristics, behaviors and personalities make up their cohort -- thus exposing their ideas about identity. Moreover, this methodology also provides opportunities for participants to critique their own assumptions about engineering identity and further develop and expose their opinions on identity. Additionally, our findings showcase the complexity around student's perceptions of engineers. For example, participants' responses pointed to: many sources that inform identity, the difficulty of identifying what is uniquely engineering, how identity is impacted by the ideal image of an engineer, that identity is a spectrum, and that identity varies with respect to associations and time. As a result, through our inquiry and representation of results we demonstrate the validity of our methodology as a Human Computer Interaction research tool along with the power of using written stories to represent results.

Acknowledgements

Thank you to my many friends and family who have supported me through this entire endeavor. Specifically:

Steve Harrison – Thank you for being an amazing mentor over the past 4 years. From introducing me to HCI, to bringing me through my research defense - you were there every step of the way, giving me support and guidance, challenging me and celebrating my accomplishments. I consider my last few years at Tech as some of the most formative in my life, and I believe that is in large part due to your being a part of it. Josh and I will dearly miss you when we move!

Deborah Tatar – Thank you for all the lovely talks and mentoring about what it means to be a woman in Computer Science, as well as helping me understand the complex landscape of marriage, research and the world beyond. I do not think my collegiate career would have been as interesting, stimulating, challenging or impacting had you not been a part of it.

Scott McCrickard – Thank you for trusting me with a lot of responsibility when we teach together, and taking the time to mentor me about lecturing, pedagogy, classroom environment, direction writing and so much more! I'm excited to graduate, but I think some of what I'll miss most about Virginia Tech is teaching with you.

Thirdlab – Thank you for welcoming me with open arms all those years ago when I was a Junior in College, and giving me the space and support I needed to engage in meaningful research.

Joshua Wenger – Thank you for being my rock during this whole process. Whether it was wedding planning, moving, grocery shopping etc. you went above and beyond to serve me during my thesis writing, as well as hold me together when the weight of research became almost too much. Through these stressful times you have affirmed time and time again that you are indeed the most wonderful man in the world who I love and am ecstatic to spend the rest of my life with.

Jesus – Thank you God for giving me the insight I needed each time I hit a wall, and assuring me that this was going to happen even when I did not believe it myself. To Him be the glory.

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1. INTRODUCTION

1.1 Motivation

To describe the larger goals of our research, let me show you a microcosm of its values, relationships and impact. I was getting lunch with my fiancé and many of his mechanical engineering friends at one of the buffet dining halls on campus. Everyone was generally relaxed, chatting about the stressors and highlights of college, when one guy who had been idling on his phone interjected into the group -- “Guys, the class rank is out.” The calm atmosphere turned into a buzz of excitement as everyone began digging out their phones and laptops to go online and check their own rank. Confused, I leaned over to whisper to my fiancé -- “wait, that’s a public list?”. He turned to me surprised -- “don’t you have a ranking of all the students in computer science as well?”

Looking into it later, I realized that we did indeed have class rank in our department -- but it was not something I had ever heard another student talk about before, let alone anticipate for it to come out each semester. This made me wonder -- was competition like this a value for all engineering branches, or just large and solidified ones like mechanical? What did this attitude mean for how these engineers engaged in the classroom, and what was it going to mean for how they worked in industry? How did this impact the way they saw themselves as engineers, and conceptualize the work they did in the field?

In fact, musing about questions like these has been something academics have been doing for a long time. Specifically, because college can be a great opportunity for engineers to develop their identity there have been many initiatives, like General Engineering at Virginia Tech, to influence that formation. In turn, there has been a lot of research on how curricula that engage students on this level impact that influence around engineering identity. Yet perhaps an under researched part of how our engineering students form their identities is inquiring into the actual content of (or state of) the identities that they construct. As such, we designed a methodology to do just that.

To begin, I was still musing over the episode I had encountered over lunch on class rank. I wondered if these engineers came across other mechanical students who were also oblivious to structures like this, would they consider them to be real engineers? Specifically, could we test our understanding of how engineering students saw identity through creating a representation of an engineer and somehow allowing them to give us feedback on its believability? A classic example of this would have been a persona - and we had many examples of these for Virginia Tech specifically from the Department of Engineering Education. And yet, trying to insert a fictional character into the lives of real students seemed impossible, or cartoonish at best.

However, the more I thought about it, I realized that proceeding in the opposite direction was actually quite easy -- we could bring a persona and person to the same level of reality by digitizing both. In fact, a possible procedure analogous to this already existed -- the Turing Test. We could have an engineering student at one end of an online conversation, and have someone assume the characteristics of a persona at the other end, and probe the student about whether they thought this character was an engineer. Or even better, we could do away with fiction all together and have real students both inside and outside engineering take the role of the conversation partner, to see what engineering students believed engineering identity is like.

1.2 Research Questions

From our methodology, we hope to answer the following research questions which we believe will yield fruitful data about engineering students conceptions' of engineers.

RQ1: What are freshmen engineering students' conceptions of an engineer?

In order to investigate the state of engineering students' ideas about engineering, we need to understand the content of their beliefs. This includes many different facets centering around the traits of the kinds of people our participants believe engineers are like, along with what they do, the circumstances they find themselves in and more. To answer this, we interpreted interrogator participant questions and the characteristics they used for assessment as criteria for engineering identity.

RQ2: Is there a consensus among students about engineering identity?

Considering that there will be negotiation of expectations of engineering both in the classroom and the working world, we also would like to know how much similarity exists between participant's beliefs of engineering identity. Through this we can better understand the unity of state and if it even exists for engineers this early on. To answer this, we have compared and contrasted students' conceptions between each other to see how much overlap exists.

RQ3: If not, how might students' conceptions vary?

In the event where consensus among students does not exist about engineering identity, we must find out if there are any patterns that lead this variance that could help us better understand the conditions of negotiation for identity. To answer this question, we have investigated where opinions diverge and looked for trends that would explain these differences.

RQ3A: What associations do participants use to form networks around engineering identity?

RQ3B: How might participants' opinions change during the task?

Even further, more specific formulations of RQ3 that our research intends to answer includes inquiring about associations and change. Associations will continue to show us the conditions under which conceptions vary, while inquiring about change will help us understand the stability of state. Also in contrast to RQ1, RQ2, and RQ3, RQ3A and RQ3B emerged later in our study after we began to see the ways in which participants associated traits with engineering identity and also the ways in which they changed their opinions during the task.

Additionally, our work will also take into account some overarching considerations in regards to methodology and design. Firstly, considering that our research also innovates with respect to methodology, we want to know if our procedure functions the way we intend, along with more detail into how it works and why, to contribute more design tools to the HCI field. Furthermore, we want to understand what appropriate representations of our findings our possible that can be actionable for design. As such, the representations of our findings can be ready for application if they are deemed significant enough to do so by designers.

1.3 Background

As our study investigates the characteristics of entry-level engineers it is important to review the infrastructure surrounding this group in our setting at Virginia Tech. To start, to be considered an engineer at this university a student must be accepted into the College of Engineering. Then, in their first year these students will be assigned the major of 'General Engineering' and must complete two semesters of 'Foundations of Engineering' and a few other math and science courses to apply for a specific engineering discipline. The goal of these classes is to expose students to engineering at a high level as well as the different branches of engineering to allow for appropriate selections of major. Then, once accepted into one of the engineering departments, the student drops the General Engineering major and assumes their specified one. As an aside, in this thesis we will use the terms "engineering student" and "engineer" interchangeably as a reflection of the academic field where engineering students are referred to as 'engineers' as early as their first day of class, unlike other disciplines [10].

Additionally, within engineering at the university there are also many different organizations that expose students to engineering at a more informal level. The ones we will focus on in this thesis are housed in Lee Hall -- a campus dormitory. Within Lee Hall is a community called InVenTs, an organization whose objective is to facilitate mentoring, support in academics and exploration of STEM disciplines. Within InVenTs are the living-learning communities Galileo, Hypatia, Curio and Davinci. While the first two are respective male (Galileo) and female (Hypatia) groups focused on engineering, the latter are co-ed groups that focus on the sciences. For our study, we are mostly interested in Galipatia -- the nickname given these sibling engineering living-learning communities. This group is a good platform for our inquiry because the students who live in them have had high exposure to formal engineering education from General Engineering classes as well as informal learning from their peers through relationships and relevant activities within Galipatia, which is necessary for identity formation to occur

according to much research [13, 30, 41]. An example of such initiatives within Galipatia includes the requirements for freshmen to acquire a certain amount of "even credits" through attending different events with either a focus on professional development, academics, service or socializing to aid in their development.

Furthermore, the specific dimension of identity that we are interested in is collective identity. According to the Handbook of Social Psychology, collective identity is the shared identity and action systems between members of a group and involves three key features -- that collective identities adapt over time, they can be differentiated from other identities and that members of a group with collective identity can recognize their membership as well as others [32]. Thus, we believe that because entry-level engineers in Galipatia have been repeatedly exposed to engineering on both a formal and informal level, they should be able to recognize and articulate the membership criteria of engineering identity which we seek to study.

1.4 Purpose Statement

Our goal is to develop an approach that helps college students articulate their own beliefs about engineering identity. Specifically, we would like to learn about the understandings and expectations that freshmen engineering students have. For our study, we are not interested in the source of such ideas, but rather the actual thoughts themselves connected to the specific environments our engineers are a part of. These characteristics will answer our research questions.

In order for this to work, our approach must avoid participants unthinkingly repeating thoughts on identity that they do not actually believe. To do this, we will have participants talk online with another student to decide if the other is an engineer or not. Performing a task that involves comparison will challenge participants to think through their own experiences and beliefs, rather than repeat others' ideas in a self-unaware manner. Furthermore, we will utilize an online environment as a medium of conversation because we believe it will hide the physical dimensions of an individual, allowing the norms of their social group to become the dominant influence [41]. Also, as mentioned earlier we will pull our participants from Galipatia because their entry-level engineers have been repeatedly exposed to engineering in both formal and informal levels by ways. Last, we will focus only on freshmen General Engineering students because we want to capture students' perceptions of engineers early, while their constructions are still dynamically forming.

In summary, as a general concept, identity can be a nebulous construct to explain. However, we believe that introducing an individual to compare against can help engineering students articulate their perceptions of what engineers are like, while avoiding the disadvantages of past research efforts, which we will elaborate on in the Literature Review Section.

1.5 Research Contributions

For our specific context of engineering, our research can help engineering students more meaningfully engage with their discipline, because the answers to our research questions can better inform interventions into General Engineering curricula. For instance, if our study indicates that participants are unsure of what having interests outside of engineering means for their engineering membership, we can represent that finding in a way that preserves the complexity and context around that idea so that Engineering Education has the opportunity to act upon these findings if they so choose. In turn, students will be better equipped with the skills they need to understand their own identity as well as those around them, allowing them to more meaningfully and productively engage with the field. Also, to be clear, we are not suggesting that there is a certain image of engineering that we want students to have, but rather we desire for them to get the exposure they need from the engineering program to come to their own understanding of their identity.

Additionally, the knowledge gained from our study can be used as a starting point for further inquiries into other aspects of engineering identity. Our research will bring to light many different aspects of engineering identity held by students. Any of these can be more specifically targeted to learn more about using the same or different technique. For example, researchers could see if any characteristics arise that could be considered barriers to entry for some student demographics, and dig deeper into where these beliefs originate from. This work could then go on to help inform diversity initiatives in engineering, and with further investigation, we could flesh out these conceptions and the prevalence they exist in the study body. Again, through using engineering education as the site of change -- educators could use our research to identify where to focus engineering awareness and resolution surrounding diversity. Furthermore, this conception of engineering identity can be contrasted with what other populations believe -- such as older college students, engineering employees, firms and more.

In contrast, at its most general, our methodology will contribute to the field a novel blueprint for how to give structure and articulation to nebulous concepts. We believe that through our study we can not only test the degree to which our technique accomplishes this, but also bring to light how and why it works. In turn, other members of the research community can repurpose our technique to inquire into other topics, such as the characteristics of a certain gender or ethnicity -- or if consensus on these topics even exists. As a result, Human Computer Interaction (HCI) contextual inquiry and analysis methods will be expanded to also provide tools that recognize identity amongst users and makers, leading to more rich knowledge that preserves the contextual and complexity of the domain to use for design. Even further, this also allows for a deeper understanding about the relationship of stereotypes within users and makers, and the impact they have in design practice.

Last, in considering how to best represent the characteristics that flow out of our methodology we will learn and share lessons about what representations can preserve complexity and context for our results. For though our research does not directly speak to

the applications of our findings, we do recognize the potential for this to happen and thus have inquired into what it means to have representations that are actionable for design. Therefore, our research can help close the gap between theory and design through investigating how to represent our results in ways that are relevant, usable and understandable for designers.

2. LITERATURE REVIEW

2.1 Overview of Identity

2.1.1 Identity as Individual Self and Social Self

Our research takes on the challenge of describing identity or the "particular state of reflection of the subject, which defines symbolic boundaries of a self-other or an in-group-out-group relation" [31]. We call this endeavor challenging, not only because it is generally complex, but also because identity is expansive -- in both the weight it carries as a human experience and the degree to which the idea crosscuts many different academic fields (which informs the multidisciplinary approach of our own research). As a result, identity is particularly difficult to ascertain, and yet identity is also so important to both have and understand that we cannot abandon the quest [30].

Fortunately, many academic fields converge on the high level organization of the idea of identity. They agree that identity is made up of the individual and social self. The individual self constitutes the traits and characteristics that define a person, mostly through that person's relation to themself [32]. In contrast, the social self is defined through two kinds of relationships -- those a person has with other individuals, and those that come with membership within social groups. In turn, both interpersonal relationships and groups inform the social self [5]. However, they also play a role in general self-construction along with self-evaluation -- showing us that the individual and social self are also interrelated [17]. Additionally, as alluded to earlier, the social self can break down even further into the interpersonal self (how someone relates themselves to others) and the collective self (how someone relates themselves to social groups), the difference being whether or not the relation involves a personal or symbolic tie [5].

2.1.2 Collective Self

Specifically, for our research, we are interested in college students' conceptualizations of engineers, a form of collective self. Building upon our definition from Brewer, according to the Handbook of Social Psychology, collective identity is the shared identity and action systems between members of a group and involves three key features -- that collective identities adapt over time, they can be differentiated from other identities and members of groups having a collective identity can recognize their membership as well as others [32]. In turn, these features inform the scope and context in which we seek to study participants.

First - the fact that collective identities adapt over time, means that we must choose a time frame to look into a snapshot of identity and recognize that our results are time bound. Specifically, we know that college is a particularly formidable time for our participants, because they are moving in between development stages while also trying to bring harmony between their personal and social identity in a stable way that can propel them into the future [21]. In particular, we speculate that this situation is especially difficult for freshmen who are at the beginning of this journey, and thus we have chosen to study these participants who are likely to be deeply engaging with many of the same phenomena as our research questions about state.

Second - the combination of identities being distinct and members being recognizable, means that in theory our research questions are answerable ones. Specifically, our findings will be informed by the collective self of our participants, which according to Brewer and Gardner means they will engage in self-evaluation and illuminate for us a group prototype [5]. Yet, we also know that because these levels of identity all relate and inform each other that aspects of the individual and interpersonal self of our participants will also come into play during our study; meaning that participants are likely to also talk about themselves (or their traits) and their relationships to other peers (or their roles) both inside and outside of engineering.

2.2 Engineering Identity

2.2.1 Engineering Identity Formation Studies

As explained earlier, identities can also exist around certain social groups -- of which engineering is no exception. In fact, numerous literature sources confirm that engineering students are indeed forming engineering identities during college, and showcase the many ways in which that formation takes place [10, 13, 30]. The approaches this research takes on are varied, though most focus on interviewing and observation of a cohort of engineers over time [10, 30]. Some even take on a more active role in the research like Eliot and Turns who conducted professional portfolio workshops with engineering students in order to more directly involve themselves in the real time process of identity formation [13]. Even further, some investigate obstacles to identity formation that can affect retention, like differences in gender [10], and students who leave the curriculum [30]. Tensions like these again confirm the existence of an engineering identity through reversal, or the initiative to expand what we know through flipping the center and margins of our inquiry [12]. In other words, describing what is out involves the same reflexive boundary that describes what is in, and a boundary like this in its simplest form is the definition of identity. Thus, we see that in seeking to study what constitutes engineering identity, we are likely to also come across descriptors about what does not constitute engineering identity. In this same vein, we wonder if attitudes about computer science, a field whose academic department is consistently contested, as belonging to engineering will surface during the study [11].

Studies about engineering identity formation confirm the many ways identity is manifested in our students through processes of socialization. As such, it follows that

socialization is an asset to identity formation. In fact, research shows that exposure to both formal and informal learning opportunities lay the groundwork for engineering students to engage in engineering identity formation [13, 30, 41]. Specifically, many organizations capitalize on this phenomenon through providing avenues for both types of learning on a daily basis by way of living-learning communities. Thus, we believe that because our participants have been repeatedly exposed to engineering on both a formal and informal level through the living-learning community Galipatia, they should be able to recognize and articulate the membership criteria of engineering identity which we seek to study.

2.2.2 Engineering Identity State Studies

Although the wealth of formation studies around engineering verifies that our engineering students are likely to have and be forming engineering identities that we can inquire into, they tell us very little about the actual content of such identities. Additionally, the few research studies that do look into the actual content of students' understandings of identity have shortcomings. For example, some studies about state inquire about engineering identity through having students pick characteristics from a given list [27]. At best, this is evidence for a partial student view of engineering identity that reinforces characteristics posited by researchers. However, at worst, this causes students to regurgitate what others have told them engineers are like. Furthermore, studies like these which do not leave room for open-ended conversation around identity force participants to represent their understandings in ways contrary to how people really think. Namely, they reject the notion of Object Worlds first put forth by Bucciarelli which explains how the meaning of an object is distributed across its form, context and interactions with others [6]. Therefore, providing discrete lists of characteristics for participants to choose from leaves no room for students to showcase the whole of their beliefs around engineering identity. However, other studies do exist which avoid the pitfalls of discrete representation of results, like the 'Draw an Engineer Test'. This study asked young children "What does an engineer do?" and had them answer this prompt through drawing a picture, from which the researchers extracted the participant's thoughts on what it meant to be an engineer [9, 22]. Though this utilized a great open method of inquiry for younger children, it does not provide an appropriate methodology for us to inquire into the same things of college students.

2.3 Contextual Inquiry and Related Methodologies

2.3.1 Contextual Inquiry: Challenge around Inquiring into Nebulous Concepts

As such, we see a need for a methodology that will help participants articulate their conceptions of engineering identity in an open and age appropriate way. Looking at the literature, we can see the many methodologies developed by HCI researchers on how to inquire into similar conceptions like work practice, along with the complications that make such phenomena nearly invisible [36]. These practices share the burden with our research to try to shine light on nebulous topics, that are both difficult to be seen in

general but also run the risk of censuring what is allowed to be seen because of their social nature [36]. However, though identities have high overlap with work practice, work roles and values, they are not the same phenomena, and thus require different contextual inquiry methodologies to investigate.

2.3.2 The Turing Test: A Medium that Supports Engagement with Identity Characteristics

The inspiration for our methodology is based on the procedural cues from the Turing Test. First posed by Alan Turing, the Imitation game (also known as the Turing Test) inquires if machines have the ability to think, through performative measures of intelligence between man and machine. In this game, an interrogator must determine who is a man and who is a woman through a series of questions via text with a machine and man. Both the man and machine try to deceive the interrogator through pretending to be a woman, and thus display their intelligence [38].

Ever since this study was published in 1950, researchers have posited whether or not this model is the correct criteria to measure computational intelligence, with many focusing on what it means to have human intelligence and its distinction from machine [1]. Still, others have taken the Turing test to inquire what it means to enact identity online. Many of these studies focus on the conventions that come into play when we no longer have biological markers of identity and what social remnants remain in the way we ’speak’, even when trying to take on new roles online [41]. Berman and Bruckman take this concept to a new level in their ’Turing game’, an online game used to investigate how individuals try on different identities online, and the gaps between intended and perceived roles. To play, multiple participants join a game centered on some social role with one moderator. The moderator poses questions to the players who all assume (or try to assume) that social role, and convince spectators of their membership with their answer. After each question and response, spectators rate where they believe each player is on the spectrum of that social role. For instance, if players were playing a gender game and performing the male role, scores closer to 0 would represent perceptions of them actually being female whereas scores closer to 10 would represent perceptions of them being male [4].

To be clear, the inspiration we take from the Turing Test for our research has nothing to do with deception, but instead adopts its set up of dialogue between two participants online – both of whom assume no roles but act as themselves. The value that the Turing Test brings to our research then, is the idea that there is something to be learned about a person through conversation with them, even in an online space. It is not that we are asserting that freshmen will be able to figure out whether the person they are talking to is indeed an engineer or not because of this set-up (nor are we primarily interested in their ability to do so), but rather we believe that this setup will allow characteristics of the conversation partner to shine through their use of speech because "our choice of words is the result of a process of socialization associated with a particular identity" [41]. In turn, this makes the Turing Test set-up an ideal medium for our interrogator participants to engage with those characteristics and showcase their own thoughts on how they align

with engineering identity. These thoughts, not the accuracy of their implications, are what we are after.

2.3.3 Articulation Work: Consideration of Negotiation of Meaning

Our research also touches upon the concept of articulation work. Traditionally, articulation work is about the meshing of people's values, work roles, interpretations and so on into an arrangement that makes coordination around work possible [24]. This enmeshing is possible because of the existence of shared objects within a domain of work -- objects in which members of the domain have access to their information along with ways to manipulate it, and thus can create shared meaning. Yet, though shared objects are constructed in this democratic fashion, they can also be siphoned off into different activities, opportunities, perspectives or interests of specific individuals within the group, thus creating new meanings that must go back through the work of being negotiated within the group, the work of articulation, again [15]. As such, there are numerous sources of research that focus on the ways that group members do articulation work, and how systems can be designed to aid in this work [24, 35, 37].

However, our research is not situated within articulation work in this traditional sense for a few different reasons. Firstly, our research does not orient our understandings of enmeshed ideas about engineering identity towards learning about how this may allow for work in the engineering field to take place. Secondly, the main interactions that inform the articulation work that our participants do experience takes place outside of our study, as our methodology does not provide opportunities for them to negotiate their beliefs with other present engineering students. As such, the enmeshed view that our participants end up with is contained only within themselves and is not shared with the larger body of engineering students.

Yet, our research can be considered articulation work in a narrower view. Specifically, that our methodology allows participants to consider the many interactions they have had with shared objects of engineering along with the responses of their conversation partner to produce a negotiated understanding of engineering identity. It is these opportunities of reflection that provide the participant a space to engage with prior values, work roles, interpretations and so on that they have seen espoused from their peers, and consider how they fit within their own object worlds and system of values. Even furthermore, crucial to the work of articulation are the working relationships of group members that are characterized by social and professional identities and boundaries [37]. Thus one could say our work on freshman engineering students' beliefs about engineering identity is inquiring into an aspect of which articulation work is informed.

2.3.4 Action Research: Consideration of Potential for Intervention

We also must consider the potential of our methodology to affect our participants' thoughts about identity, which brings us to action research. At its most basic, action research is research that helps the practitioner -- or in our case students [23]. Specifically, action research seeks to share knowledge gained during a study with participants to imbue them as catalysts of change in the context studied, rather than take the results away

to apply them outside of cooperative agreements [39]. In this way, action researchers often consider how to engage and cooperate with subjects during research, because of their belief that involvement of all affected actors is needed to take action that leads to substantive change [23]. Specifically, for our context, according to Wagner's model of types of cooperative arrangements -- we take on notions of both clinical partnerships and co-learning agreements to engage with participants about engineering identity [39].

Still, action research is a contested concept that traces back to the rift between social and natural science. The general difference between the two sciences is that social science has to involve itself with context -- meaning that its work can never be completely divorced from the situation under which it is studied or be perfectly reproducible like natural science [14]. Yet, this view is in stark contrast to the general ideal held by natural science to study systems without disturbance, which has also been absorbed by social science. As a result, the beliefs around whether we can and should avoid such disturbance during research complicates matters for action research. Thus far, it seems that three camps have emerged around the issue -- namely that we can and should avoid intervention, that we cannot avoid intervention entirely but should limit it as much as possible, and that we should embrace and use intervention to improve existing systems [39]. The latter of these claims are that in which we see possible potential for our study.

2.4 Representing Knowledge

Additionally, we must consider the ways in which we represent our findings. From the literature, we know that there are almost infinite possibilities to do this. From Hartson and Pyla's UX Book alone, we come across numerous entities that embody information from contextual inquiry. These include raw forms of data like observations, interviews and work artifacts, along with crafted forms like Work Activity Affinity Diagrams (WAADs), multiple Design Informing Models (DIMs) including user models, usage models and work environment models, Information Needs and Barriers, Mental Models, Storyboards and Scenarios [19]. Yet, at some point we must make a decision about which representation to use, which we will not take lightly because our representations are what will be seen, discussed and used for designing the systems they involve [36]. Even further, we must be vigilant to recognize the ways that our own interests and goals cause us to make selections about what to represent and how, and thus see them also as an interpretation on the work studied [15, 36]. In turn, production of representation is work, and thus also deserves analysis [36].

However, this poses the question of what characteristics of representation we will strive for, and to more deeply consider what we mean by "actionable for design". Unfortunately, instead of providing frameworks to inform these initiatives, the majority of literature on this topic recognize the gap between theory and practice that explains why no such robust frameworks exist [3]. Still, a few related works do surface that can vaguely inform our selections among representations. Namely, we take actionable for design to mean those representations which consider relevancy, are usable for design, and avoid loss of information. The first two qualities derive itself from one of the first academic papers that recognize the gap between theory and practice, and call for guiding

structures to help showcase research results in relevant and usable ways for practitioners [7]. The latter trait, comes out of long standing initiatives to work disparate knowledge together [40], rather than taking on reductionist forms that leave out parts of lived experience of participants that are usually removed from standard representations, and make understanding the context in which knowledge was generated difficult and problematic for designers [35, 36].

2.5 Grounded Theory: An Open Approach for Open Research Questions

In order to choose an open approach for data analysis that matches our open research questions, we turn to grounded theory. Grounded theory has been used in HCI to study many different phenomena, in many different ways [28]. Specifically, grounded theory is a family of methodologies to develop theory, in which theory is drawn out from research through systematic analysis of data -- and thus it is said that the theory is "grounded" in data [2]. As such, grounded theory involves iteration and curiosity that creates opportunities for researchers to be surprised by the findings, because of its openness to discover new directions that can be freely pursued [28]. Additionally, one major practice of grounded theory is coding [20], or iteratively creating a set of descriptors that achieve increasing levels of detail and abstraction that illuminate an emerging theory [28]. Even further, grounded theory is particularly useful for making sense of a domain without dominant theory and with diverse phenomena [28]. As such, grounded theory fits nicely within our study which spans multiple disciplines (along with HCI which itself is interdisciplinary) and holds no dominant theory considering the lack of holistic research on the content of engineering students' conceptions of engineering identity.

3. METHODS

3.1 Study Procedure

In order to inquire into what freshmen engineers believe engineering identity is, we developed a technique that helps them articulate their ideas through comparison. Going over the basics, we had two types of participants -- we call the participant performing the main task (answering the question 'Am I talking to an engineer?') the 'interrogator' and the participant volunteering information about themselves the 'conversation partner'. As with any methodology study, it took us a couple iterations to get to the final product, though the heart of the method shown by the main task remained unchanged. Below we detail our pilot study, our reflections on it and the resulting changes we made to strengthen our approach into the main method we used for this thesis.

3.1.1 Pilot Study

To test our initial method, we employed a small round of the study with three interrogator participants from Galipatia and one conversation partner from the College of Engineering

at Virginia Tech. Before getting to the main task, interrogator participants first were asked a series of demographic questions that are listed in appendix A.1. Then they talked with their conversation partner online through a text-based chat room for ten minutes to assess whether or not this student was an engineer. To do this we used an IRC channel on freenode, after taking cautions to lock it and make it secret. Additionally, we registered the usernames 'studentguesser' for the interrogator and 'mysterystudent' for the conversation partner.

Also, in order to keep a participant focused on perceiving and decoding the characteristics of their conversation partner, rather than relying on other means that circumnavigate the goals of the study, we developed some ground rules for both parties.

- You must be truthful the entire time.
- You cannot talk about or mention anything with a proper noun that pertains to engineering or education:
    - Your name
    - The name of your college or major
    - The name or material of your classes
    - Whether or not you have ever lived in Lee Hall, or been a part of any engineer-only organization or group
    - Whether you are an engineer or not
- You can assume that your conversation partner also must follow the same rules.

After the ten minutes had passed, interrogator participants were given a span of up to 5 minutes to reflect and decide whether or not their conversation partner was an engineer. Once they reached a decision or time was up, they then explicitly stated their assessment and backed it up with reasoning derived from the conversation. Additionally, if the participant decided that their conversation partner was an engineer, they also claimed what specific major they thought this student was from and why.

However, the procedure for the conversation partner was slightly different. After being recruited they were asked to answer a few demographic questions found below.

1. What are your major and minors (if any)?
2. What is your year of graduation?
3. What is your gender?
4. What is your ethnicity?

During the study session, the conversation partner was tasked with answering all of the interrogator's questions and abiding by the same rules. They were also asked to give room for the interrogator to mostly lead the conversation, though they were still encouraged to ask polite questions or make casual remarks if they felt it necessary to keep the conversation flowing. The only major difference for this participant in terms of procedure was that they were located in a different room in the same building, to ensure that they did not cross paths with the interrogator on their way to the study.

To record data from the interrogator, we compiled written notes of observations of this participant during the task, a log of the conversation saved from online, an audio recording of their thought process while formulating their assessment as well as their final assessment, and answers to the demographic questions list as typed notes. For the conversation partner, we only collected their responses to the demographic questions as typed notes.

3.1.2 Initial Results, Reflections and Updates

After completing the initial study, we came across some odd behaviors and results. Firstly, our participants were taking a relatively large portion of their time in the chat room to engage in polite conversation with their conversation partner, rather than accomplishing the task. One participant in particular got so deep into conversation, that he completely forgot about the task and only remembered that his main objective was to figure out if his conversation partner was an engineer or not a minute before time was up. Additionally, some of the arguments participant's made from their time in conversation were not entirely believable, possibly not even to themselves. One participant said that the proper capitalization and punctuation that their conversation partner used pointed to a propensity towards technicality which meant they were an engineer. Another participant explained that most engineers at Virginia Tech were from Northern Virginia and that since the conversation partner liked outdoor recreation they were not likely from Northern Virginia and thus not likely an engineer. Lastly, participants seemed overwhelmingly hesitant to ask questions about anything academic related -- which missed a whole aspect of identity that we were hoping to acquire data on.

For a small while, we wondered if these shortcomings were a result of the task itself being too difficult for anyone to perform. Yet, taking our lead from literature we knew that even this early on our participants were acculturated enough to have some heart and head knowledge about engineering identity. Thus, instead we reoriented our focus to what was cognitively happening during the task, and in turn came up with some tweaks we believed could help. Firstly, we realized that our participants were probably experiencing some disorientation going straight into a conversation with a stranger in an online environment, as well as struggling with coming up with questions to ask on the clock. It was also possible that this stress led to poor questions, or at least less effective ones, which was why we were seeing odd conclusions drawn during the assessment session. Additionally, we believed that participants likely got locked into a conversational mode with their conversation partner because of this hesitation and disorientation, leading to confusion on what to ask them.

A simple but powerful fix to solve to all of these problems was to move the demographic questions to the end of the study and instead add a small session of brainstorming questions before coming to the main task, and augmenting the assessment session to 10 minutes. We believed that allotting five minutes to come up with questions for the task while thinking aloud, would both mitigate the disorientation that would come with talking to a stranger in an online environment, and produce more data for us on participant's conceptions of engineering identity. This added to our recorded data the

audio of interrogator participant brainstorming along with the paper that held the questions they brainstormed. Additionally, we felt that the wording of the task rules was also putting a strain on participant's ability to come up with fruitful questions that matched their actual thoughts. In looking over our notes, we realized that several participants did not know what a proper noun was, and that this formality was likely communicating to participants a large set of barred topics which we did not intend. Thus, we decided to change our task rules to be simpler, which can be seen below.

- You must be truthful the entire time.
- You cannot talk about individual persons, places, or organizations related to engineering, including:
    - Your name
    - The Name of your college or major
    - The name or material of your classes
    - Whether or not you have ever lived in a living-learning community based on an academic discipline, or been a part of any such organization or group
    - Whether you are of a certain academic discipline or not
- You can assume that your conversation partner also must follow the same rules. Therefore, do not ask for:
    - Their name
    - Their college or major
    - Anything about their classes or labs
    - Textbooks
    - Whether or not they have ever lived in a living-learning community based on an academic discipline, or been a part of any such organization or group

Lastly, we realized that though our methodology was likely to give us a lot of data on what interrogator participants thought about engineering identity in general, we had yet to create explicit opportunities for them to tell us what they thought about their own membership status. To add potential for this in our study, we created a question where participants could rate themselves on the degree to which they considered themselves engineers with an odd number scale to allow for participants to claim the middle, and then go on to give their reasoning. We also began to wonder if there was a way to get at any thoughts our participants had on engineering membership that they were not comfortable formulating into a question to ask during the task. In hopes to create opportunities for these ideas to be heard, we also created a survey question asking each participant if any such questions existed, along with a question about their ethnicity that we had missed earlier. All of these questions were added to our demographic survey, the updated version of which can be seen in appendix A.2, and can be found below.

3. What ethnicity are you?

18. To what degree do you identify as an engineer in general?
1 2 3 4 5 6 7
(1 - I do not identify as an engineer at all, 7 - I completely identify as an engineer)

19. What qualities about yourself make you feel that way?

20. Were there any questions during the task that you had but did not feel comfortable asking?

3.2 Recruitment

First, we recruited the conversation partners to set the base of our scheduling for the interrogator participants. Our primary goal for the conversation partners was to utilize different kinds of people to generate a wide array of characteristics for the interrogator participants to respond to. Thus, we decided to have 2 upperclassmen engineers (one male and one female, one from Galipatia and one not) and 2 upperclassmen non-engineers (one male and one female, one from Curvinci -- living-learning community collocated with Galipatia, and one not). In this way, we could test whether interrogator participant opinions were generated based on the entirety of what it means to be an engineer, or just what they have been exposed to in their living-learning community. We also wanted to ensure that all of our conversation partners had fully identified with their discipline, and thus we chose upperclassmen who had matured into their field. Lastly, the pairings between participants were made such that each conversation partner participant talked with about 6 interrogator participants, specifically 3 in two different sessions to avoid fatigue. In this way, we could gather multiple data points on identity with the same stimuli.

Next, we recruited the interrogator participants from Galipatia. To incentivize our potential pool of applicants, we struck a deal with Susan Christian-Arnold (Associate Director of the Center for Enhancement of Engineering Diversity (CEED) and by extension one of the leaders of the Galipatia community) that any interrogator participant could get one professional development credit for completing our study. As mentioned earlier, members of Galipatia have to acquire a certain amount of credits to pass the requirements posed by the community. Then to announce our study, we created a short advertisement that included the shallow aims of the study, a general description of the procedure, the necessary characteristics of the participant along with compensation. We dispersed this request primarily through Susan-Arnold who emailed this advertisement to members of Galipatia, but also through posting a paper copy of this advertisement in the main entrance of Lee Hall (where Galipatia members resided), and through the word of mouth of Resident Advisors (RAs). Interested students contacted us by email to sign up, during which point we checked that they were eligible and available at the same time as our conversation partners.

3.3 Analyzing Data

To recap the methodology, our open ended research questions led to an exploratory study which was designed to provide many directions and candidate phenomena for further inquiry. As a result, analyzing our data was not straightforward, and instead required an equally open ended process that involved time, iteration, and surprise. To fit within this approach, we decided to incorporate many aspects of grounded theory that allowed for such exploration. The following paragraphs explain how we combined systematic processes and open ended interpretation to achieve both rigor and an open mind in our research.

To start, immediately after the study we reflected on our initial observations and documented some emerging themes we were seeing just from experiencing the research sessions. These theme labels were as follows:

BUILD: to mark all instances of participants speaking about engineers' interest, ability, or involvement with building, creating, making etc.

CHARS: to mark all instances of participants speaking about personality traits of engineers

REAL/IDEAL: to mark all instances of tension between conflicting dynamics in engineers brought up by participants

SOCIAL AWK: to mark all references to stereotypes, participants being uncomfortable with the task or misunderstandings about the task

LIKE ME: to mark all instances where participants made references to themselves and similarities to their conversation partner

CS: to mark all references to computer science, specifically negative stereotypes put forth by participants

Next, we transcribed all of our data using parroting -- a technique where the researcher listens to an audio recording and speaks into a program via microphone that transcribes the speech to text, and then goes back over the transcript to rectify any small errors. After transcribing a participant's audio for the brainstorming and assessment sessions, we went back through their entire transcript and highlighted and annotated the text that corresponded to the initial theme set described above. Then, we noted any interesting dynamics that we were noticing for this participant in a separate data journal, before moving on to the next participant. As we continued in this process, we began to see other interesting themes emerge that were outside of our initial theme set, and thus began to also highlight them and annotate them with the theme label 'CHAR'. In order to keep our data set consistent, we then added to our process revisits to earlier participants after transcribing a few sessions to check their transcripts also for points of interest we had missed the first time. To be clear here, the quotes that we pulled out and marked as

interesting from the transcript had to relate to engineering identity in some way. For the brainstorming section, this meant all overt claims about engineering identity along with all questions participants proposed asking. For the assessment piece, this meant only overt claims about engineering identity and did not include the places where participants were generally reading off the transcript of their dialogue with the conversation partner.

After all audio was transcribed for all participants, we moved on to our first pass of coding the data using a grounded theory approach. To do this, we again checked that we had marked all interesting data points in a participant's transcript, and then added them to an aggregated table of codes. This table had a column for the code, a list of corresponding participant's IDs, along with the participant's quote tagged by the section of the data sheet where the quote could be found (Q - brainstorming, A - assessment, FA - final assessment, SI - self-identification) for traceability. Through this process we stuck to a bottom up approach, taking our cue from the data about when to create, split, merge or modify a code. Additionally, our codes were labeled using participants own vernacular to help us focus on describing engineering identity from their perspectives. This work continued until all participant data was coded.

Having a better understanding of the data, we moved on to double check our selection of data points as well as added duplicates to our table. To do this we again went through a participant's transcript to ensure that we had marked all interesting data, and marked any new points that emerged and added them to our table. Additionally, up until this point we had not allowed duplicate data points to exist in the table -- meaning that each data point was only associated with one code. Yet, during this pass when we checked each data point, we also went through our codes to see if there were others that the data was described by and added these duplicates to that code in the table. At the same time, we also took each data point and added it to a new table that organized all data from our study in chronological order per participant with no repeats or duplicates.

While coding, we began to see some emergent phenomena, which we will expand upon later in the Results and Discussion section. In brief, we noticed that participants often used indirection as a strategy for the task, and so we began to record these in a separate excel. We also started to pick up on other strategies that participants used, like relying on extrinsic values, asking about personality characteristics, and frequently pointing out commonalities between themselves and their conversation partners. Additionally, we began to realize how associative the data was -- in that participants described a vast network of interrelated criteria for engineering, rather than discrete entities. Lastly, we also documented the criteria and aspects of engineering that we were seeing across participants which surprised us in our separate data journal. Many of these initial points of interest gave us direction for what to pursue further, and ended up being the main findings of our study.

After this first pass of coding, we began to realize that the participants were not only articulating their ideas about engineering identity, but also working through their ideas during the task. To better understand how this development was occurring, we decided to do another pass of coding, but this time split the data into the subsections of the task --

namely brainstorming, conversation, assessment and final assessment, and track the changes in between each of them. Through this we hoped to get a better understanding of how participants were developing their ideas about engineering identity, as well as create a more comprehensive coding scheme.

For this second pass of coding, our process changed slightly depending on the subsection of the study being coded. For brainstorming, we started our coding in a new table, going through each participant's data points in our cleaned pool of brainstorming quotes. Our approach for this was much like that for our first pass of coding using grounded theory, and involved two cycles of going through the data. However, unlike our first pass of coding -- for this segment, we employed the use of a hierarchy of codes, and recognized more nuance between codes. For instance, instead of only having the code "Math", within "Math" we had sub codes like "Likes Math", "Is Good at Math", "Does Math", etc. Additionally, we had a cross cutting column to mark quotes that were only related to a code by way of indirection. Lastly, we also created a column to write down any other codes a code may relate to that were outside of the hierarchy of its parent-child relationships.

In contrast, our process for coding the conversation portion of the study required much more work because we had not factored this data into our coding up to this point. Thus, the beginning of our process involved going through all the pieces of the IRC Chat transcript and marking all interesting data points, and then adding them to our cleaned pool. During this time, we also went through each participant's question sheet to make sure that they did not write down any questions that they did not voice during the study. We then incrementally added these conversation data points to our codes in the table. Following grounded theory, we continued to create, split, merge and modify our codes to better describe our unfolding data set, and marked all newly created codes in blue to indicate that they emerged during this leg of the study. At the same time, we also checked to see if the conversation data point was related to the same code as its corresponding data point in the brainstorming section (if it had one). If it did not match, we filled out the indirection column with information on how this data point had changed between the legs of the task. After all conversation data points were factored into the table, we also went back to add annotations to mark the data points of codes that were talked about in brainstorming but not conversation for a given participant, and vice versa.

For assessment, our process looked like a combination of the procedures for brainstorming and conversation. We made two cycles through all the data, coding all quotes for each participant, and marking how they may have changed between the legs of the task. Codes continued to be created, split, merged and modified to accurately describe our growing data set. All codes that were created during this portion of coding were marked in purple. Coding the final assessment had the exact same process, except new codes that emerged were marked in pink.

On this second pass of coding, even more dynamics around engineering identity emerged from our data. For instance, during the brainstorm and conversation subsections, we came to realize that high school was a cross cutting aspect of the codes and began to mark it as

such in our excel sheet. Additionally, when we came to the assessment section, we began to see some of the criteria that surprised us from our first pass of coding emerge again, except this time more fully. These included phenomena like seeing engineering as effort and a discipline of challenge, the prevalence of math and science which were at odds with English and the humanities, and the contrast between the independent nature of engineers and the teamwork required by the field. Even further, we began to conceptualize participants' questions as generally targeted towards -- what I've seen in myself, what I've seen in others, the required nature of the work, and what fits in this university context. As another note, while coding the assessment we realized how similarity to self, which we had noted earlier, was actually the most prevalent strategy that participants used to sort out engineering membership. Lastly, while coding the final assessment section, we realized this was where the weight of stereotypes around computer science most often occurred.

Around the same time, we began to compile the results from our survey, which can be seen in appendix A.3. Specifically, we looked at general demographic information like age, gender and ethnicity, along with participant's intended majors, whether their parents' and loved ones were engineers, and the degree to which they considered themselves engineers. Most of these did not lend themselves to fruitful findings. However, our critical hit and miss table of guessing accuracy made us wonder which conversation partner participants categorized correctly and incorrectly most often. From restructuring this table to factor in which conversation partner was being categorized we were able to see how majors at the extremes were able to be spotted as engineering and non-engineering by participants, but those on the spectrum were most often missed.

At this point, we also realized that our process to analyze participant development was becoming unworkable. In trying to track the changes between the subsections of data, we were getting lost in minutia rather than forming a usable narrative about how participants changed their opinions about engineering identity during the task. To correct course, we decided to look at individual participants to see their flow and change throughout the study. Specifically, we were curious how participants reacted to the responses they received. To look into this, we decided to make a table that tracked what interrogator participants planned on asking their conversation partner, along with what they did ask, what responses they received and their reactions to those responses. We then annotated each of these tables in order to categorize the different kinds of behaviors and attitudes participants were demonstrating.

From creating these tables, we realized that one of the most interesting contributions of our study was how the methodology allowed participants to critique their own bias. Specifically, the developments they made were entirely from reflecting on their own opinions and pointing out their strengths as well as shortcomings. Additionally, we saw different types of change from our annotations - including adding more ideas, projecting onto their conversation partner, nuancing thoughts, and reworking their opinions partner. Even further, we found that there was similarity across groups of participants who enacted change in similar ways with similar attitudes. As a result, we formulated some case studies to use for further analysis later on, which can be found in appendix B.2.

During this time, we also realized that we had an enormous amount of codes (235 to be exact), which was limiting our ability to see patterns and trends across participants. Furthermore, our codes had many cross cutting aspects that made aggregation difficult which in the end we decided to simplify. In order to merge the codes we had, we used an open card sort to group topics in the spirit of what participants themselves were getting at. By this we mean that codes that held the same attitude or were about the same actual thing were merged, not codes that had similar language because of the same words used by multiple participants which were actually speaking to different phenomena. In the end, we were able to take our total code count down to 43 codes with high level categories of People in the Field, Personality Traits, Engineering Mindsets and Skills, Academics, Interests, Development, Effort and University Context, along with Place in Larger and My Thoughts. These can be seen in more detail in appendix B.1.

After creating these tables and merging our codes, we began to have clarity on some of the main contributions of this thesis -- namely articulation and development of engineering identity. For the former, our results centered on what participants articulated as their beliefs on engineering identity during the study. This piece was mainly informed by our aggregated codes which were possible because of the methodology's aid in allowing participants to project and add new opinions, and answered our research questions RQ1, RQ2 and RQ3. For the latter, we would develop a new research question, RQ3B, to cover the interesting findings we were seeing about participant's development of engineering identity. In contrast, this part was mainly informed by the tables and case studies we developed from tracking changes within participants, which was highlighted by the methodology's opportunities to nuance and rework opinions.

However, though discovering the duality and dialogue of these two aspects was an important step for our research, our grounded approach allowed us to continue to refine our understanding of our findings even after this point. Specifically, in trying to assess our participants' strategy and compliance of the task, even more complexity emerged around their conceptualizations of engineering identity. But to back up, first to ascertain strategy we tabulated the frequency of prevalent topics and behaviors and crossed referenced this deliverable with our interesting findings log to pick out common strategies. Then, we read through our aggregated codes and general transcripts to pick out the smaller tactics within these strategies. Additionally, during this time, we also looked into orientation and compliance through reading our prior notes and general transcripts.

From all of this review (and most centrally from strategy) we saw many of the ways that participants associated codes together. As a result, we developed a new research question, RQ3A, to cover the interesting findings we were seeing about participants' associations around engineering identity. Investigating this further, we continued to see just how complex participant's network of engineering identity was. This meant that the articulated aggregate that we had formed from the codes was only a shallow representation of how participants really understood engineering identity. In response, we moved towards highlighting these associations as well as contextual anecdotes about identity, which captured this complexity more fully; and as a result the thesis was

reconstructed to reflect these three levels of complexity - initial categories, associations and stories, along with the duality of articulation and development in each stage. Moving forward, further minor discoveries were made through referring back to these and prior deliverables.

4. RESULTS & DISCUSSION

4.1 OVERVIEW

Before discussing these three levels (4.2 Initial Categories, 4.3 Associations and 4.4 Stories) mentioned above that represent our findings on what participants believe engineering identity to be like, we first will give an overview of the data (4.1 Overview). Specifically, we will look into some of the traditional components of our research -- namely the demographics of our participants (4.1.1 Demographic), their common behaviors and topics of conversation (4.1.2 Common Topics and Behaviors), the strategy in which they performed the task (4.1.3 Strategy), along with their orientation and compliance (4.1.4 Orientation and Compliance). In this way, we hope to give a sense of our data that sets the stage for answering our research questions.

Then later, we will go on to showcase our results in more detail through describing levels of increasing complexity around our engineering students' conceptualizations of engineering identity. Specifically, we aim to not only share some of the complex and interesting notions participants had around identity (answering our research questions), but also use these to illuminate some of the affordances of the methodology and consider how we can represent our results in a way that is actionable for design. As such, this thesis is primarily structured around presenting each level of complexity, and then using commentary about the methodological and design implications that are illuminated from each level as the bridges between them.

Lastly, to be clear our goal in these sections is to represent the ways that participants' see engineering identity. As such, our results are meant to be read as the presentation of participants' beliefs about engineering identity, though we will try to limit the ways our own meaning making as researchers will come to bear on this as best we can. To provide an example of what this can look like, all references to "stereotypes" in our data refer to notions that participants identified as stereotypes, not what we as researchers or the general public consider stereotypes. This initiative will manifest differently in each section of our results, which we will point out as we discuss our findings.

4.1.1 Demographics

In the end, we were able to administer our study to 19 participants in total -- 4 of which were male, while the remaining 15 were female. All of our participants were 18 years of age except for one who was 19. Additionally, we had one Indian participant, one Hispanic, two Asian, and one participant who identified as African American and Caucasian. All of the rest of our participants were Caucasian. Also as indicated earlier, all

participants were freshmen in their first semester of General Engineering at Virginia Tech, who were also a part of the living-learning Community Galipatia. Lastly, all participants reported that they intended to continue majoring in Engineering at Virginia Tech. More in depth demographic data of our participants can be found in appendix A.3.

4.1.2 Common Topics and Behaviors

To get a feel for the collective sense of identity across participants, we looked into the frequency of prevalent topics and behavior. As mentioned earlier, we have labeled all of these topics using participants' choice of words from the study and described them to reflect participants' point of view. Our findings are summarized in the table below.

Table 1: Frequency Table of Most Common Topics and Behaviors of Participants

	Effort	Activities and Clubs	Science	Compare Majors	Hobbies and Free Time	Math	Gender	Indicator	Like Me/ other Engineers
Freq.	11	12	12	13	14	15	15	16	18

Additionally, we have also provided a table which explains each of these topics and behaviors.

Table 2: Description of each Common Topic and Behavior from Table 1

Common Topic or Behavior	**Description**
Effort	Notion put forth by participants that engineering requires a lot of effort, up to the point that even engineering extracurriculars can put weight or pressure onto a student who participates in them
Activities and Clubs, Science, Hobbies and Free Time, and Math	Most frequently used topics to create questions for the task
Comparing Majors	Technique in which participants made claims about engineering and their conversation partner's possible membership within it, based on comparing and contrasting engineering with other academic fields
Gender	Number of participants who either inquired about gender, made claims about how gender intersects with engineering, or tried to consciously or subconsciously place the gender of their conversation partner
Indicator	Commonly employed technique, where a participant would ask their conversation partner about a characteristic that would point to a characteristic of an engineer, while bypassing the engineering

	characteristic all together. For instance, one participant decided to ask their conversation partner if they played an instrument, explaining that this could indicate if they were good at and liked math -- a prerequisite for being an engineer, rather than just asking if their conversation partner was good at and liked math itself
Like Me/Other Engineers	Most common behavior that all but one participant employed was comparing their conversation partner to themselves and other engineers that they knew

What is particularly striking about this last behavior in our table, is that it means that participants have indeed begun to see themselves as engineers, to the point that even this early on in their academic development they have membership status that can indicate whether someone else belongs to their field.

4.1.3 Strategy

4.1.3.1 Overarching Strategy

Not only did we consider participants' strongly held beliefs about engineering identity, but we also looked into the widely held beliefs about how identity can become known. In particular, participants expressed strongly held beliefs that membership status could be found out through asking about their conversation partner's experiences, interests, circumstances, skills, personality, and activities.

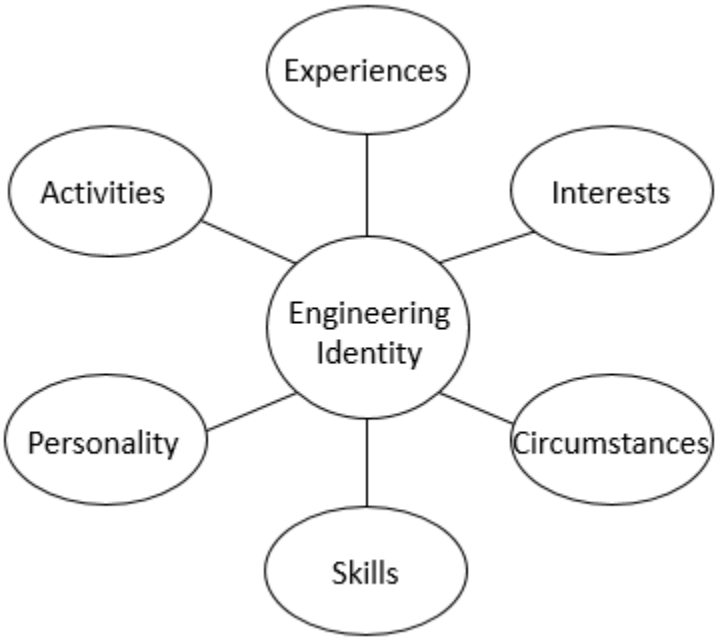

Figure 1: Diagram of Strategy Categories of How Engineer Membership can become Known

Circumstances was by far the most surprising of the strategy categories to emerge during our study. For participants, this usually related to aspects of Virginia Tech's Engineering program, with 10 out of 19 participants relying on this technique at some point to sort out membership. Some examples of questions about university context along with how they relate to circumstances are explained in the table below.

Table 3: Beliefs about Circumstances of the Engineering College that lead to Questions

Belief about Engineering College Circumstances	**Resulting Questions**
College requires that engineers have Windows Personal Computers	What type of computer do you have?
College requires a special form to exceed 20 credit hours	How many credits do you take?
It is difficult to graduate on time without taking many credits because the college program is credit heavy	How many credits do you take?
Students must have demonstrated high academic achievement in high school to become accepted into a competitive program	What were your grades in high school? What was your SAT score?
Students are stressed and overwhelmed because of the demanding nature of the program	Are you stressed out?

In fact, one participant even went so far to say that because engineers were so diverse, that university circumstances was the only definitive criteria for engineering membership, quoted below.

23A6|7: "And the biggest one I asked was what kind of computer and they said a Mac book. Which I did – they do say it can run windows but like – but like on the engineering website it says specifically like 'Hey we do not recommend MacBooks so like I haven't seen anyone engineering that has a MacBook 'cause like you have to split the hard drive to run windows in which case you basically have 2 separate computers and like it makes no sense not to just get a windows so like, I don't know I think that's like the biggest piece of evidence... On- that's kinda like I don't know like everything else is like I met a lot of unique people in like engineering so like they're all kinds of all over the place with like everything else is kind of like doesn't really narrow it down as much but I feel like that part they have a MacBook it's like, I haven't seen anyone with a MacBook in engineering I feel like that's like – and the engineering specifically says like 'Hey don't get a MacBook'. I feel like that's kinda, the most concrete proof I have that they are not

an engineer. "

Circling back to the categories as a whole (experiences, interests, circumstances, etc), interestingly enough, the topics that apply to these categories could live in multiple at any time. For example, participants asked about the topic Math in the context of all of these categories.

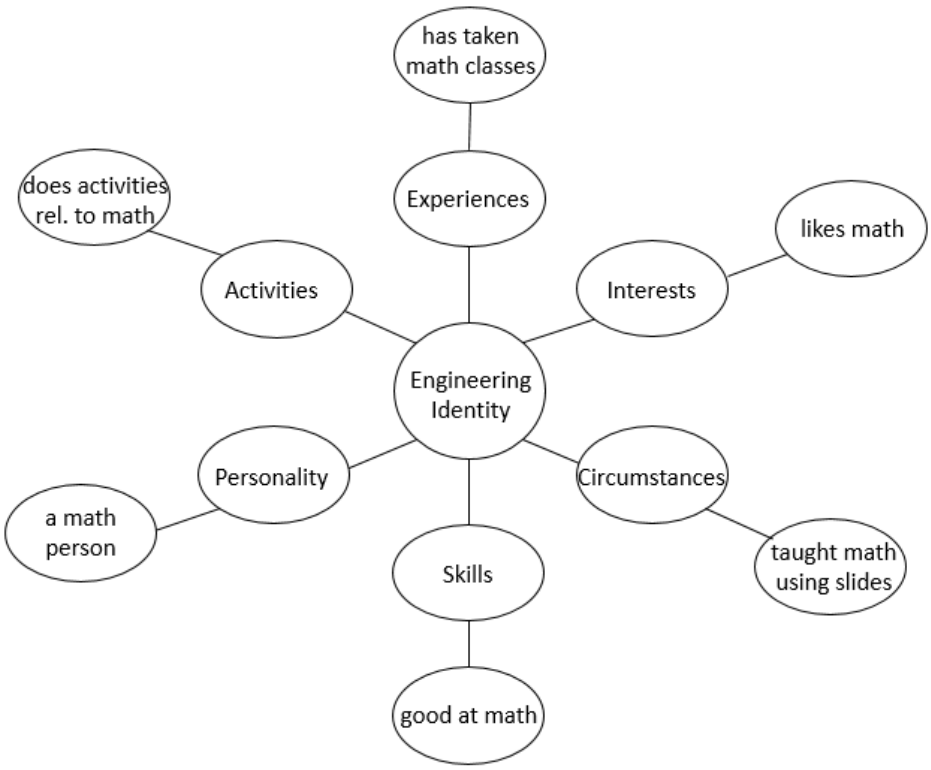

Figure 2: Diagram which Demonstrates that Categories have No Firm Boundaries

Even further, in some cases a single participant talked about a topic in multiple categories, and switched between them at multiple points while describing their ideas about engineering identity. For instance, participant 16 first said that she would like to ask her conversation partner if they liked math -- but then in her explanation talked about how being interested in math was derived from being good at doing math. Then in the conversation she only asked about interest in math, but in her assessment she again spoke to the nature of interest in math fluctuating with someone's ability in a math course during the semester.

*16Q4|7: "I think engineers - can I ask about like math? Like what they think about math?... Um what's your view on math? *laughs* ... (Um can you tell me a little bit more about um your thoughts behind 'what is your view on math'?) Yeah. Um I don't know I feel a lot of – um a lot of kids get scared if they don't like math in high school there like 'Oh I can't do engineering'... Like yeah so usually when they're engineers they're like yeah I was really good at math in high school I was doing well. So."*

16C3: <studentguesser1> Are you a fan of math?

*16A11: "Um 'Are you a fan of math?' 'I don't hate it but I wouldn't say I love it either' I mean that could be anybody *laughs* … Yeah she doesn't like hate it then um she doesn't love it. I mean I could say that about myself right now I'm having hard time. So like um I don't hate it either but I'm not like 'Yes! let's go to math class now'."*

Thus, this example and others in our research data show that participants do not see firm boundaries between these categories. Yet, it does indicate that they believe these categories can give fruitful data that speak to engineering membership.

Additionally, as mentioned earlier, many participants (16/19) focused on asking about traits that were not directly related to engineering identity, but instead indicated that their conversation partner could have engineering traits, which would then point to engineering membership. Expanding on our previous math example, participant 13 relied on this strategy to find out if her conversation partner was good at and liked math through asking if they played an instrument. Her explanation for her use of this technique, along with the depiction of how this relates to the general strategy categories, can be found below.

13Q8:"OK I'm gonna say like do you play an instrument. (Sure. What are your thoughts behind that question?) I know that um we were always told in high school that if someone plays an instrument that it like help - makes them better at math. I don't know but that's always been a correlation I guess 'cause like I play an instrument and um… I don't know I always thought that those 2 things went together well because I really liked math in high school and like playing uh the saxophone so."

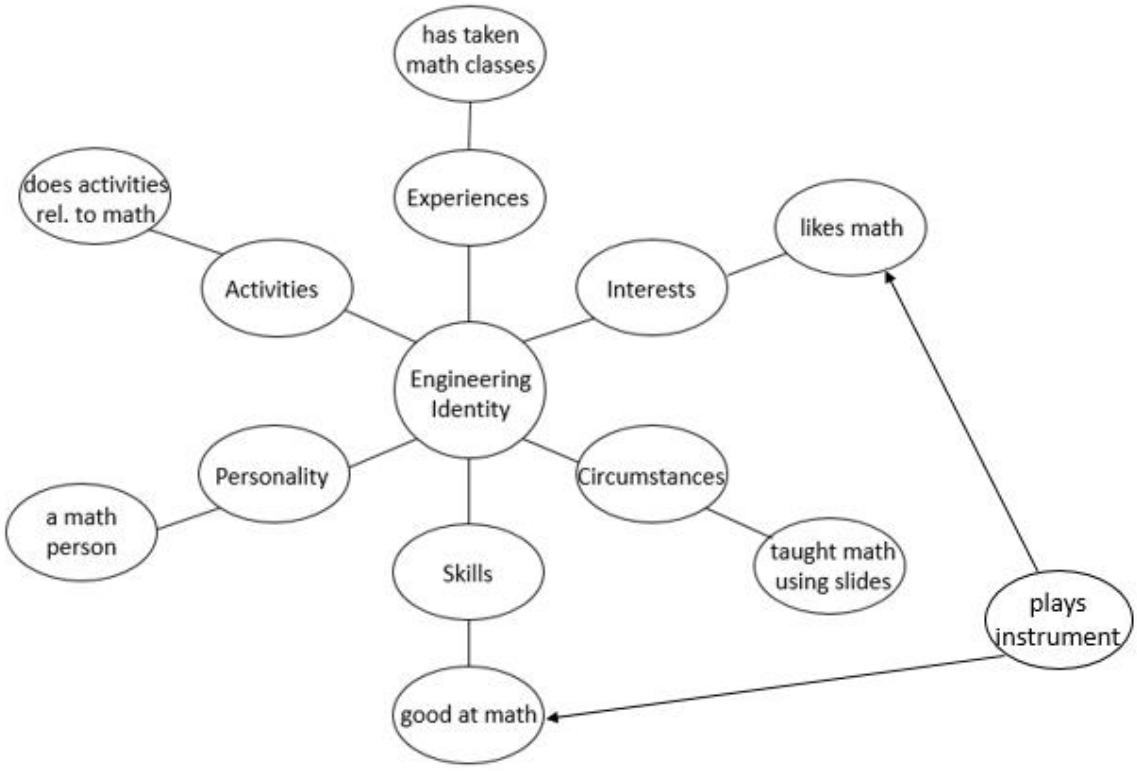

Figure 3: Diagram of Indication Strategy that Augments Strategy Categories

Though many participants used the indication strategy, they did so in many different ways. Some, like participant 13, decided to ask about indicators during brainstorming. Of these, some participants did so as a way to still inquire about characteristics that were barred by the rules imposed by the task. For example, participant 23 decided to ask how many clubs their conversation partner was in, as a way to identify if they were in an engineering club -- which was prohibited from asking by the task rules.

*23Q4: "Ask how like involved they are with school like a – not - like a extracurriculars I guess? … Yeah like how many like clubs and stuff they're in… 'Cause like - I don't know - a lot of the engineering specific clubs are like super like labor intensive and they like - so I don't know if they could - if they're in a bunch they're probably not in any of the engineering ones, so then they may not be an engineer. *writing* *fiddling with pen* "*

Still others relied on indicators during assessment by projecting onto the responses that they received, thus connecting them to engineering characteristics by way of indirection. For instance, participant 20 asked her conversation partner what they liked to do, and from the response learned that they liked hiking and volunteering at animal shelters. From this, she explained that maybe enjoying animals and nature could indicate that the conversation partner was a hands on person, which is characteristic of an engineer.

20A1: "We also talked about how they enjoyed playing with cats at animal shelters and at first that made me believe like maybe like they are more of a hands on person they like to you know – they're more outdoorsy so they like to um, actually like make stuff I guess. Um with like raw materials or something."

Thus we see that participants used a form of indirection both in anticipation for the task, and as a way to find use of the unanticipated responses they got from the task. However, it is unclear whether participants were cognizant that they were using this indication strategy. Only one participant made overt claims about this strategy, and gave a clearer reason for why asking about an indicator could be more powerful than asking about the trait itself, specifically for catch all situations.

7Q3: "What they like to do outside of class that doesn't really have to do with school… (What your thoughts behind asking that?) Um well even though it's not really gonna indicate whether or not there an engineer, 'cause I know for me my activities aren't directly related to engineering um. It'll kinda indicate what kind of skills they have, like depending on what they do - like teamwork. Um, 'cause like I know I'm in choir so teamwork or like working with other people or if it's more like an individually based task so."

Lastly, some participants ultimately decided to base their decision on intuition rather than any of the more concrete categories or the evidence they had acquired in each. In a way, we can see this as a rejection of the categories as a decisive strategy to unveiling engineering identity.

6FA4: "Umm they seem introspective which is - I'm also introspective so I guess it's less the information they presented and more how I'm connecting to it to myself that's giving me that the conclusion that they're an engineer. Because I can see some of the characteristics in between myself in them."

4.1.3.2 Smaller Tactics within Overarching Strategy

Within this overarching strategy of categorization, participants also employed some smaller tactics to decide whether their conversation partner was an engineer or not.

Firstly, participants often asked about their conversation partner's lives both in the present and past for many of the categories. One particular cross cutting criteria in this regard, was asking about high school -- with 9 out of 19 participants having one or two questions utilizing this aspect. Usually, participants asked their conversation partners what their favorite class was in high school, though on occasion they would ask about high school grades as well. However, the most prevalent question about high school was about the clubs that the conversation partner had been a part of. What is particularly interesting about this, is that all participants who asked about clubs in high school, also always asked about clubs in the present. What we can draw from this, is that participants believe that engineering identity is demonstrated overtime and not completely divorced from the past.

However, the by far most pervasive tactic that participants employed was making comparisons to themselves, their peers and other majors outside of engineering in order to sort out their conversation partners engineering membership. All but one participant utilized this strategy at some point during the study. Additionally, this topic was also the most consistent one to surface in all 3 parts of the study: brainstorming, conversation, and assessment. As mentioned earlier in Common Topics and Behaviors, what is fascinating about this is that even at such an early stage of their academic career, many participants are considering themselves engineers to the level of being able to use themselves as criteria to judge whether someone else belongs in their field. This showcases the way participants are developing their own sense of identity in engineering, and engaging with what it means to be an engineer. To provide an example, participant 6 explained the differences she saw between her problem solving approach and her mother, and how other engineers would be more likely to perceive problems and solutions the way that she does.

6Q8: "Can I ask them about how they problem solve or is that like too close to the material?... (What are your thoughts behind that question?) Um a lot of engineering is problem solving… Um. Again I have met some people um who are not in engineering and the way they try to solve problems is a lot different than the way that engineers try to solve problems. Um -... - Not in a bad way it's just different. Um like my mom for example – like obviously I'm not gonna like tell like if my mom… But like she jokes that - she's sad I'm not at home because I can't fix things for her because I always look at things differently than she does. And she has a Masters in um English and she like edits newspapers and stuff like that... But um the way that I look at a problem is a lot different than the way that she looks at a problem. (Mm can you give an example?) Sure! Um like

for example I have 3 dogs, so one of my dogs the latch on his crate broke and um because he likes to paw at it when he gets nervous cause he's scared of storms. And so my mom freaked out and thought like 'oh we have to buy a new crate now' and I was like 'um no we can just use a rubber band to like secure the latch so that way he can't break out'. Because he feels comfortable in there but if the door's open he gets even more nervous... I know he's a mess but it's OK. So like that was just an example of different problem solving."

Furthermore, the fact that participants also used comparison to their peers as a tactic for the task demonstrates their attentiveness to their peers and their status of belonging. This underscores the notion that participants are not only forming an idea about individual identity, but also starting to develop a sense of engineering identity as a collective. For instance, participant 24 mentioned the way she noticed her upperclassmen friends feeling pride and joy in creating artifacts for themselves rather than buying them, and how that could be used to decide whether her conversation partner was an engineer.

24A4: "So um, and they said that they do like creating things by themselves which - when I was thinking of like my friends that are either upperclassmen engineering or they have like the skills to make things there always like making things for themselves. This person thinks that they could buy like you could go by like an electrical long board or you could you know buy a drone but they you know like to build themselves 'cause they feel like 'oh I did that'."

Yet, two other tactics also emerged during the study that were in conflict with these strategies that relied on a sense of belonging, and intrinsic knowledge. When considering how a sense of belonging impacted participants, 5 participants grappled with how their own divergence from engineering factored into their decisions about their conversation partner's membership. The most common form of this was when a participant would share a trait with the conversation partner that was not representative of the engineering population. In some cases, this mismatch did accrue evidence for the partner not being an engineer. For one participant (22), it was even the main argument against the conversation partner being an engineer. Yet for other participants, they either completely stopped conversation for brainstorming about a topic they shared after identifying themselves as being different from engineering, or in assessment acknowledged a response from the conversation partner that was unlike engineering but made no comment about the bearing of it on their decision. From this, we see how though participants see themselves as valid members of engineering, they are not fully confident on what it means when their identities diverge from what they perceive most engineers to be like. This dilemma manifested in many different ways in our study. One example of this was when participant 22 wanted to ask if her conversation partner liked to read, because in her mind engineers do not like to read, but yet she does.

22Q7: "Yeah. Um… Um maybe ask do you like to read books? (What are you hoping to get out of that question?) It's very stereotypical and like, I'm an engineer and I like to read books but a lot I know a lot of engineers don't like to and they're more of the math and science based. It's very stereotypical but I don't know what else to go on. Um -"

Additionally, though participants relied heavily on using themselves as criteria for engineering in an intrinsic fashion, and at times wrestling with that, 5 participants also used perspectives from extrinsic sources to make decisions. To do this, participants would often state a claim about engineering and then explain that it had come from an authority in their lives, not from their own observations and lived experience. A good example of this is when participant 13 explained how she was told in school that engineers liked taking things apart and putting them back together again.

13A6: "Um I think the main thing is the working with their hands like taking things apart and putting them back together. Because that's something that I feel like is stereotypical typical of engineers. Like I remember whenever we went over engineering in school when we were kids they were like 'If you like taking things apart and putting them back together then you should be an engineer' and that's one thing I like doing so um. That's - I don't know I've always thought that was kinda indicative um but they said that they don't – or, they like the idea of it but never been good at it. Um which indicates to me like not - well one we have to do that in one of our classes. I don't know it just indicates that they're not – they're focus on something else and not on that."

What is curious about this is the fact that participants showcased trust in these institutions, through accepting the professed values as their own. We do not have much data on how that acceptance took place, but it does show that there are many sources at play that are dynamically interacting with participants' world views when it comes to engineering identity. This begins to showcase how complex the landscape of identity really is, and how our methodology provides an arena for participants to really wrestle with it.

Lastly, 9/19 participants actively tried to dissuade themselves from using stereotypes as a strategy. Again, stereotype here refers to what participants believed as stereotypical. As best we can tell, for them stereotypes are problematic characteristics constructed in their mind as "out there" -- a distant and often shallow or inaccurate social construct that they are responding to. Specifically, for strategy, this dissuasion included both decisions on what to ask their conversation partner and what to infer based on the responses they received. This phenomenon usually involved the participant calling out traits that they considered stereotypes or generalizations, and their apprehension about using them. For instance, participant 6 felt that her conversation partner's sentiment about the outdoors was particularly uncharacteristic of engineers, because she believed engineers are normally more objective, but then she went on to point out her reluctance in using that as a deciding factor because it was a generalization, as seen below.

6A11: "Um… they said 'when you're in the sun everything feels better' which is kinda like a romantic… less objective more emotional statement. Um in general I found that a lot of engineers aren't in touch with their emotions. So that once again makes me kind of again lean away from it. Um but again that's just a sweeping generalization so it's kinda tough. Umm so I'm kinda 5050."

This anti-strategy suggests that participants believe that there is a set of characteristics that describe engineers that are not stereotypical in nature, and that it is their job via the task to find this set. In turn, this has even bigger implications about the belief that such a set is findable, which leads us to the next section about compliance.

4.1.3.3 Summary of Strategy

Through presenting these strategies, we begin to answer our research question RQ3A about associations participants use to form networks around engineering identity. Additionally, we find that the methodology is not just showing what participants believe engineers are like, but is also presenting the complexity of that landscape and inviting the participants to walk through it. Specifically, participants believe that engineering membership can become known through asking about categories that do not hold firm boundaries between each other. Additionally, these categories are often associated with tertiary topics that can indicate engineering traits. Yet, some participants reject the notion that such descriptors truly do help define engineering membership, and favor using intuition and connection to make decisions instead. In this, we see the diversity that engineers have in their beliefs about how engineering status can become known.

Even further, participants believe that identity is formed overtime, and parts of one's past can inform engineering status in the present. Participants also see themselves as belonging to engineering to the degree that their likeness can be used to judge engineering membership, and yet, this criterion breaks down when participants identify the ways they themselves are not like engineers. This shows the uncertainty participants have around what it means to diverge from the collective sense, which they also are forming, of what engineers are like, and identifies the length they have yet to go to make peace with it. Lastly, participants also are actively factoring data from sources outside of their own experiences into their beliefs about what engineers are like, but become apprehensive about doing so when this data is attached to stereotypes.

4.1.4 Orientation and Compliance

4.1.4.1 Expressing Doubt about Ability and the Task

Some participants expressed doubt about their ability to perform the task. Specifically, 5 participants initially complied with the task, then started to indicate verbally or through using body language that the task was difficult, and eventually became unsure how to proceed. Some even went so far to say that they were unsure if the task would be possible without asking a question barred by the rules, as can be seen through participant 24's reaction below.

24Q4B: "No… I guess I don't know. I don't know how if I would tell if somebody's an engineer or not without asking them you know like 'Hey, what classes are you in by the way?' Um."

Some others explained that they felt that if they could talk to their conversation partner in person they could "tell" if they were an engineer, like participant 10.

10Q10: "Um hmm… what else are engineers like? (softly to self) I feel like it's hard to like find specific… it's more like - I don't know you just like know if someone's an engineer… (Mm. That's interesting. So you feel like you know? Like you can know?) Mm, like If you have like a long conversation with them and get to know them. I don't know. But then like there's always people like who don't fit that mold, so."

In turn, it becomes unclear if it was the task that was difficult, or it was the situation in which they had to do the task that was difficult.

Furthermore, for the subtask of figuring out the engineering branch of the conversation partner (if the participant claimed they were an engineer), 4 of 7 participants expressed doubt about completing this task almost immediately, rather than trying to perform the task first and then casting doubt on its reasonableness. Participants did this either through saying that asking for engineering branch was difficult, having startled and overwhelmed reactions when asked to do so, or both.

*6FA6B: (Which branch?) *breathes in overwhelmingly**

6FA7: "Sure um so because I'm not certain it's kinda difficult. There was no like one specific thing that like made me think yes they're an engineer and yes they're in this. So going off my instinct I guess assuming that they're already an engineer I'd probably say… Man um. I don't have - I don't know a lot about the different branches of engineering like I know that they each do but I haven't met – there isn't one specific person I could say because of these specific characteristics then they're civil or their environmental or the mechanic or biomed or um they're electric."

Additionally, a few participants were unable to articulate their rationale for why they wanted to ask a question, and there were varying levels of confidence in ability to perform the task across all participants, though generally all participants did get more comfortable as the task worn on.

Yet, although all participants completed the task, one which implies engineering identity is possible to decode, almost all participants wrestled at some point or another with trying to find such a set of descriptors. By the time they came to assessment, many gave up the belief that any one characteristic could pinpoint engineering membership, and instead described how the many different characteristics of their conversation partner interacted together in complex ways to illuminate membership.

Yet, a select few participants were never fazed or surprised by the difficulty of the task -- suggesting that they doubted from the onset of the session that a finite set of descriptions about engineers existed. Specifically, these participants were very reluctant or hesitant to say that any one characteristic points to or against engineering. For example, participant 6 explained the conflicting dynamics surrounding engineering students' relationships with research.

6A7: "Um they're not doing any research. Um I haven't met a lot of people in engineering who do research. I do research personally but not through - like kind of engineering kind of not. You don't have to be in engineering specific research you can be in research that is not based in engineering and still be an engineer... So not being in research makes me think that there probably um either one of 2 things. One they're probably not in a STEM major because a lot of STEM majors are really research focused. There's a lot of push for that especially in Virginia Tech, the undergraduate research is a big part of the STEM community... But conversely a lot of engineers don't initially get into research because it's very difficult uh to do that as an undergraduate so. That's kind of like the two sides of the same coin, it's just um kind of tough."

Even more so, participant 18 was very reluctant to ask almost anything because of the overlapping relationships with other majors. In general, he seemed to be looking for a silver bullet, questions that would "give it away". This was interesting, because it still posited that there was a finite set of characteristics that could point to engineering membership, but it also nullified asking about almost all such traits because of their potential to be a part of a different field's personality.

18A10: "A couple hours a week - I don't know I've heard horror stories about how hard some of these upper classes are but then again a couple hours a week most colleges should have to spend… (What are your thoughts on the procrastinating versus getting it done immediately?) Uh the reason I asked if they were procrastinating immediately was 'cause if they get it done immediately but they still have to stay up late I'd assume they have a lot of work to do... they study a couple hours a week, I could see that actually. If they go to class and pay attention that doesn't count as studying. Then they got just have to review what they know and then -"

Taken all together, these reactions suggest that participants were not entirely convinced that the task itself was a reasonable one. In turn, this doubt has even deeper implications about the ability for engineering identity to become known, and further complicates the landscape of participants' beliefs surrounding identity.

4.1.4.2 Embracing the Task

Still, many participants went beyond what they were asked to do and decided to insert themselves more fully into the study process. For instance, 3 participants said that they came up with questions beforehand while reading about the study. Participant 19 even brought a whole written list of 17 questions to the study, where she even marked ones that could tie together to make the conversation more fluid.

19Q10B: "(Yeah cool. Uh what do the triangles mean?) Oh triangles are um more of personality questions I would say. Yeah I was trying to group them 'cause when I wrote them those questions it was more of just like oh what questions can I like think of. And then eventually… especially with regards to fluidity I wanna make sure when I'm asking whoever I'm asking then it would be like slightly segwayed or something like that."

She also identified that she chose to do the study because she was curious about her own conceptions of engineering and wanted to learn that about herself.

Furthermore, 11 of 19 participants opened up about the status of their own merging and diverging when it came to their membership in engineering. Those that did so spoke to this both during the task and the survey where we asked them to self-identify the level to which they saw themselves as engineers and why. Thus, it was not surprising that engineers spoke about their own engineering status, but the amount of vulnerability many showed when explaining themselves was particularly striking.

8SI: I am definitely not a 7 because I did not come to VT knowing exactly what wanted to do as engineer. I did not know what engineers did so I could not be really engaged in it. I feel disconnected from people who are gun hoe about engineering.

11SI: People at home would ask - ask me what I was doing in college. I would say engineering – and they were surprised by it.

22SI: So well first of all, I wonder if I shouldn't be in engineering... Sometimes I wonder if I am smart enough. Also I like other things - I did well in English and history in high school. Sometimes I think I should branch out but I don't know what I would do.

25FA: "(Yeah. What um - you said that she didn't say anything that um made you feel like she was going towards mechanical. What would you have expected her to say that would have pointed her - pointed you to feel like she was going to mechanical.) So a lot of my classmates um in my engineering class, they just have backgrounds with certain things like they used to work cars or they like - they were like just like super into machines they like planes. And her hobbies didn't say anything like 'I really like this thing'. She's kinda just like 'Oh I did a bunch of different things I enjoyed'. Um, and I don't know - I feel the same way. I wasn't - sometimes I'm like did I come from a different world?!... Like they already have so much experience with like coding and like um, just machines and they already know like the jargon like what everything is called and I'm like what? I don't know any of this, so it's kinda like - I don't know…"

4.1.4.3 Summary of Orientation and Compliance

In summary, we see the irony in how using a methodology which suggests that engineering identity can become known, allows participants to wrestle with the truth of such a claim. Additionally, this methodology gave participants a platform to struggle with the status of their own merging and diverging process within engineering, through comparison of someone else's membership. Taken overall, it seems that participants had equal parts casting doubt upon the task, and embracing it to further develop themselves.

4.2 LEVEL 1: INITIAL CATEGORIES

With a general understanding of our participants' behaviors within the task in tow, we can now move on to explain the content of their ideas in more detail and thus describe our first level of complexity here. Specifically, to answer our research question about

participants' conceptions of engineering (RQ1) and our research questions about consensus and variance among such conceptions (RQ2 and RQ3), we compiled our codes from grounded theory to showcase the image of what freshmen engineering students believe engineers are like. Through this we are able to demonstrate the initial forms of complexity that exist around our participant's beliefs.

4.2.1 Consensus and Variance in Participant Beliefs about Engineering Identity

To represent our findings on these initial categories, we constructed the table below. All codes are labeled using participants' own terms, though we recognize the limitations of a word to capture the same meaning across participants, us as researchers, and the readers of this thesis. As such, we have worked hard to best capture the overarching spirit of participants' beliefs, and we will also go into more depth on what they mean in the section that follows our discussion here (4.2.2). Additionally, these codes are pulled from the brainstorming, IRC conversation and assessment portions of the study -- and thus makes no distinction between participants initial and final thoughts on identity. Some of these codes overlap with those we reported in Common Topics and Behaviors, though everything represented here is based on participant belief about engineering identity and not also their behavior during the study. Here we report the engineering trait, its popularity, its valence and whether or not the valence opinion was unanimous. Terms that appear together under a code are those that co-occur together across participants. Also, Diverse valence means that there was no prominent valence view on that code, while NA means that an orientation towards that code does not make sense and thus one does not exist.

Table 4: Codes that Describe what Engineering Students believe Engineers are Like

Code	**Number of Participants**	**Majority Valence**	**Unanimous**
Math	13	Positive	Y
Science	10	Positive: but 5 also mentioned the importance of balancing with other fields	Y
Problem solving	8	Positive	Y
Team Player (allegedly)	8	Positive: but ⅜ point to tension	N
Enjoys Challenge	7	Positive: but 19 is negative	N
English/Read/Write	7	Negative: except 25 and contradictions exist	N
Humanities	7	Negative: except 13	N
Likes Outdoors	7	Diverse	N

Thinker/Objective	7	Positive	Y
Introvert vs Extravert	7	Positive: stereotype about introvert, Negative: need good people skills to do group work, and many others point to a mix	N
Build/Fix	7	Positive	Y
Makes/Creates/Invents	6	Positive	Y
Hands On	6	Positive	Y
Involved in STEM	6	Positive: though 6 points out some tension	Y
Has Hobbies Related to Engineering	6	Positive: 20 sometimes	Y
Likes certain kinds of TV Shows/Movies	6	Positive: 13, 18 (maybe more)	N
Involved in Engineering Activities/Clubs	6	Positive: except 10 says probably not	N
Organized/Structured	5	Positive: but 16 is 50-50	N
Likes Video Games	5	Positive: weak 13, 15	N
Does/Not Sports	5	Diverse	N
Inspired by Role Models, Activities, Current Events/Inventions	5	NA	N
Creative	4	Positive: but 10 thinks not necessary	N
Service Work	4	Positive: but 6 believes it could be diverse	N
Has Parents who are Engineers	4	Positive	Y
Does not take more than 20 credit hours	4	Positive	Y
Likes Specifics/Details	3	Positive	Y
Someone who Perseveres	3	Positive: but 13 thinks is	N

		generic	
Draws	3	Positive: but 24 negative, 21 says could mean art	N
Programming Experience	3	Positive: 18 claims it is weak because other fields have this too	Y
Music	3	Positive: though 13 says is not unique to engineers	N
Likes science fiction	3	Positive	Y
Spatial Visualization Ability	2	Positive	Y
Does Internships/co-ops	2	Positive: 16 though other majors could as well	Y
Has mostly Engineering Friends	2	Positive	Y
Likes Puzzles/Legos	2	Positive	Y
Not Motivated by Money	2	Positive	Y

From this, we can see that there is a large amount of overlap in the way that participants saw engineering identity, and yet also many discrepancies. There are many categories that had unanimous opinion -- in the sense that all participants who brought up this topic agreed that engineers would have the same orientation to it. These traits include:

- Math
- Science
- Problem Solving
- Thinker/Objective
- Build/Fix
- Makes/Creates/Invents
- Hands On
- Involved in STEM
- Has Hobbies Related to Engineering
- Has Parents who are Engineers
- Does not Take more than 20 Credit Hours
- Likes Specifics/Details
- Programming Experience
- Likes Science Fiction
- Performs for Admissions
- Spatial Visualization Ability

- Internship/Co-Op
- Has Mostly Engineering Friends
- Likes Puzzles and Legos
- Not Motivated by Money

One interesting thing to note here, is that some participants agreed on the same valence for engineers even though they themselves diverged from this. To use the same example that we mentioned earlier in the Strategy Section, in English/Read/Write participant 18 and 22 both reported that they themselves like to read, but that the majority orientation of engineers was negative when it came to reading.

However, there were other categories that had a majority valence but also included a few participants who felt that the trait could lean either positively or negatively depending on the individual, while also recognizing the overarching orientation. These traits include:

- Team Player
- Enjoys Challenge
- English/Read/Write
- Humanities
- Likes Certain Kinds of TV Shows/Movies
- Involved in Engineering Activities/Clubs
- Organized/Structured
- Likes Video Games
- Creative
- Service Work
- Someone Who Perseveres
- Draws
- Music

For example, most participants identified a positive valence towards engineers participating in service work. Yet, participant 6 explained that though she usually sees service work as a pastime of engineers, she also knows many engineers who are quite selfish and do not fit into that description.

6Q2|6: "Whether they are service based or not. Like do they enjoy doing service work… Mm… (long pause) Can you tell me a little bit about the service based question?) Yeah. Um the reason I'm asking about service work is because a lot of the engineers that I've met like personally all have some sort of desire to help people whether - through something that they make. Um I've have some friends who are not engineers and I notice that's not a big - as apart – like there still interested in helping people but it's not as much a big deal with them. Like it is…"

6A10: "Um um of course it varies from person to person. I don't wanna make any like over generalization characteristics because I've met so many different people. I've met engineers who are completely self-less and I've met engineers who are completely selfish.

So uh it's difficult to say entirely um. Especially since my perspective is so limited to people like me so - who happen to be engineers."

Still, there were some other topics that had such diverse opinion, there was no prevailing consensus or valence. These include:

- Extravert vs Introvert
- Likes Outdoors
- Does/Does Not Like Sports
- Efficient

For example, for introvert/extrovert many participants expressed a positive valence towards engineers being introverts either because of their own experiences or stereotyping. Yet, some participants explained that because engineers had to involve themselves in a lot of group work, that it would make more sense for them to be extroverts, thus having a negative valence towards introversion. Still other participants reported that since many of the engineers they knew were a mix, or they themselves were, that a mix of introversion and extroversion was most common, thus almost rejecting a valence towards one side all together.

23Q3:"Ima ask them um whether they consider themselves introverted or extroverted… It's kinda a stereotype for engineers, to be like more introverted. I feel like that one doesn't have as much to do with like the specific majors' kind of like a stereotype though so -"

*5A4: "Umm... *tut tut tut* He's um ESTJ so he's like more one the extraverted side... He's also like a thinker, and J is like organized and stuff like that so… Um, yeah – I'm definitely leaning towards saying he is an engineering."*

6A4D: "Um they said they are introverted and extroverted and which is a mix. Um most people I know also are - most people being in engineering are both introverted and extraverted so I'm not entirely sure about that. "

Furthermore, participants not only explained their conceptions of engineers, but many also made claims about the nature of the field itself. Some of these findings about conceptions of the field have also been showcased earlier in our Common Topics and Behaviors section -- the difference again being that behavior of participants is not represented here, but all other sentiments participants had about the field as a whole are summarized in the table below

Table 5: Codes that Describe what Engineering Students believe the Engineering Field is Like

Code	**Number of Participants**	**Majority Valence**	**Unanimous**
Relationship to other	14	NA	NA

majors/fields			
Sees engineering as a lot of work	9	Positive	y
CS is different from the other branches	6	Positive: but 19 says the same because of problem solving	n
20 Credit Hours	4	Negative	y
Women have different interests than men - eclectic	3	Positive	y
Performance for admissions (well rounded, balanced): grades and well rounded	3	Positive	y
Windows Computer	3	Positive	y
Demonstrative Nature of Engineering	1	Positive	y
innovation vs invention…	1	NA	y
work is about helping people	1	Positive	y

What is interesting about this snapshot of the field is that every topic that came up about the engineering field had unanimous agreement on valence across participants, except the notion that computer scientists were different from other engineering branches. When it came to this topic, many participants explained that computer scientists were different than engineers because they were more conceptual rather than hands on and they had even worse people skills than other engineers, along with one participant explaining that she felt their curriculum was more rigorous. Yet, participant 19 explained that at their core computer scientists were still problem solvers, and using that as her ultimate definition of what an engineer is, for her that meant they fit within the discipline.

19SI1: (Do you have any family members or older close friends who are engineers?) I don't think so (family/engineer) – lots of people in computer and computer science. (I think it's interesting that you make this distinction between engineering and computer science – can you elaborate on that for me?) Whenever I talk about engineering, people say that it is not engineering. But I do because engineering has a whole lot of subsets, and there is definitely an overlap. You [referring to me the computer scientist] solve problems in regards to a more analytical way I guess? Like program and logic, make solutions with regards to a problem. I find that you guys are problem solvers and if you are problem solvers then you are engineers.

4.2.2 Interesting Themes within Participants' Beliefs about Engineering Identity

As far as the actual content of participant's conceptions, there exist a few interesting dynamics in the most frequently brought up codes from both tables (in bold) that we would like to draw attention to. To do this, we will present more on our own assumptions as researchers, along with the context in which participants made claims about engineering identity, and point to some specific participants who championed certain topics as being meaningful to identity, all in an effort to better reflect the meaning held by these different groups.

Firstly, we were surprised that intelligence was never mentioned as a characteristic of an engineer by any participant while performing the task. Instead, like mentioned earlier in Common Topics and Behaviors, participants constantly and consistently pointed to the amount of effort that was required of an engineer to do engineering work. This included things like the large amount of work that engineers do on a daily basis, the intensity of stress they experience because of it, the association of effort even with extracurriculars in engineering and the difficulty of the material that leads to tutoring and requires dedication to push through the curriculum.

*23Q2: "And then… And then uh for uh, the next one I'll ask like 'bout how many hours they spend on homework a week... I know personally from my engineering classes I have like a lot of homework, and I know some friends who are in like uh - some other - other majors that have like nothing to do ever. *smiles* "*

*24Q5|7: "Hm. Are you stressed out? *chuckles*… I feel like everybody stressed out but… (Can you tell me more about the - the stressed question, like where is the – for engineers where do you think –) I think like everyone in engineering I mean everybody in college is stressed out. But I know when I was like, you know I decided to come to Virginia Tech – wanted to come to Virginia Tech everyone's already sending me memes about how stressed Virginia Tech engineers are – (*gasps*) compared to everyone else."*

23Q4: "Ask how like involved they are with school like a – not - like a extracurriculars I guess? … Yeah like how many like clubs and stuff they're in… 'Cause like - I don't know - a lot of the engineering specific clubs are like super like labor intensive and they like - so I don't know if they could - if they're in a bunch they're probably not in any of the engineering ones, so then they may not be an engineer. "
16A4+5:"Uh she doesn't tutor but I know not everybody tutors I should have asked if they've been tutored /'cause I know -… - I should have asked have they been tutored... I know a lot of kids a lot have to go to office hours they have to, 'cause a lot of classes are really challenging… (Oh you mean engineers.)"

*25Q9: "Um, how dedicated are you to school. 'Cause you gotta be dedicated to engineering 'cause it's hard. *chuckles* "*

Another category that seems to be missing is gender. In this table, we take gender to describe situations in which participants made claims about gender in terms of engineering, which does not include the amount of participants who made references to the gender of their conversation partner -- which is instead represented in Common Topics and Behaviors and elaborated on in Stories. As our table shows very few participants explicitly asked about gender, but those that did explained that women engineers have more eclectic tastes than their male peers.

*15A9:"... fiction and then when she said sappy romantic novels I'm like you're a girl. *chuckles*... (At one point I remember you said 'this is so much harder because she's a girl'.) Yeah. (Could you elaborate on that?) Yeah so, the girls in engineering I feel like tend to be much more diverse in what they like. The guys tend to be much more straightforward like - a lot of the girls are tomboys but a lot of the girls aren't. A lot of girls are like to dress up and a lot don't. Like if you see me... Um my roommate and I are really similar in like the kinda person that we are but we also have very different likes. So it's really hard to like tell. I feel like with a guy it would be easier to tell. Um, I don't know girls are just more abstract. *chuckles*"*

What is interesting about this, is that participants were indeed willing to use population as an elimination category for other less taboo subjects like reading, as mentioned earlier. And yet, they did not do so when it came to demographic categories that are statistically known for the engineering field, like gender and race. However, two participants did bring up race but from a point of trying to reject the validity of using it for the task.

9A5: "And Indians how we get the engineers. Um so you know like that stuff definitely exists like the – like you are doing well in school can go into like uh… X you know field… (So are you saying that - which fields are you saying… So there's like getting high grades and getting high grades point people…?) I'm not - I feel like people just kind of assume, like 'oh you're doing well in school what are you – you're gonna be a engineer, lawyer or a doctor'... So I was just trying to step back from that."

19SI7: There's also always the question about asking race and gender – but race does not define anything about engineering.

19AI8: Assuming this person was a male – Eagle Scout. There is definitely a mix of different genders, but I know a lot of males are doing engineering but you can't always base that.

Additionally, we would like to point out that the category of Outdoors crops up as often as it does because many of the conversation partners liked outdoor recreation and explained this when asked about their hobbies. This then spurred on a conversation about how engineers intersect with the outdoors, and resulted in widely different interpretations of that relationship amongst participants. Yet, for the 8 participants whose conversation partners did not talk about interest in the outdoors, only one directly initiated conversation around this topic.

From our table, we can also see some interesting tensions come to light between characteristics within this image of engineering identity. For one, participants pointed out that engineers look at the world objectively and work through tasks pragmatically, but they also spoke about engineers as creative people who enjoyed and participated in more subjective ventures like drawing and science fiction. Even further, often the same participants who spoke about engineers as objective and practical, also professed that they had creative values. In fact, for participant 25 almost all of her ideas of what engineering is, hinged on the balance between creativity and practicality.

25A12: "Um and then you have to be both practical and creative and that's a very engineering like too 'cause like as I said before you have to have a plan and be like 'Oh this is a problem' and be creative fix it and can't go on like a long tangent you have to like - you know actually brainstorm regarding the problem at hand. Hm, I'm leaning towards yes she is an engineer."

25FA6: "Um 'If it's something interpersonal or related to stuff I'm working on I like to implement them' so if it's relevant. And if it's practical. Which is what I'm getting so that makes me think she's very, logistical and like 'This makes sense I will do it'. She's also creative but she just kinda like – um what's the word like - not a - like in moderation. Like she's very creative but she knows when is the time to implement her creativity and when it's the time not too."

Another tension we see from our table is between the necessity of teamwork for the field and the prevalence of the independent nature of engineers themselves. Most participants talked about the importance of teamwork to have successful engineering projects, and how in turn that ideal encouraged them to consider traits such as liking teamwork, having experience with group projects or having skills within teamwork as highly indicative of an engineer. One participant even went so far to say that she believed an engineer would come to value teamwork primarily because of their formative experiences with it through the school curriculum. Yet, two participants talked about how this ideal is in conflict with the strong independent nature of an engineer's personality, that they have seen manifest in disastrous ways in their classes, like participant 16 below.

16Q10B|11|12: "Uhh how do you experience group projects. (What are your thoughts behind how engineers experience group projects?) Um I just know that um - are these freshmen? I wasn't sure… are these freshmen… or could they be…? … OK. Well I just – I don't know I feel like you get exposed earlier I don't know in - because in my engineering class like Foundations of Engineering they do a lot of - like every project is a group project and you have to learn how to work with everybody even if they're like different majors than you. And - and everyone has just like a different way – some people take charge and some people are lagging behind. Um. (Do you think that… So there's the idea that in your foundations class that there is group projects uh, and that's kind of like something that you know engineers here experience. Do you think that engineers have a propensity to um uh gravitate towards or away from group projects or or - or do they have some kind of way that they - they handle that or…?) I think it's harder for a lot of - I don't - I just say this 'cause when I sit in a room with STEM majors I can tell like talking

*to them. And it's it's - it's there's a lot of butting heads and like especially at first, um there's not a lot of agreement 'cause I just feel like they're very like – we're very headstrong some times. And we're gonna do it this way we're gonna do it this way beforehand. Like we were - at least at Virginia Tech, we did well in our high schools and there's like a lot of head butting. I know like - I mean my group got along but I know other groups like hated their entire engineering group - (Oh wow okay.) -'cause no one gets along cause they all have different ways of thinking. Um at least freshmen I guess at least freshmen - (*laughs*) - because everyone is new... Um, because, it's a lot more, I don't know I know especially 1216 which is like a very hands-on kinda semester class um you have to get along with people."*

One participant also indirectly pointed to this tension when she explained engineers' tendency towards self-reliance, but also then also pointed to the importance of being an external thinker to more easily facilitate group work.

7A3: "Um she doesn't like to work in group projects as much. Um. She prefers working individually which I find is like very common with engineers, like we don't really like doing group projects just because um we're very reliant on our own skills. Even though engineering itself is generally like team based."

7A4: "Um she says she's an external thinker which I think is like a good skill for an engineer to have. Um because that's generally what you'd be doing in the job like talking things over with other people."

Moving on to other tensions and referencing back to our Common Topics and Behaviors Section, we see that not only did some participants consider computer science as different from the other engineering branches, but they also believed that they were anti-social. Even further, participants explained that though most truths about stereotypes for engineers were circumspect at best, for CS these negative perceptions were indeed true.

6FA8: "I'd say probably not a computer engineer. A lot of computer engineers I've met, this is a stereotype that is kind of held true, um are very like antisocial so – and like kinda like recluse. So the fact that they go out with their friends I'd say probably not that... Um going out and enjoying nature I've found is not something that's typical of computer engineers so I can rule that out."

Yet, as we see from the table -- asking about programming experience was an important criterion for some participants when assessing engineering membership. That being said, there was no overlap between participants who believed in the negative stereotypes about computer scientists, and those that saw value in programming for the field of engineering. Still, this tension suggests a complex relationship between engineering and computer science that we have yet to fully uncover, but will expand more on in the Stories section.

Additionally, initially alluded to in Common Topics and Behaviors, participants reported that engineers associate themselves with math and science -- either that they are interested in it, good at it, or often involved with it. Though this finding did not surprise

us, the amount of antagonism towards other subjects like English did. From the start of brainstorming, many participants explained that engineers would not like English, reading, or writing, and some even anticipated asking their conversation partner if they liked math *or* English, showing that they did not believe someone (or at least not an engineer) could enjoy both. After talking with their conversation partner in the IRC chat, participants continued to harp on a negative orientation towards English, reading, and writing, and even expanded this to include other academic fields that cropped up from the humanities. In addition, as mentioned earlier, this antagonism was so prevalent that even participants who did like these subjects identified the prevailing negative view towards the topic, and did use it as evidence for engineering identity like participant 22 below.

22Q7: "Yeah. Um… Um maybe ask do you like to read books? (What are you hoping to get out of that question?) It's very stereotypical and like, I'm an engineer and I like to read books but a lot I know a lot of engineers don't like to and they're more of the math and science based. It's very stereotypical but I don't know what else to go on. Um -"

22A3: "he did say he is more of a math person. So I'm definitely leaning towards he's majoring in something not on the English side so it's definitely math or science related."

Lastly, participants also spoke about engineers as people who enjoy challenge, though this took on many forms. Some participants talked about engineers in terms of their innate desire to fix the issues they see in the world, and engage in that process rather than taking on a passive role. Other participants talked about the independent nature of engineers, like participant 16 who gave an example of how engineers might enjoy the challenge of caring for themselves and solving all of the problems that come up in backpacking. Similarly, participant 24 gave an example about creating things yourself rather than buying them to illuminate the pride engineers have in providing for themselves. Other participants talked about the importance of being able to persevere, because engineering work often involves multiple failed attempts before success.

24A4: "So um, and they said that they do like creating things by themselves which - when I was thinking of like my friends that are either upperclassmen engineering or they have like the skills to make things there always like making things for themselves. This person thinks that they could buy like you could go by like an electrical long board or you could you know buy a drone but they you know like to build themselves 'cause they feel like 'oh I did that'."

Thus in the end, we get an initial glimpse of the complexity and contradictory understandings of engineering identity professed by participants as whole. Yet, this snapshot would not be possible if it were not for the opportunities provided by the methodology we developed.

4.2.3 Methodology Affordances: Helping Participants Articulate Beliefs about Engineering Identity

Thus, from our findings we can see that the methodology did indeed help participants articulate what they thought engineers are like, because of its reliance on comparison. Specifically, this technique provided two important opportunities to participants -- stimulating their thought process and in turn allowing them to report more characteristics as the task wore on (which we call 'adding'), as well as giving participants the chance to project engineering characteristics onto responses from the conversation partner that they did not anticipate (which we call 'projecting').

We believe 'adding' occurred during the study because participants had time to delve deeper into the task through its progressive stages. As a result, participants' wheels would turn and they would begin to call upon more dynamics around engineering and report them. In fact, participants continued to bring up new traits about engineering even when they no longer had the chance to ask corresponding questions. For example, participant 5 was talking about how her conversation partner liked music when she remembered a tendency of engineers to be detail oriented which could showcase itself through practicing music. As a result, she wished she had asked about that dynamic more specifically earlier in the task.

5A5: "And I think like oh he really likes music and stuff which I do too… Ugh, you know what I should have asked?... It would have been interesting to ask if like when it comes to music, does he like - like the more technical side of it, like making it sound like perfect ... and like when he's practicing does he spend hours like perfecting something specific or does he just, just enjoy listening to it and the beauty of music sort of... (What's your – What's your thoughts behind what – how that question could be interesting?) Um – I don't know because for me personally like I – I love both -... But at the same time like when I'm like sitting down to practice piano or if I'm like learning a song or something I will – I get very caught up in the details because I want it like all to sound perfect throughout. And I mean I get that might just be a personal thing. But um I do feel like a lot of engineers that I've met are like very detail oriented and they like – kinda like the logistics or like the - the technical aspects to be on point sort of... And I guess that would also tie in with like the left brain part."

Similar to 'adding', participants would divulge more about their thoughts on engineering identity through 'projecting'. Since participants were trying to figure out if their conversation partner was an engineer, they operated in the mode of looking for engineering traits. Though this sounds like a simple observation, what it really means is that participants were constantly trying to 'read' engineering traits into the responses of their conversation partner. Essentially, this scenario helped draw participants' beliefs about engineers out into the open where we could record them. For instance, this is illuminated by the example mentioned earlier in the Overarching Strategy section about participant 20's conversation partner who reported that she liked the outdoors. Prior to receiving this response, participant 20 had not mentioned anything about the outdoors, but during assessment projected onto this statement a tendency to be hands on. It is

possible that participant 20 had a pre-existing notion that the outdoors was linked to a hands on nature, but considering how that association did not pan out which confused participant 20, this rather suggests that this association was quickly put together in order to assess engineering membership. What matters here is that we do know participant 20 does believe that engineers are hands on, which was brought to light through the opportunities embedded in the methodology.

20A1: "We also talked about how they enjoyed playing with cats at animal shelters and at first that made me believe like maybe like they are more of a hands on person they like to you know – they're more outdoorsy so they like to um, actually like make stuff I guess. Um with like raw materials or something."

20FA4: "Um. I'd say like when I was thinking before when I said that they seem to be more of an outdoorsy person possibly, but I believe that their answers from that kinda muddled the playing field a little bit. (Can you talk about that? Maybe – yeah maybe talk about some of the places in the transcript that, swayed you into maybe thinking they weren't an engineer?) Um Some of the things that like made me believe they weren't would be that um - well they did say they're outdoors but then they said that they didn't consider themselves as a hands on individual. And so that kinda – that's kinda iffy because at first maybe - I thought maybe they are part of an engineering field where it's more like - maybe like computing and a ... thing rather than actually making stuff."

4.2.4 Critique of Representation: Seeing Engineering Identity through the Lens of Object Worlds

Though not captured by the table above, an additional layer to our work is how the way participants associate these traits are vastly different. For instance, to return to our math example we presented in the Overarching Strategy Section, we can provide an association to math for every category of identity.

Experience: For participant 9 math manifested in engineers through their experiences of taking math courses.

*9Q6: "*mutters* like in high school maybe it's the AP courses that they took like - *more muttering* 'cause like I took more AP math and science, like it's something you know um. Maybe – (OK so like where were they putting their focus in?) Yeah."*

Interest: In contrast, participant 23 explained that engineers would relate to math because it would be one of their favorite subjects.

23Q1: "Alright, so like first question I'm gonna ask is like what was your favorite uh subject in high school, 'cause I feel like it's - most engineers are going to say math and science. I feel like it's a pretty strong link uh..."

Circumstance: Still participant 16 believed that engineering identity could be sorted out through looking for the type of learning style that came with the circumstances around math classes.

16A7: "Um and like the last question uh she takes notes on things the professor says isn't in the slides. I personally don't have a lot - haven't had a lot like classes, well I'm only a freshman so like personally I don't know much, like the classes that I really need to be writing very vigorously they aren't using slides. They usually use an overhead projector where they are also writing with us, where they're like saying it out loud... Um or like they're on the chalkboard and like - it's like very rigorous like you write everything that's on the board they don't usually use slides. I just say that about my math classes. Um um I'm sure it's like kind of the same for - for I don't know I haven't taken chemistry here. I just know like in physics 2 when I was in high school – when I was in high school there - there were hardly any slides um. I know they usually use that for like my history classes and stuff. Um I don't know how professors teach professors do different things but, um it just went through my head um. "

Skill: However, participant 13 pointed to the relationship engineers had with math through being good at it.

13Q8: "OK I'm gonna say like do you play an instrument. (Sure. What are your thoughts behind that question?) I know that um we were always told in high school that if someone plays an instrument that it like help - makes them better at math. I don't know but that's always been a correlation I guess 'cause like I play an instrument and um… I don't know I always thought that those 2 things went together well because I really liked math in high school and like playing uh the saxophone so."

Personality: Participant 22 explained that math is linked to engineers because they are math based people.

22Q7: "Yeah. Um… Um maybe ask do you like to read books? (What are you hoping to get out of that question?) It's very stereotypical and like, I'm an engineer and I like to read books but a lot I know a lot of engineers don't like to and they're more of the math and science based. It's very stereotypical but I don't know what else to go on. Um -"

Activities: Lastly, participant 21 believed that engineers were associated with math because they were involved in activities based on the application of math.

21FA1: "I would say that this person is not an engineer… I think that just because they um just bec- they do like math but I don't think that they like the applications of math based off of what their hobbies are um, a lot of times like people who play - who play instruments um have like sort of math brain because they have to like think about the notes and stuff, and um Sudoku and brain teasers like that they involve numbers are fun but they're not about like the applications of numbers."

Thus, though most participants agreed that math had a positive valence, the way they imagined math manifesting in an engineer's identity was vastly different.

And yet, taking a cue from Bucciarelli's work on 'Designing Engineers' we should expect this. More specifically, in the same way object worlds exist in the work of engineers, they also exist in the identity of engineers. Thus, if we take identity itself as an object, or manifestation of the way our participants understand how engineering works through defining the workers, we see that the principles of object worlds apply here as well. This means that there is no one maker, and no one knower of engineering identity, instead, the understanding of who an engineer is, is distributed across multiple people and constructed and negotiated through the many experiences of those people within their unique contexts. Furthermore, not only is this object of identity distributed across people but it is also continually shifting with time, because the scenarios that our participants lived through and used to construct identity are continually modified, told and retold both in life and during the task [6].

In fact, what our study is actually surfacing is much more complex than a list of engineering characteristics. Through the task our participants are doing the work of negotiating their object worlds through trying to sort through and reconcile these scenarios in real time. Through this, we are getting a sense of the deep complexity and intertwingled nature that identity takes on [33]. Additionally, with this frame of reference it makes sense why engineering students did not just talk about what an engineer is, but also spoke to what they do, as "What is it?" and "How does it work?" are intimately tied in the object world. Lastly, it should not surprise us that university context has arisen as a trait of engineers, for this reflects the specific context our participants were operating within, since infrastructure brings its own to bear on the object of identity [6].

4.2.5 Summary for Initial Categories

In sum, the aggregation of our codes for our research did bring about some initial fascinating and nominally complex ideas around participants' understandings of engineering identity and how they may vary, which begins to answer our research questions RQ1, RQ2, and RQ3. Specifically, some codes had unanimous orientation in terms of how they related to engineering, while others held a majority stance with a few outliers, and still others were widely diverse. In addition, we were also pleasantly surprised that participants also articulated some of their thoughts about the nature of the engineering field at large. As for some of the specific content of these findings, we learned that participants valued effort over intelligence, avoided gender as a strategy for the task, relayed some relationships between outdoors and engineering, showcased tensions between objective and creative tendencies of engineers, held a prevailing negative view of computer science, outlined the standoff between math and science and the humanities, spoke to how the teamwork required for the field was at odds with engineers' personalities, and that engineers in general enjoyed challenge.

Yet, all of these findings would not be possible if it were not for the opportunities provided by the methodology which allowed participants to articulate these opinions through 'adding' and 'projecting'. Still, when critiquing this representation through

lessons from object worlds, we come across another important finding in this section. Namely, that conceptualizing our results through discrete categories is a weak and inaccurate way to represent participants' beliefs. Thus, we move on to the next level of complexity by representing our participants' conceptions of engineering identity through associations in the next section.

4.3 LEVEL 2: ASSOCIATIONS

Flowing from the previous sections, we see that the landscape of engineering identity is quite complex and composed of many associations rather than the clean categories we presented in the Initial Categories section. To come to the same conclusion theoretically, academics in the field of cognitive science model this phenomenon as the combination of Classical Computational Theory of Mind and Representational Theory of Mind.

Classical Computational Theory of Mind (CCTM) postulates that the mind is a computational system whose core mental processes are computations that execute in the style of Turing Machines. In contrast, the Representational Theory of Mind (RTM) proposes that thinking happens in the language of thought, or mentalese - a compositional structure of symbols. It postulates that the meaning of a complex mentalese expression is the function of the meaning of its parts along with the way the parts have been combined. Thus, together CCTM + RTM theorize that mental activity involves Turing style computations over the language of thought, or that mental computation stores mentalese symbols in memory which are manipulated by mechanical rules [34].

Otherwise stated for our study, we can model participant's conceptions of engineering identity through noting not only the objects (symbols) they invoke and their composition (mentalese expressions -- represented by the entities in Table 4 and 5 in the Initial Categories section) along with their valence (propositional attitudes -- also in these tables), but also the kinds of associations they use to connect them (the way mentalese parts, be it simple or complex expressions, are combined -- represented by the strategies explained in the Strategy section). Up until now we have mostly talked about these objects and associations in isolation to help describe their particular role within engineering identity. Yet, this depiction of how engineers perceive identity is incomplete. To showcase a better representation of participants' beliefs about engineering identity, in this section we will demonstrate the CCTM + RTM model through showcasing a few mind maps of some participants and calling out how their objects and strategies interact together to produce them.

For reference, mind maps are graphical nonlinear hierarchical representations of ideas (nodes) connected to a central theme, by way of links [26]. They first emerged as a note taking technique developed by Buzan that utilized both sides of the brain in order to help students learn more effectively [8]. Mind maps were then elaborated on further by researchers like Novak and Gowin based on the theory that meaningful learning occurs when students relate new concepts to their preexisting network of ideas. To showcase this, Novak and Gowin used mind mapping to represent the structure of students'

knowledge and discuss how they could then fit what they were learning into this structure [29].

Even further, mind maps have long been used to represent the knowledge a group has about a certain subject, including unconscious thought [26]. Additionally, research has shown that through the process of creating mind maps, the creators more deeply learn about the topic area [16]. Thus, mind maps are not just a great choice for us to use to represent participant's conceptions of engineering, but also to help us understand their mental model more deeply through creating them.

For our purposes, we have chosen three cases to showcase. Firstly, we have a participant (5) who heavily interrelated her own ideas about engineering with the responses she received from her conversation partner through many different kinds of associations. From this we hope to present an example of how associations can be used to form a tightly integrated image of engineering. In contrast, we also have a participant (18) who was reluctant to use almost any criteria to judge whether his conversation partner was an engineer, because of the potential of each of those criterions to be associated with other academic fields. From this we hope to present the complexity of engineering as related to other fields, along with some initial difficulties of representing progression of thought with mind maps. Lastly, we have a participant (20) whose conception of engineering underwent the most change during the task because of her effort to reconcile her initial associations with the responses from her conversation partner. This example will lead us into the following section about how the methodology did not only help participants articulate their ideas about engineering identity, but also helped develop them.

Furthermore, in each case we will describe the participants' mind maps in terms of the subtasks of the session - brainstorming, IRC chat, and assessment, and use their own terms as the basis for labeling each node so that we can better represent their individual perspectives on engineering identity. In turn, we will answer some of our research questions, including those about conceptualizations of an engineer (RQ1) and which associations participants use to form networks around those conceptualizations (RQ3A) in detail on an individual basis, along with some of how participants' opinions might change during the task (RQ3B).

4.3.1 Case 1: Heavy Interrelation and Projection

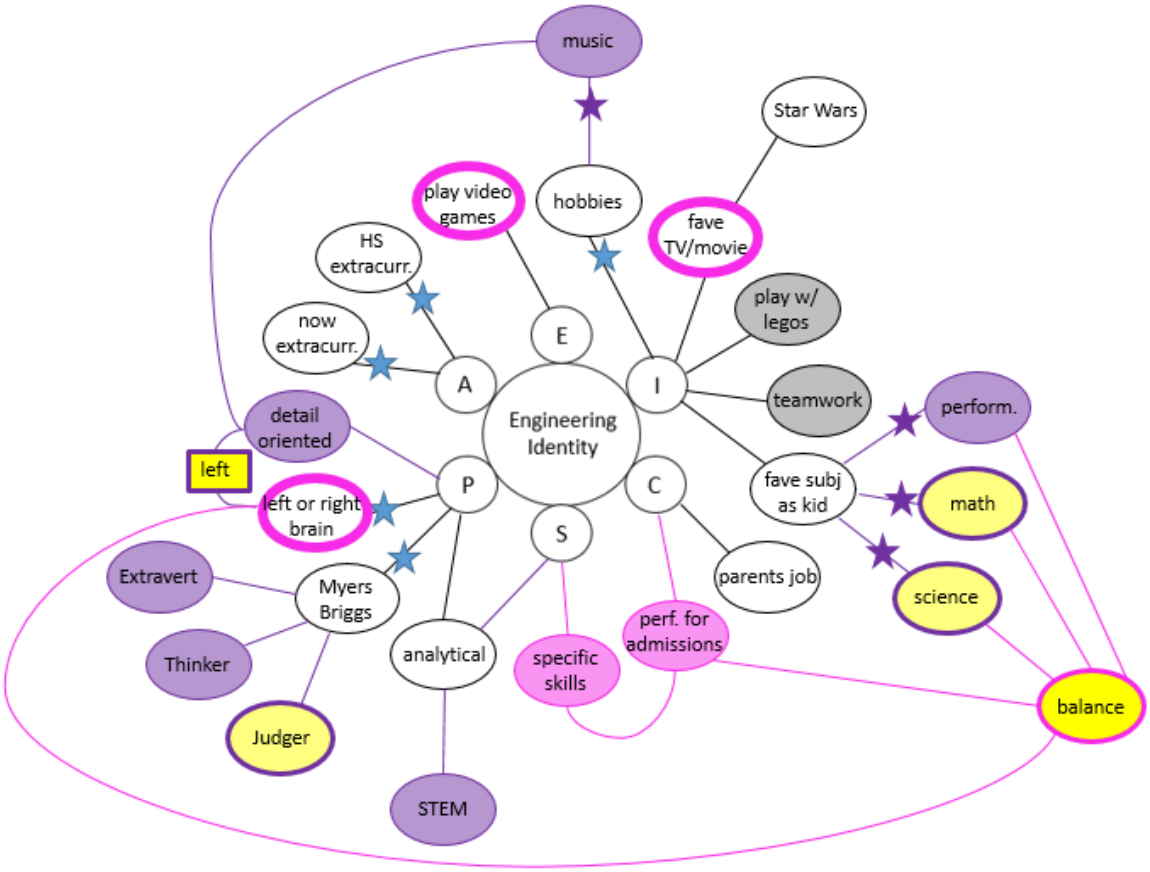

Figure 4: Participant 5's Resulting Mind Map

4.3.1.1 Participant 5: Brainstorming

Starting with participant 5, we learn a lot about her ideas about engineering identity from the questions she asked in the brainstorming session.

5Q1: "Can I ask them like – what their Myers Briggs personality is?... Mm okay. So I feel like that could kinda give some indication possibly."

5Q2: "Can I ask them like, what their hobbies are?"

5Q3: "Umm or like maybe what they are involved in in high school?... like extracurricular? "

5Q4: "Oh – can I ask them like what they are involved in now, as well?"

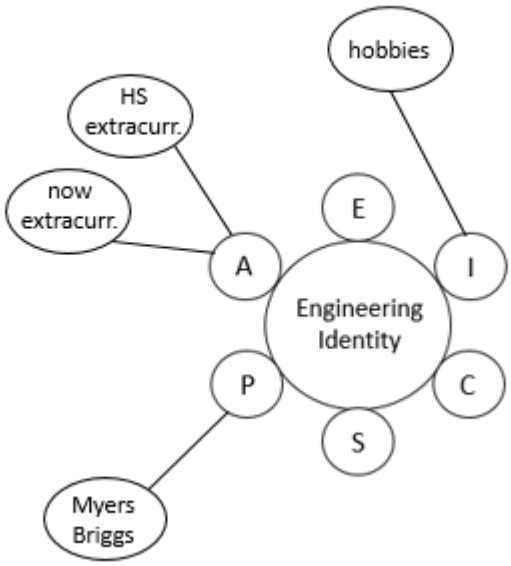

Figure 5: Participant 5 Mind Map 1

Here we see the initial mind map starting to form. Basing this off of our original categories we established around how identity can become known in the Strategy Section, we see that participant 5 intends to learn about her conversation partner's interests through asking about hobbies, their personality through asking about their Myers Briggs and their activities through asking about extracurriculars. As such, we can consider these facets as ones that participant 5 believes have a relationship to engineering identity and so we add them to our mind map. Additionally, we also see the association across time come into play, mentioned earlier in the Strategy section, as participant 5 asks about extracurriculars both in high school and the present.

5Q5: "Can I ask them what their parents work as maybe?"

5Q6: "I could do personality things maybe… So... Can I ask them something like, would you consider yourself like an analytical person?"

5Q7: "Oh – and maybe if they like working in teams?... Well... I guess it can go two ways. I guess I think engineering is like basically all about teamwork and stuff so… and at the same time there are a lot of engineers who don't really like working in teams - "

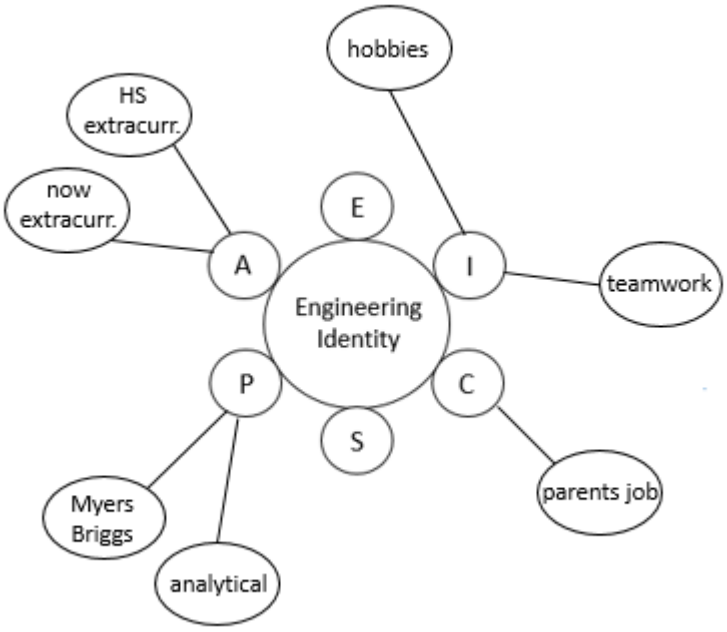

Figure 6: Participant 5 Mind Map 2

Progressing with the mind map, we now see that participant 5 wants to ask about her conversation partner's parent's job, along with if they are interested in teamwork and are an analytical person. Even further, participant 5 has now identified a conflict with two associations. On one hand, she associates engineering identity with what is required by the nature of the field, namely teamwork. Considering Bucciarelli's Object World Model where doing and being are intimately tied, this makes sense [6]. However, this is in stark contrast to her belief that there are also many individuals within engineering that do not like to work in teams. What we will see later on, is that whenever participant 5 comes into contact with a large conflict like this, she often drops the criteria all together, as she does in this case, rather than trying to reconcile these inconsistencies.

5Q9: "Is it… Is it – I can't ask them like what their favorite subjects were… like maybe as a kid?"

5Q10: "Maybe like… Do you like… Do you like playing with Legos?"

5Q11: "Umm… Is it too obvious to ask if you are left brained or right brained?"

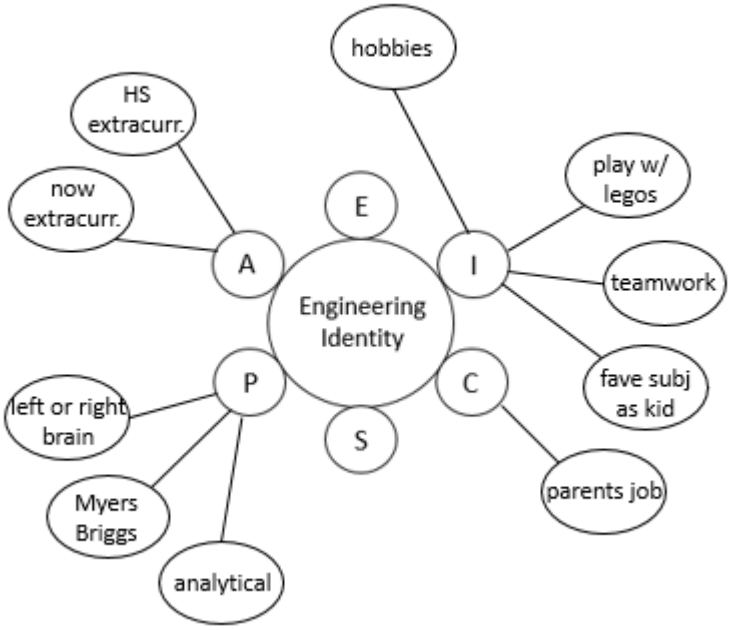

Figure 7: Participant 5 Mind Map 3

Here, participant 5 again harkens to the past and thinks about asking about favorite subject as a kid and playing with Legos. She also proposes asking her conversation partner if they are left or right brained.

5Q12: "And… and... Oh and what's your favorite TV show slash movie?"

*5Q13: "Do you play video games?" *smiles**

*5Q14: "(What kind of responses are you thinking about getting for movies and TV shows? To use -) … Uh… I don't know, I feel like it depends if it's a guy or a girl… Umm I think like, almost, like every single engineering guy that I've ever met like loves Star Wars... But I mean that's again like something across the board. But I feel like… I've never met an engineer that doesn't like Star Wars - except for me... (Oh no!) Yeah so… that's interesting." *laughs* … I think TV Shows… Huh… I don't know, like it's hard – 'cause I mean I don't wanna like stereotype... - but I guess at the same time like, part of this is seeing like if stereotypes are true in a way (Yeah I – yeah the study could lend itself to that)."*

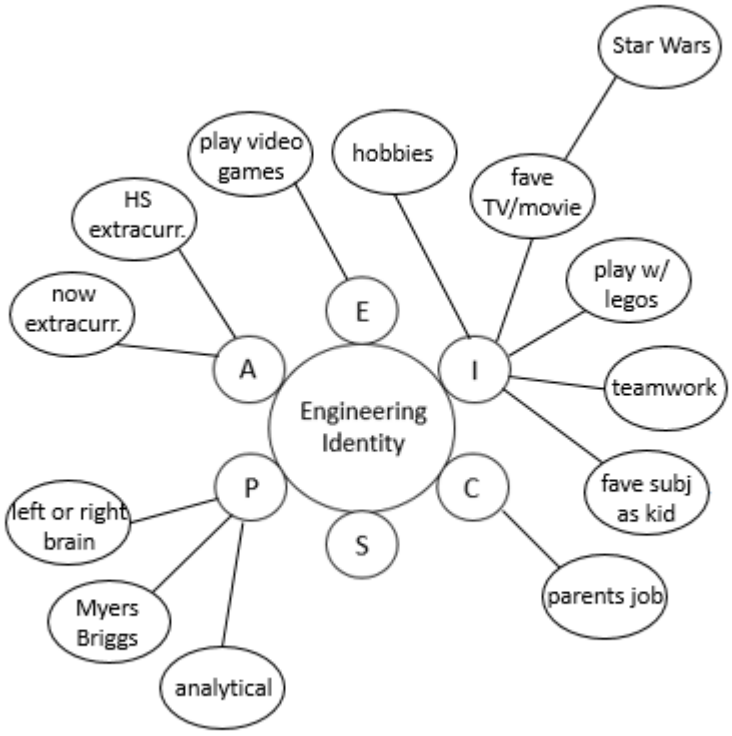

Figure 8: Participant 5 Mind Map 4

At this point, participant 5 has added to the model some recreational aspects like movies and TV shows along with playing video games. Along the topic of movies, we get information on how female and male engineer interests may vary. Additionally, participant 5 goes on to explain that though she does not like Star Wars, every other engineer she knows does. This puts the strategy of similarity to self and population in contrast to each other. Participant 5's reaction to this is to call stereotypes into question. In some ways, she wants to avoid stereotypes (employing the anti-strategy), but in other ways she also wants to leave room to explore if stereotypes live up to their claims in the real world.

4.3.1.2 Participant 5: IRC Chat

Below are the quotes from the IRC Chat -- where participant 5 is 'studentguesser' and the conversation partner is 'mysterystudent'. For convenience we only show the portions of the chat that are relevant to our results. From the chat we can see participant 5 employ the similarity to self strategy several times, announcing when her and her conversation partner had things in common. These are highlighted below and represented as blue stars in our mind map. We chose blue to represent all new annotations to our mind map during the conversation, so that thoughts about engineering identity could be generally traced to the subtask in which they emerged. Additionally, participant 5 never asked about some of the questions she proposed in the brainstorming session - namely teamwork and playing with Legos, but she also did not add any new questions. To reflect this, teamwork and playing with Legos are greyed out in our mind map.

5C1: <studentguesser> Hello! <mysterystudent> Hi there! <studentguesser> Guess we'll get started haha

5C2: <studentguesser> do you know what your Myers-Brigg personality type is?

5C3: <mysterystudent> I've gotten different results depending on the test but the one I think is most fitting is ESTJ <studentguesser> similar to mine!

5C4: <studentguesser> do you have any favorite hobbies?

5C5: <mysterystudent> My hobbies include singing, rock climbing, and almost any other outdoor activity <studentguesser> that's pretty cool! i love singing too but i've never tried rock climbing

5C6: <studentguesser> what kinds of things were you involved in while you were in high school?

5C7: <studentguesser> and also here in college?

5C8: <mysterystudent> I did choir for three years in high school, I'm part of an a cappella group here, I did a play in high school, and I've been involved in my churches back home and here <studentguesser> oh wow that's so awesome! haha we sound pretty alike. I did choir for twelve years and it's strange not doing it anymore. and i've also been very involved in my church

5C9: <studentguesser> what are your favorite tv shows/movies?

5C10: <studentguesser> do you like star wars?

5C11: <studentguesser> do you play video games?

5C12: <studentguesser> gotcha. what do your parents work as?

5C13: <studentguesser> okay nice. would you consider yourself more right or left brained/

5C14: <mysterystudent> left <studentguesser> yep same. what were your favorite subjects in school as a kid?

5C15: <studentguesser> awesome! well that's the last question- have a great day! <mysterystudent> You too!

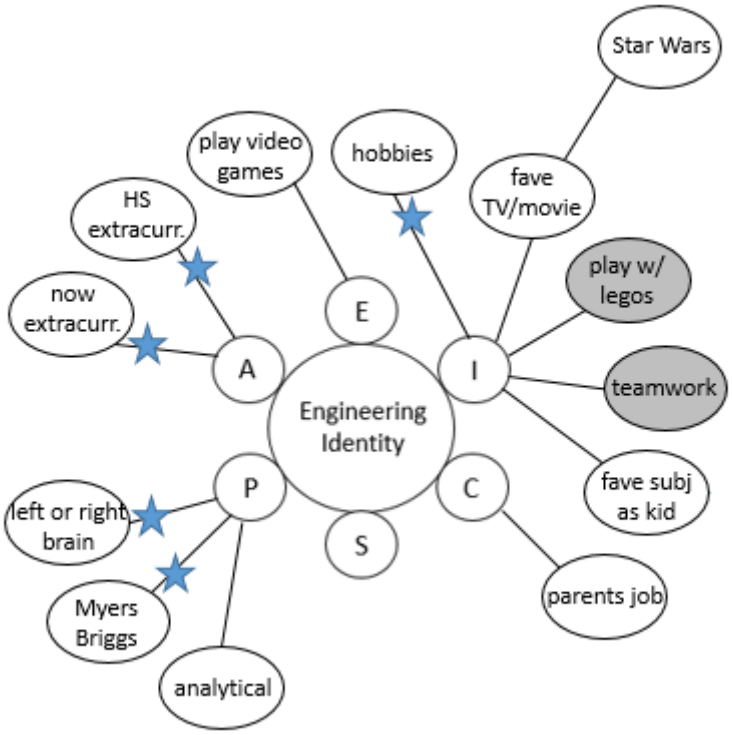

Figure 9: Participant 5 Mind Map 5

4.3.1.3 Participant 5: Assessment

During assessment, we see participant 5's associations between topics continue to strengthen.

5A1: "So first off you – I think that it's a he... Umm, I could be wrong though, but… Just like – kinda the way he types almost... Does that make sense? Cause I feel like girls tend to use like a lot of exclamation marks and stuff like that. But he like capitalized everything like no exclamation marks, like he still sounds friendly. I don't know."

As a tangential point, though there is no representation for this in our mind map, here we see participant 5 guess the gender of her conversation partner as male, and indeed she was right. This is an example of intuition about gender which we pointed out in Common Topics and Behaviors, and will expand on later in the Stories section.

5A2: "Umm growing up he said he had an interesting in science, math and performing arts stuff. That's interesting – that's something we have in common. And like he did choir for 3 years in high school and joined an acapella group."

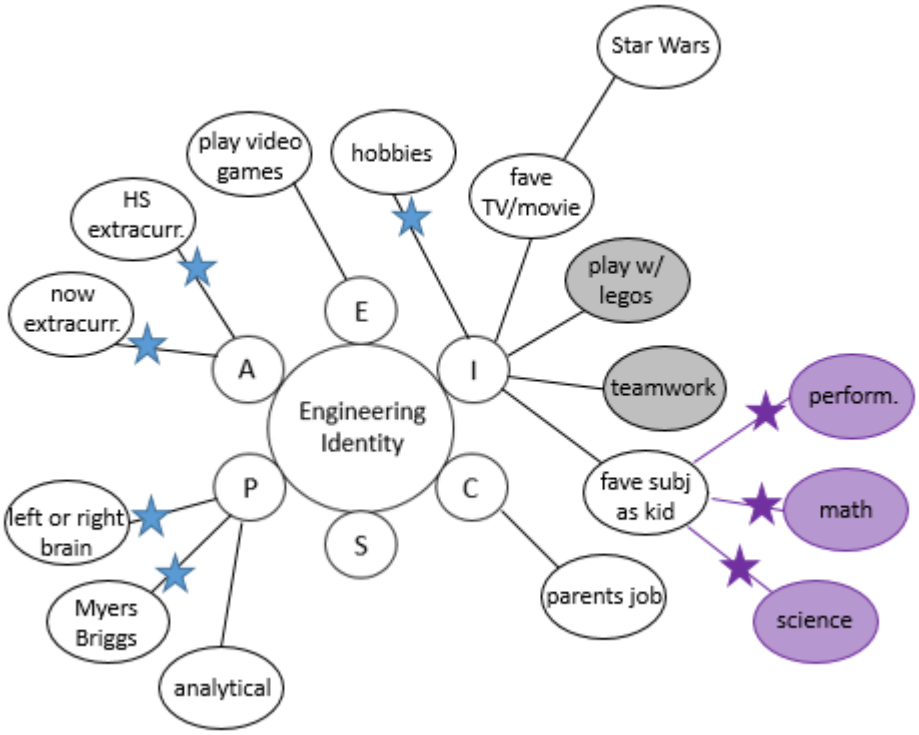

Figure 10: Participant 5 Mind Map 6

Moving on, participant 5 again points to the commonalities between herself and her conversation partner, showcasing the strategy of similarity to self. These commonalities are represented as purple stars on our mind map placed over the notes of performing, math and science. We chose purple to represent all parts of our mind map that emerge in assessment, again to showcase temporal change.

5A3: "Um and like, analytical I guess...? Um I think that's… something that's… usually steers people towards like STEM and like engineering… Because it's kind of like a skill that's needed in that aspect I guess."

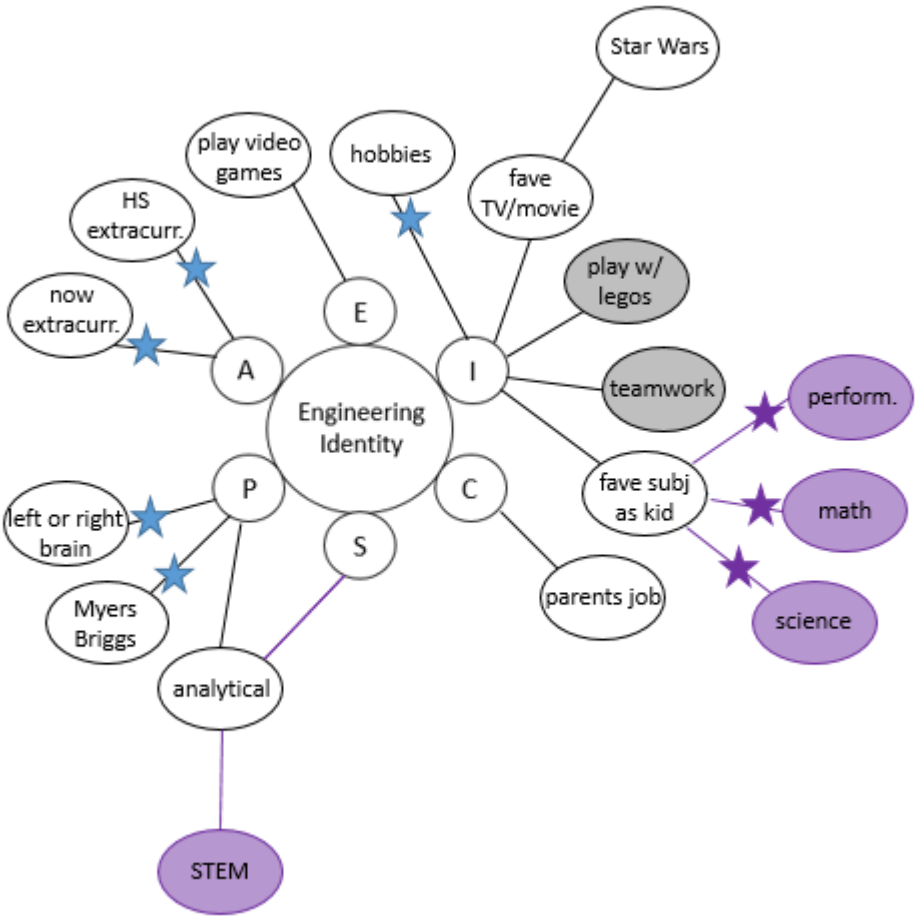

Figure 11: Participant 5 Mind Map 7

Next, we see how participant 5 does not hold firm boundaries between categories like we mentioned earlier in the Strategy section. While she talks about analytical as a skill here in assessment, we note that earlier in 5Q6 during brainstorming she spoke about analytical as a personality trait. This particularity calls into question whether participant 5 believes that being analytical is a trait people have that attracts them to engineering, or a trait that is grown in them because of the nature of the field, or both. Additionally, participant 5 points to the overlap that engineering has with STEM.

*5A4: "Umm... *tut tut tut* He's um ESTJ so he's like more one the extraverted side... He's also like a thinker, and J is like organized and stuff like that so… Um, yeah – I'm definitely leaning towards saying he is an engineering student."*

5A5: "And I think like oh he really likes music and stuff which I do too… Ugh, you know what I should have asked?... It would have been interesting to ask if like when it comes to music, does he like - like the more technical side of it, like making it sound like perfect ... and like when he's practicing does he spend hours like perfecting something specific or does he just, just enjoy listening to it and the beauty of music sort of... (What's your – What's your thoughts behind what – how that question could be interesting?) Um – I don't know because for me personally like I – I love both - ... But at the same time like when I'm like sitting down to practice piano or if I'm like learning a song or something I will – I get very caught up in the details because I want it like all to sound perfect throughout. And I mean I get that might just be a personal thing. But um I do feel like a lot of engineers that I've met are like very detail oriented and they like – kinda like the logistics or like the - the technical aspects to be on point sort of... And I guess that would also tie in with like the left brain part."

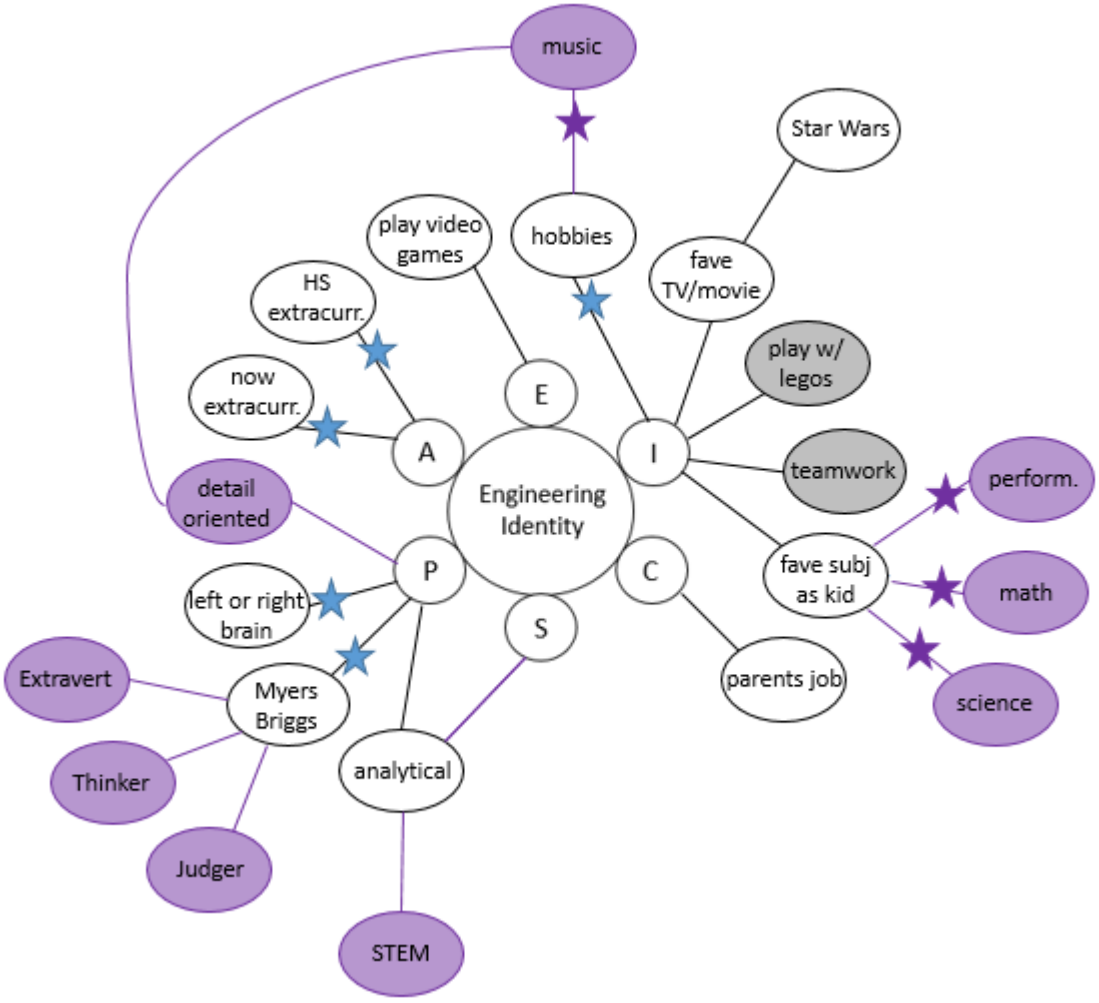

Figure 12: Participant 5 Mind Map 8

Moving forward, participant 5 adds more categories to the mind map - like music, detail oriented nature, and some specific categorizations within the Myers Briggs personality framework. Also, we see participant 5 use the indication strategy mentioned earlier in the

Strategy section. She talks about how practicing music could showcase a detail oriented personality, which is a trait of an engineering as well as a connection to left brain tendencies. In this, we see a few different interesting dynamics. Firstly, this is a perfect example of how the methodology gives the participant time to get into the mode of the task and as a result lets them articulate more on identity than they would have otherwise. Additionally, participant 5 makes the leap of connecting these two topics (music and detail oriented) through highlighting a tendency she sees in herself for the specific instance of music, but then she goes on to also rationalize why a detail orientation nature would be considered an engineering trait overall because of its prevalence in the engineers she knows. As a result, here we have an interesting example of individual and collective likeness working together to illuminate more about engineering identity. Also notice, that participant 5 never got to ask her conversation partner about the scenario she is proposing; and yet, just doing the work of proposing such a link between topics is helping her and us progress in our journey of learning about engineering identity. Lastly, this showcases how topics do not only have a relationship and orientation toward the object in question, engineering identity in our case, but also toward each other, as detail oriented and left brain both have positive valence towards engineering identity, and each other.

5A6: "(You mentioned organization is that - which way does that trait lean if- if it leans it all?) Yeah I mean again like Myers Briggs is not like a definite like if you have these 4 letters you are this major sort of thing… but um… I do feel like - you know like what the different letters are? Right ok - you know I feel like J's tend to be more like list makers - like they like to plan things out and stuff and um organize stuff like that. So I think that in combination with a left brain and like that he likes math and science and all those things in combination make me think that he's definitely an engineering major."

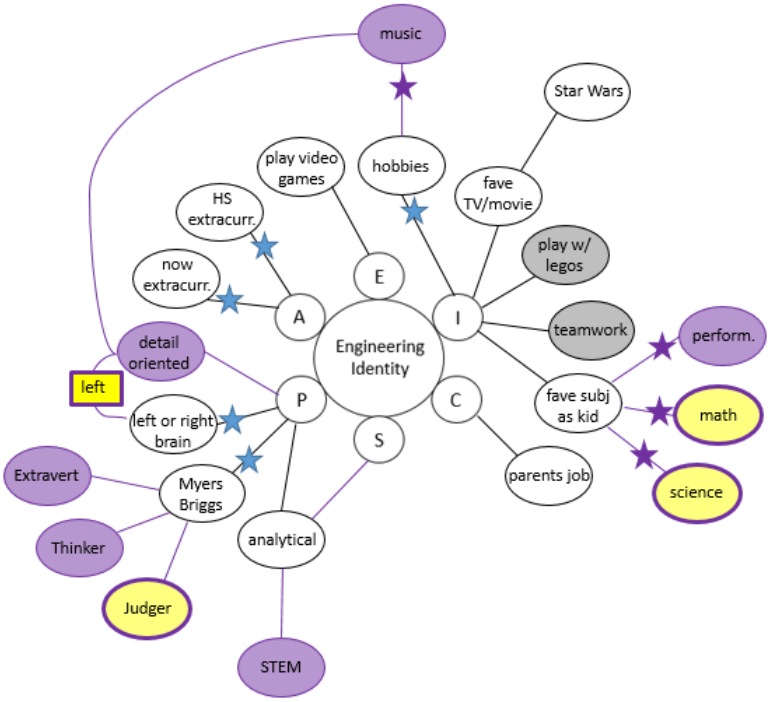

Figure 13: Participant 5 Mind Map 9

As participant 5 continues to develop her mind map, we see the strategy of combination comes into play where multiple topics, like organization, left brain, math and science in this case, come together to point to membership inside engineering, represented in yellow on the mind map (though the outline of these nodes is kept as purple to trace it back to emerging during assessment).

5FA1: "Here, the movies and this part a little bit of video games. Uh definitely the left brain part. Oh right here I was always find a science, math, performing arts I feel like… um he's like you know branching out and stuff… It's something I've always loved to do, cause I like I don't know when it comes to right brain left brain I like to bounce it out because I don't wanna lean too far one way. So like I always took art classes like I've been taking music classes since I was 5 like playing the piano and like in choir and stuff. (confident) So um - and also that's another thing like especially as a Virginia Tech student in engineering most of them are very like, um what's the word… Uh they've been involved in all kinds of things you know... I think that's like a very common thing they uh yeah… like not just one thing because I think that something they look for in admissions, like wide spread interests but also like a skill set in specific areas."

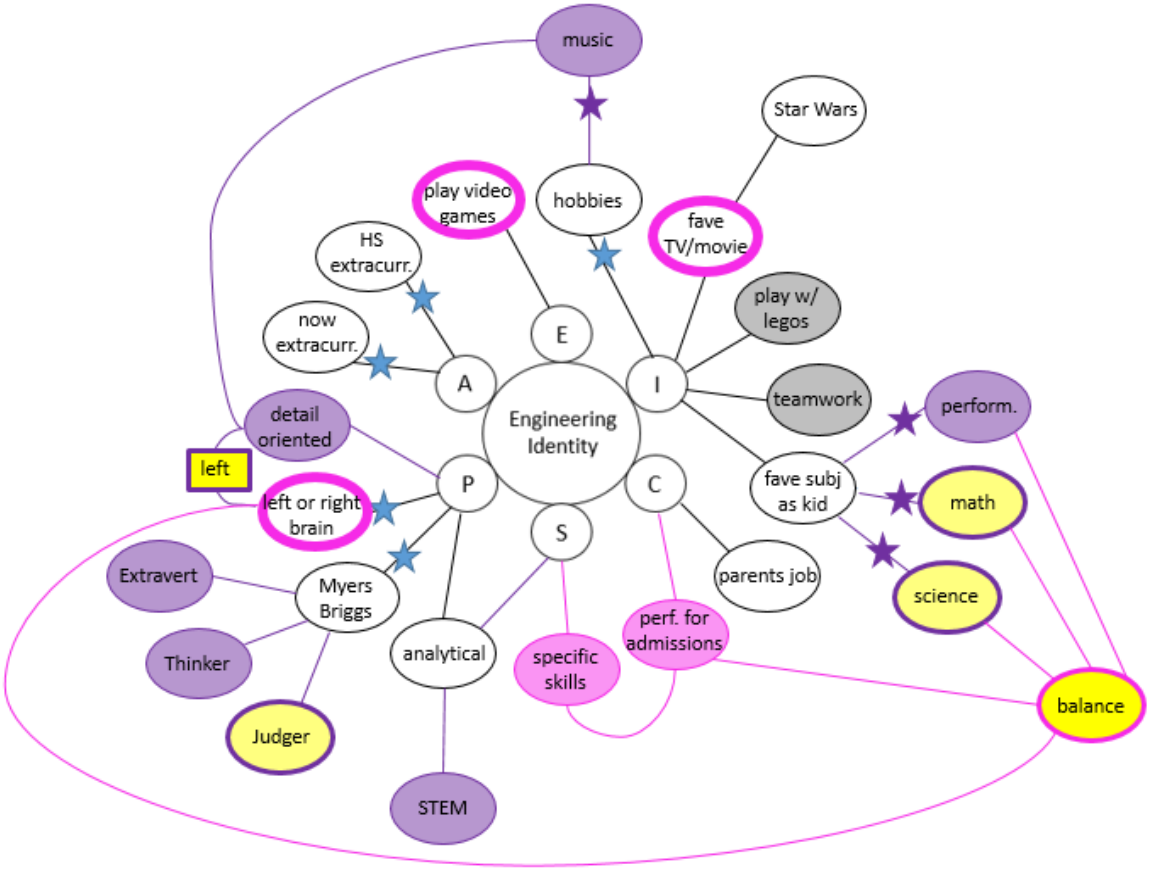

Figure 14: Participant 5 Mind Map 10

In this last quote, participant 5 is stating all the parts of the transcript that serve as evidence that her conversation partner is an engineer. We represent these final criteria as pink in the mind map. At the tail end of this list, she unveils one last interesting association about 'branching out' that she validates through both her own experiences and what she expects to be valued by University Admissions. What is interesting about this, is that she uses two seemingly opposite sources to converge value in the same area. One comes from her own values making it an intrinsic source, that is associated by similarity to self. Yet the other comes from the values of the infrastructure making it an extrinsic source that is associated by circumstance.

Additionally, her point about balance here is in stark contrast to the dichotomy about left and right brain she had mentioned in 5Q11. Even further, during brainstorming participant 5 even went so far as to say that choosing either left or right brain may make the task too easy and be an unfair question. Yet, here, we see participant 5 prioritize balance among creativity and analysis (another form of the combination strategy), rather than viewing these as discrete binaries.

4.3.2 Case 2: Avoidance of Topics Related to Other Majors

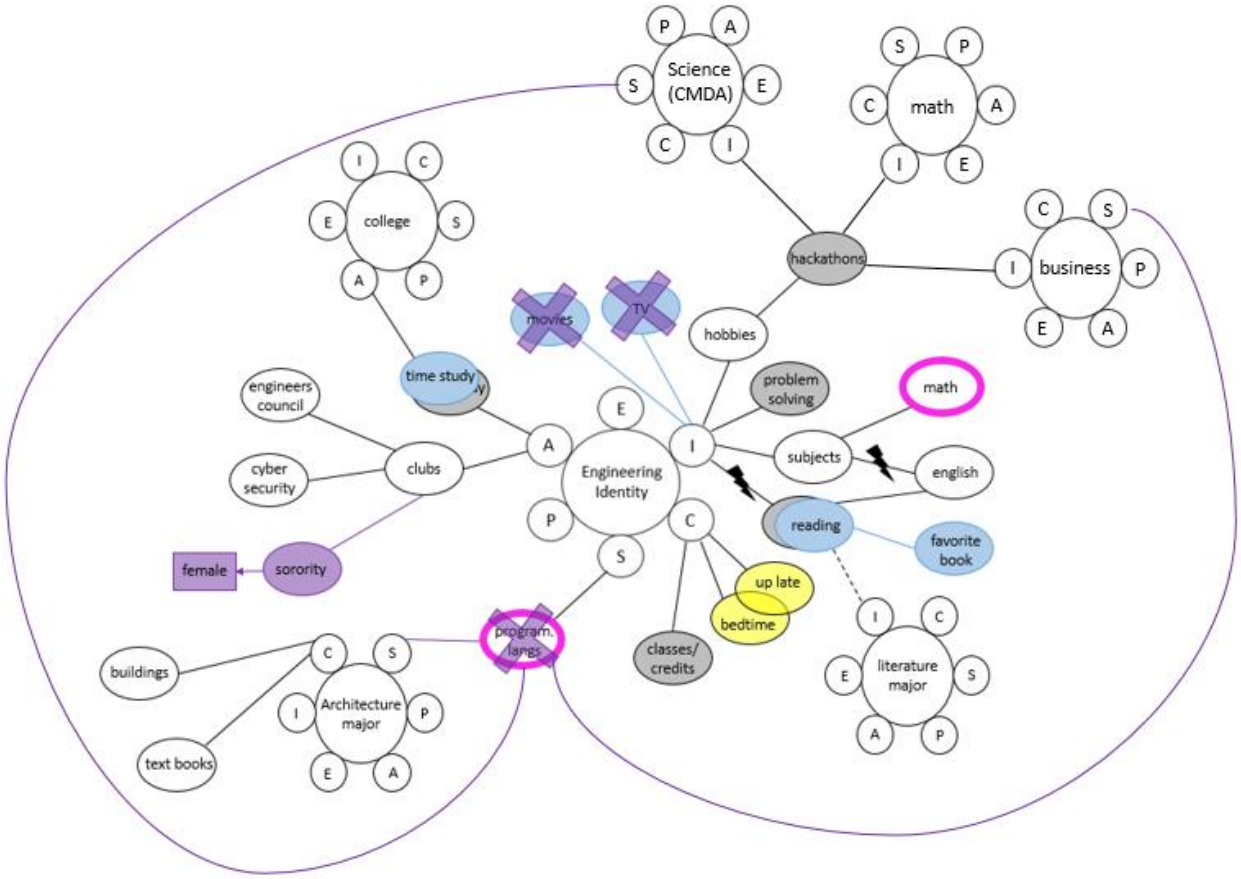

Figure 15: Participant 18's Resulting Mind Map

4.3.2.1 Participant 18: Brainstorming

In contrast to participant 5, participant 18 did not produce a large interconnected network of topics because he rejected all of that which could be associated with another academic discipline.

18Q1: "Alright I'll first ask do they - what clubs they are in."

18Q2: "How they feel about certain subjects. (Like what?) Like do they like Math do they like English."

18Q3: "On average how long do they study… But I don't think that will change much average how much study, because most people will probably study if they're in college. Um I don't know they're - how much people need."

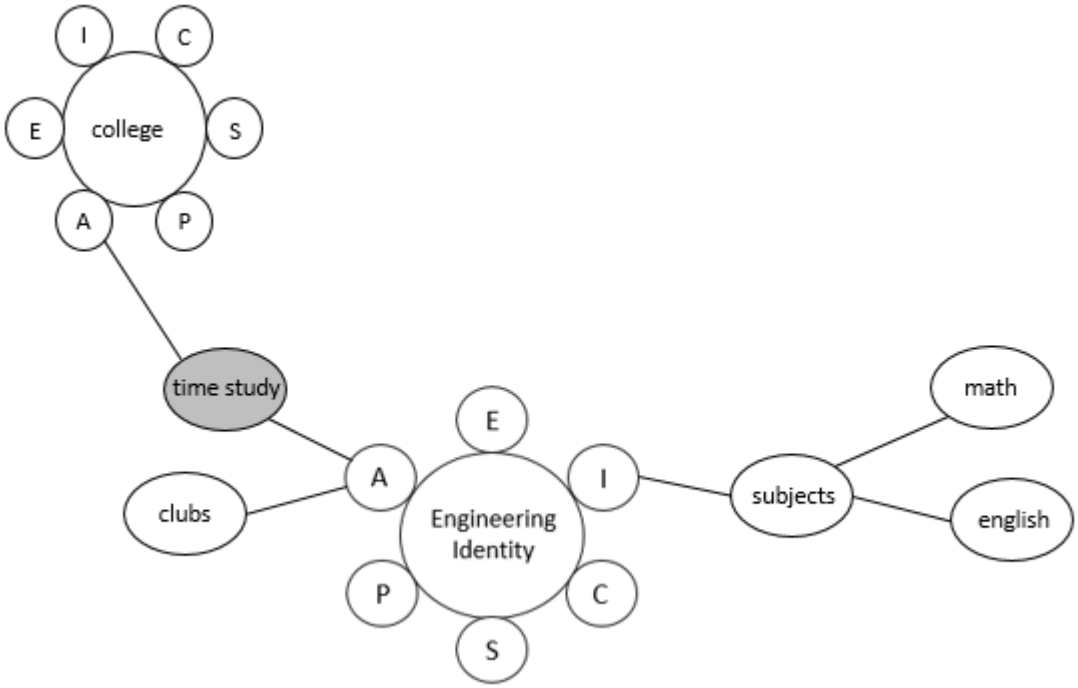

Figure 16: Participant 18 Mind Map 1

To begin, participant 18 connects clubs and subjects to engineering identity. Next, he posits asking about amount of studying, but then decides not to because of his association of studying with college in general (bringing another entity into our mind map), and thus it is greyed out in our mind map. This is a dilemma that participant 18 runs into most often during the study. From the repetition of this behavior, it seems that he is looking for a silver bullet, something that is unique to engineers. Thus whenever a candidate criteria has the potential of being associated to another field, he chooses to reject asking about it.

18Q4: "Let's see I can't - I can ask them if they know any programming languages. "

18Q5: "Uh let's see what - let's see what literature books do they like reading. Um do they like reading um - (Well what are you thinking about for that question?) I'm just thinking in general do people - to see…? if they're maybe more a literature liberal arts rather than preferring - 'cause I know a lot of people in my group of engineers don't like reading as much as I do. But since I like reading that also doesn't give much information."

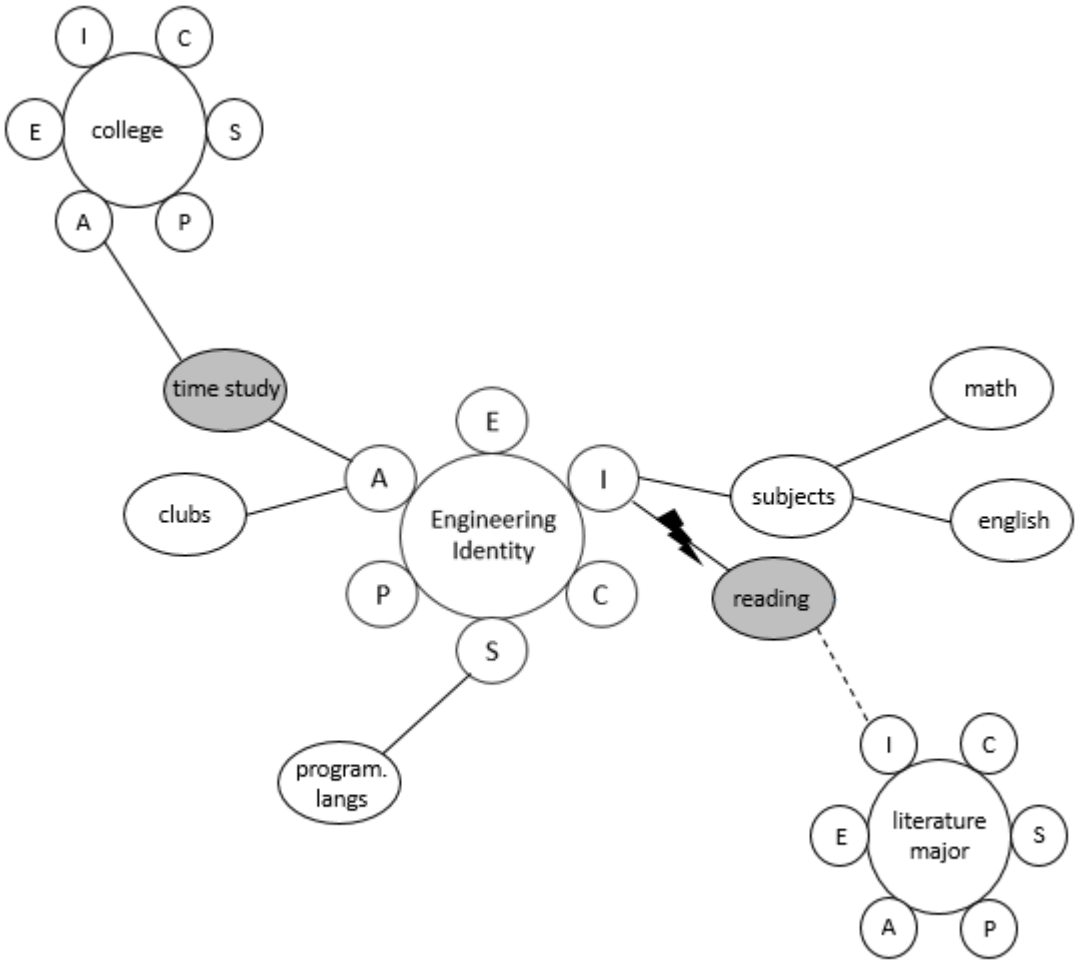

Figure 17: Participant 18 Mind Map 2

Moving on, participant 18 proposes asking about programming languages and liking to read - represented with a lightning bolt on our mind map to show it being negatively associated with engineering. Then, he wrestles with conflicting associations. On one hand, he partly (thus it has a dotted line in our mind map) associations reading with the academic field of liberal arts, along with a negative valence towards engineering considering the many engineers he knows who do not like to read. On the other hand, he himself is an engineer and does like to read. In response to this conflict between population strategy and similarity to self, participant 18 decides (at least temporarily) that this topic probably does not have a leaning in either direction.

18Q6: "Um let's see how what classes how many credit hours that's eh, that doesn't really tell much that might just get stuff out of the way."

18Q7: "(Can you tell me a little more about the clubs, what you're hoping to find from that?) I'm saying if they say there in say cybersecurity club the student engineer council that's a pretty big give away that they're in engineering. Um if they give that they're in the - I don't know the chess club that doesn't tell much though."

18Q8: "Do you like problem solving that's a very generic question though."

*18Q9: "Uh okay I'll think more - more broad more broad, okay not okay subject. If they're in the college of architecture what could give that away. I can't ask what buildings they go to because that would give it away… Um Textbooks, can't ask… *tut tut*"*

18Q10: "(Can you talk a little bit more towards um the reading, and you said you like reading but you have friends who don't like reading and…?) Well it's more the fact that I like reading and I enjoy reading I'm an engineer but - but I know a lot of engineers they liked reading 'Hey it's there I had to do it for an English class and once I'm done with English class I'm never taking it again'."

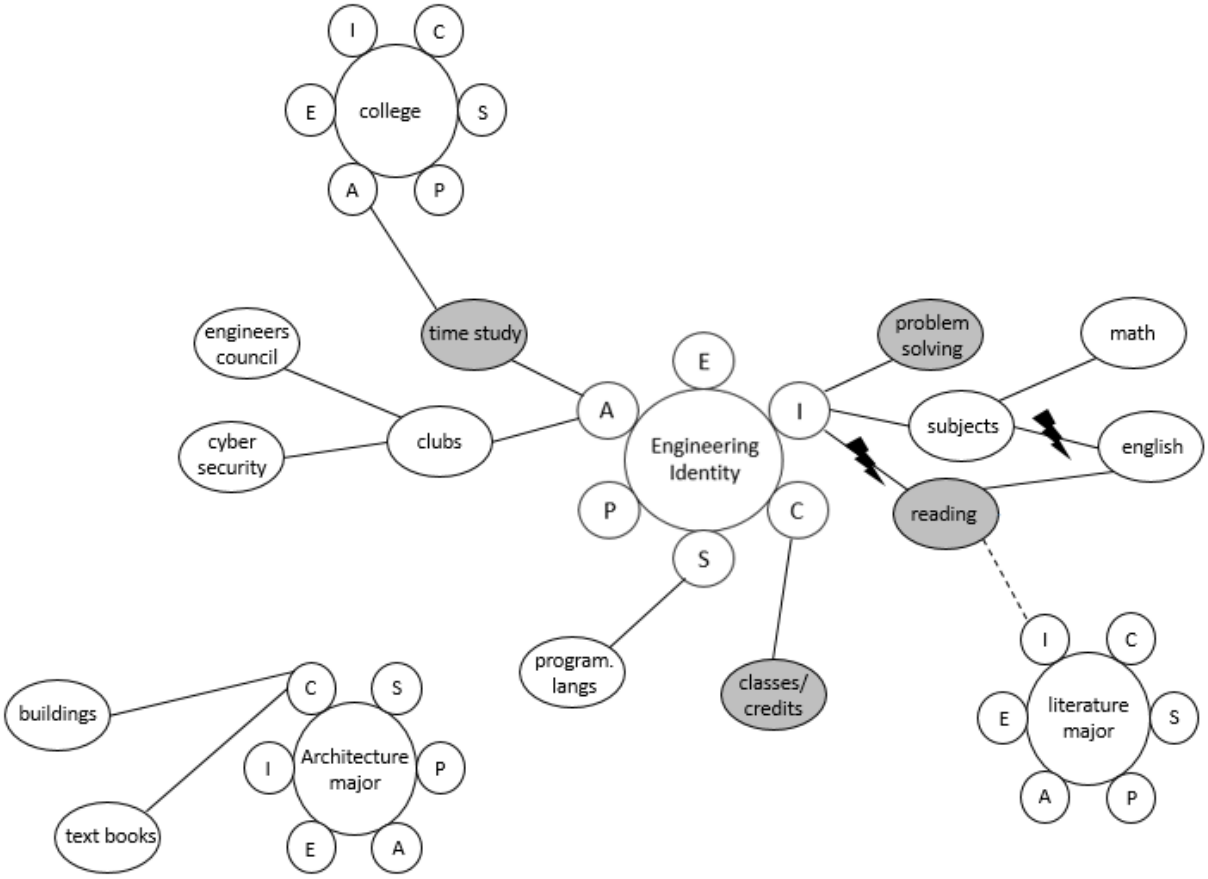

Figure 18: Participant 18 Mind Map 3

Participant 18 then goes on to continue to make more associations, while simultaneously rejecting them. First, he suggests asking about the circumstances around his conversation partner's academic schedule, but then decides that these questions would result in elimination not specification. Next, he posits asking about problem solving, but considers that too broad to be of use. He then decides to switch strategies, instead trying to identify if his conversation partner is from a field different than engineering. Yet, he approaches this task with the same goal of trying to find criteria that would "give it away". From this, he identifies questions that are barred from the task, and fits within circumstantial evidence.

After being asked about his comments around reading, participant 18 again brings up the conflict between population and similarity to himself. Additionally, like participant 5, here we also see how topics have relationships to each other as well as engineering identity - for instance, between English and reading.

18Q11: "Uh I guess their hobbies that would be one, because if I know they like hackathons in their time I could – it could be college of business CMDA college of math though. "

18Q12: "Do they like reading I like reading 'cause - what is - what does that show if they like reading? Well I guess you could be a literature major without liking to read."

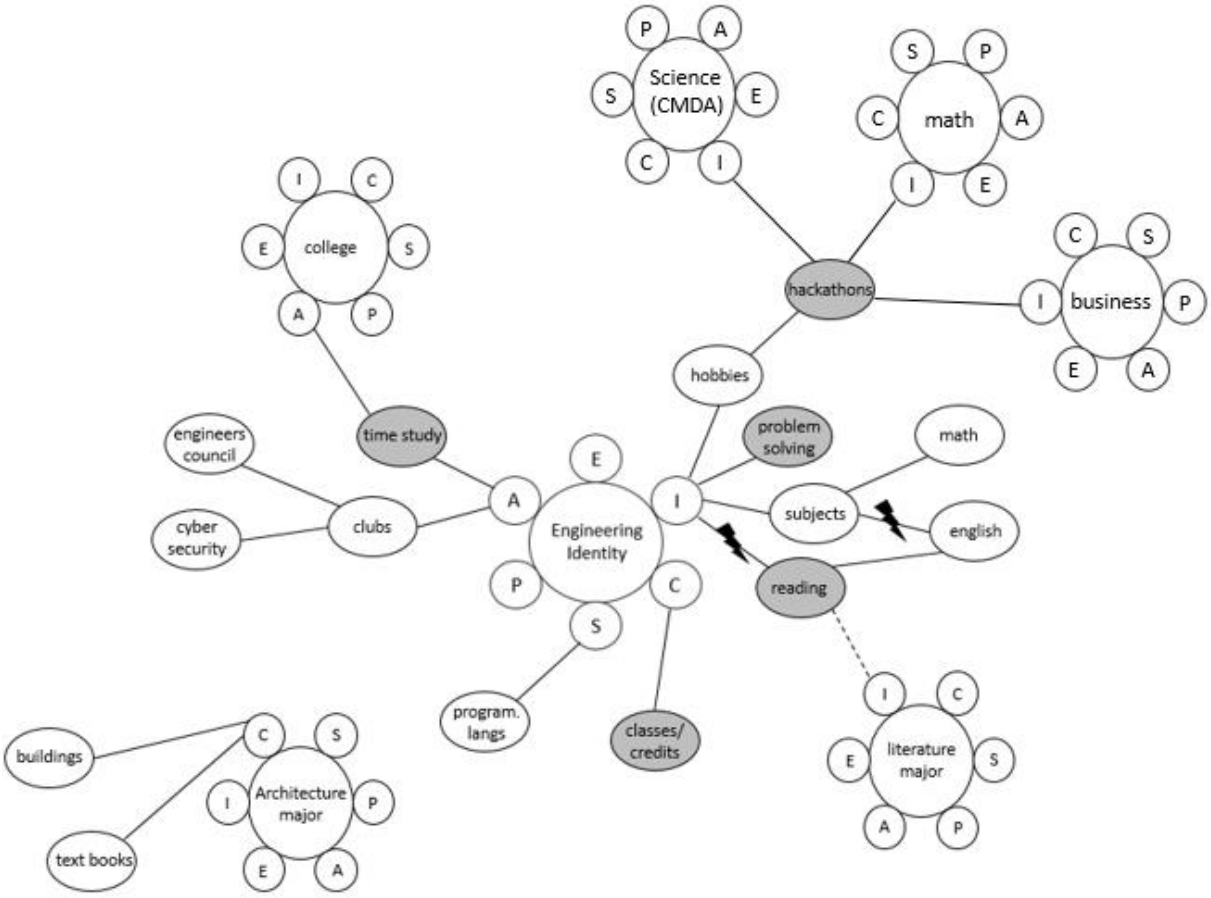

Figure 19: Participant 18 Mind Map 4

Participant 18 also considers asking about hobbies, giving an example that enjoying hackathons could point to engineering. Yet, he stops himself midway when he realizes that students in the College of Business, Science and Math could all possibly be interested in hackathons as well. Next, we see participant 18 draw a striking contrast between the work required for a field, and an individual's interest within it. For literature, he believes that someone could major in that field without enjoying one of its core disciplines - reading.

18Q13: "Um let's see - but I think just asking hobbies in general could be nice. "

18Q14: "What time do you go to bed?"

*18Q15: "Um *tut tut tut tut* do you stay up late to complete work?"*

18Q16: "...I don't know if - maybe a couple of these questions are if you work 'em together they'll say something but just one of them in general is not really helpful."

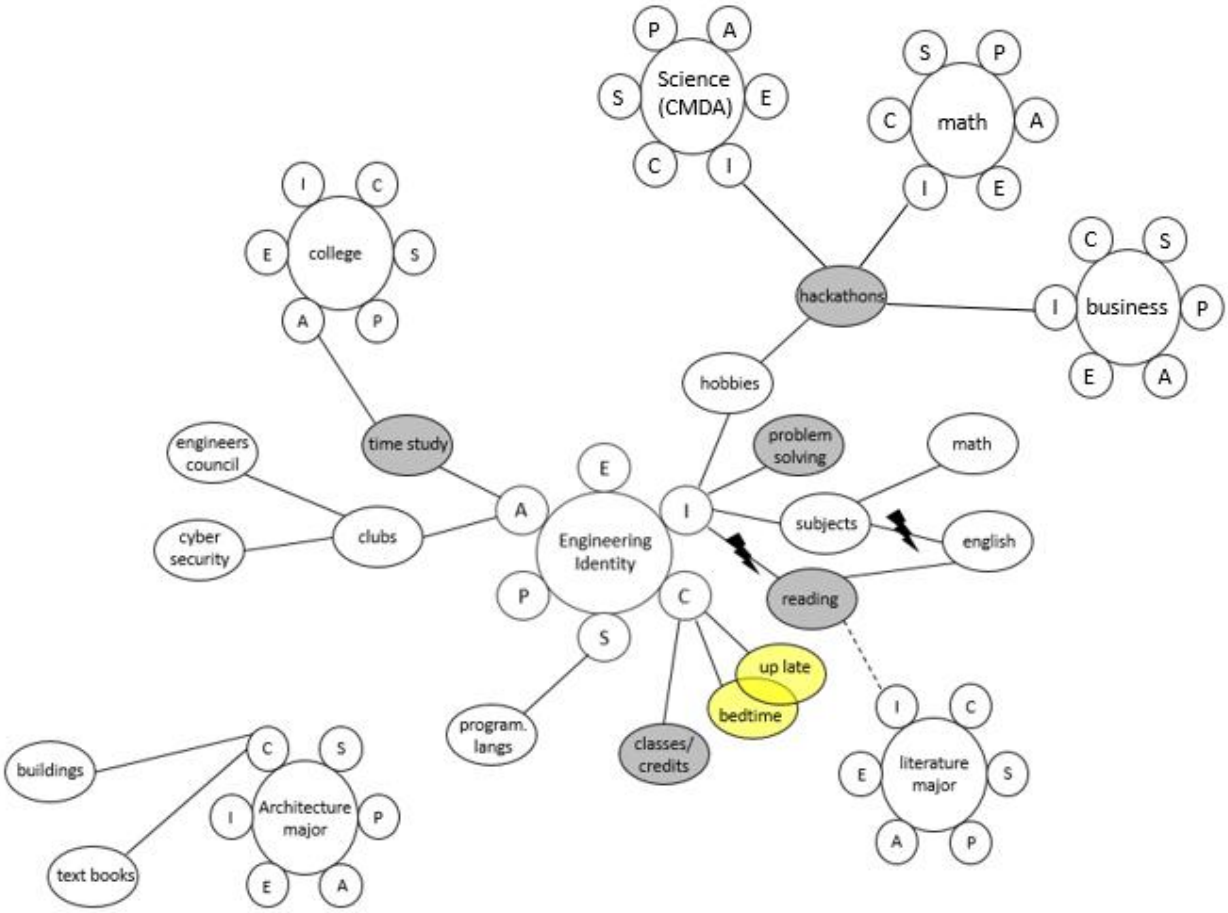

Figure 20: Participant 18 Mind Map 5

Backing away from providing an example, participant 18 goes on to explain that the open ended question about hobbies might still yield valuable data. To end his brainstorming session, he comes up with a few questions about his conversation partner's routine. Before moving onto the actual conversation, he remarks that perhaps a combination strategy will do better to suss out engineering membership, another association from our Strategy section. To showcase this, we have created overlap between the nodes of bedtime and staying up late, along with coloring them in yellow to showcase the combination strategy like we did with participant 5.

4.3.2.2 Participant 18: IRC Chat

Interestingly enough, during participant 18's conversation he does ask some questions that he had previously rejected as fruitful during the brainstorming session. These are highlighted in the conversation quotes below in orange, which are represented in the same way as participant 5. For our mind map, these questions that were originally rejected are represented through a blue node that is on top of the original association. Additionally, participant 18 added questions about movies and TV shows also highlighted below but in blue, and slightly changed his questions around routine.

18C1: <studentguesser> Hello <mysterystudent> Hi <studentguesser> I suppose I should ask some questions. What clubs are you in?

18C2: <mysterystudent> I am in a sorority and a service/advocacy club called Challah for Hunger <studentguesser> Alright cool. What does Challah for Hunger focus on?

18C3: <studentguesser> What do you like to do in your freetime aside from schoolwork and clubs?

18C4: <studentguesser> That's good to hear that it's plural! What type of movies do you like?

18C5: <studentguesser> Nice. Do you know any programming languages?

18C6: <studentguesser> Do you consider yourself a procrastinator or someone who gets work done immediately?

18C7: <studentguesser> Alright. Do you find yourself staying up late often to complete coursework?

18C8: <studentguesser> How do you feel about having to do math?

18C9: <studentguesser> Do you enjoy reading? If so, what is your favorite book?

18C10: <studentguesser> On average, how much time do you spend studying for classes?

18C11: <studentguesser> Alright, final question. What is your favorite television show?

18C12: <studentguesser> Nice! Thank you for your time.

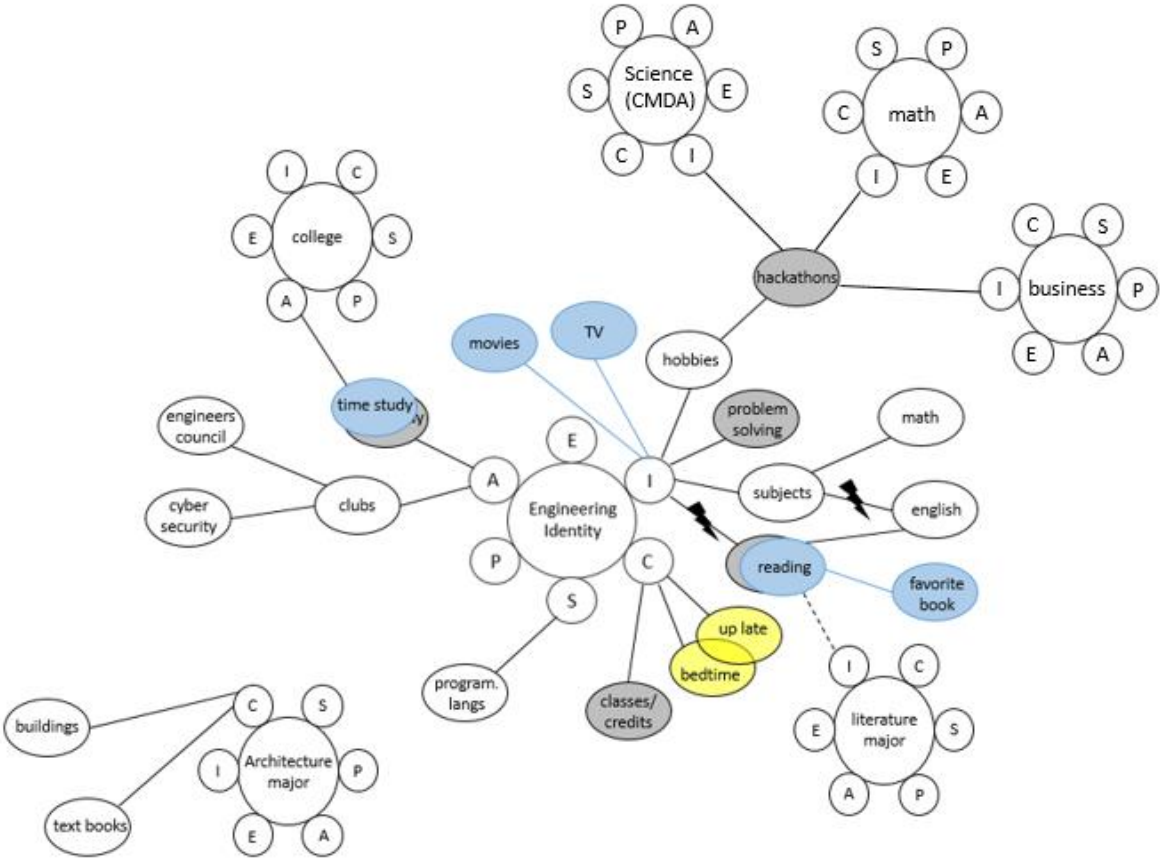

Figure 21: Participant 18 Mind Map 6

4.3.2.3 Participant 18: Assessment

During assessment, participant 18 begins to reflect over his conversation and continues to work the topics in his mind map.

18A1: "What did they do with their free time they just did normal things like hang out with their friends, watch movies. So I'm like alright figure out what type of movies do you like see if they like, I don't know dramas I don't know, I don't know what I was expecting from that really."

18A2: "So then I'm like okay I should start asking real questions do you know any programming languages?"

18A3: "So they know programming languages that's the biggest thing here there that they might be."

18A4: "So if - since they know programming languages, I don't wanna immediately stereotype that hey they - that people in the college of architecture might not know programming because I have a friend that's in the college of architecture who's like a better programmer than me... Um and I'm going into CS. Uh let's see do you know any programming languages, it's a better chance that they're an engineer than they're not they could also be College of business 'cause I know – college of business or college of science 'cause better – 'cause I know another friend in college is science whose in CMDA."

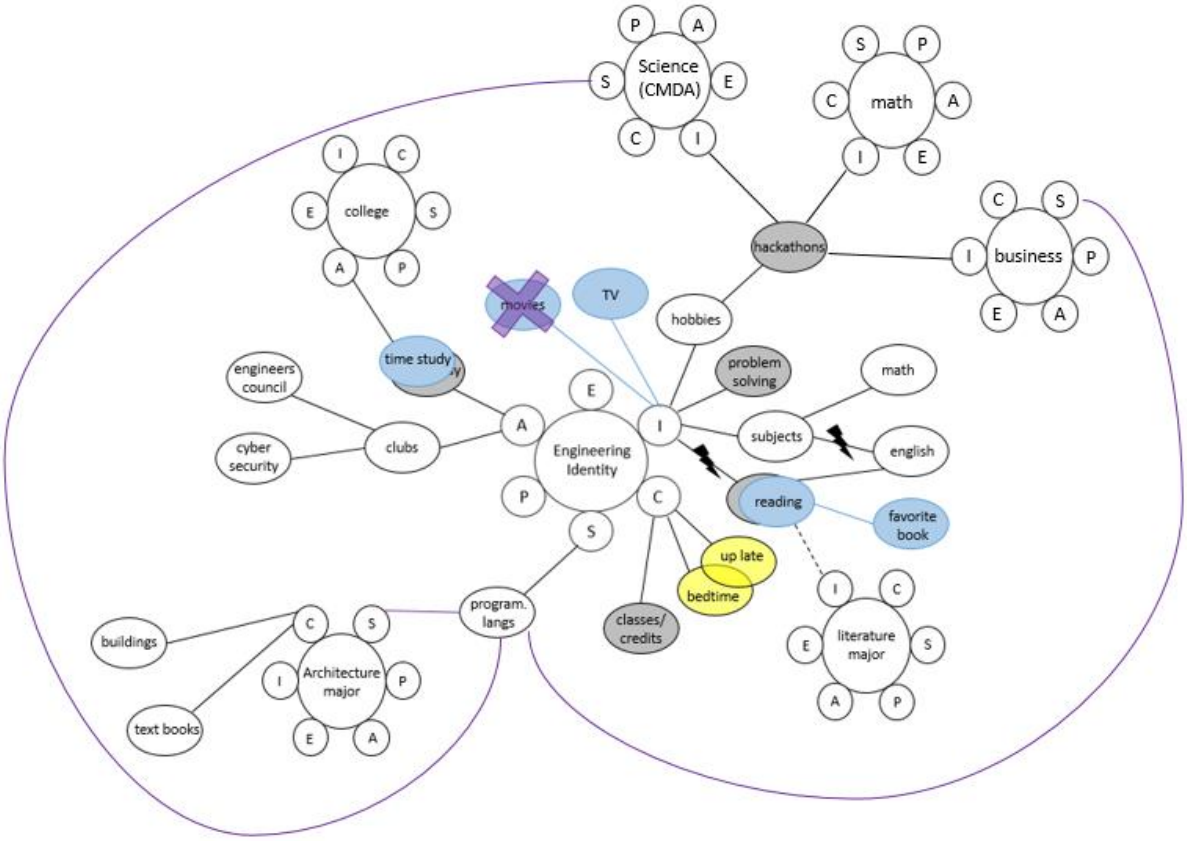

Figure 22: Participant 18 Mind Map 7

After identifying some of the responses of his conversation partner as 'normal', participant 18 goes on to evaluate how knowing programming languages fits into engineering identity. At first, he claims that his conversation partner knowing programming languages could be the biggest piece of evidence for them being an engineer. However, in thinking about his peers he brings on the anti-strategy, namely wanting to avoid the stereotype that engineers are always the ones who know programming languages. To show that this stereotype does not always hold true, he explains that though he is going into the field of CS a friend of his in architecture actually has better programming skills. Here we can see an interesting intersection of stereotypes, similarity to self and observations about peers coming together to showcase relationships among academic fields.

18A5: "... and they spent a couple hours a week studying for classes. Um can I ask is this a sophomore or freshman or -?"

18A6: "Alright final question - what was your favorite childhood show - Friends. That was just a shot in the dark doesn't really tell much either."

18A7: "Um okay based on - they know programming languages that doesn't tell much."

18A8: "How they feel about math he can do it if he has to do is but it's not their favorite. I don't know if they would choose a math based - heavy based major like engineering but then again mm. (What would you have expected if -) Most people I know including me have math as their favorite subject, they just love doing math - ... And it's just super interesting super fun to do. Just being - hey let's do some differential equations for fun I don't know differential questions I haven't taken that class. But it's - having it not be their favorite is - I mean again they could just have other interests but be like 'I wanna be an engineer 'cause it seems the most interesting'... I guess when you boil down to it math is not as important for mm some other majors but we're all still pretty math heavy."

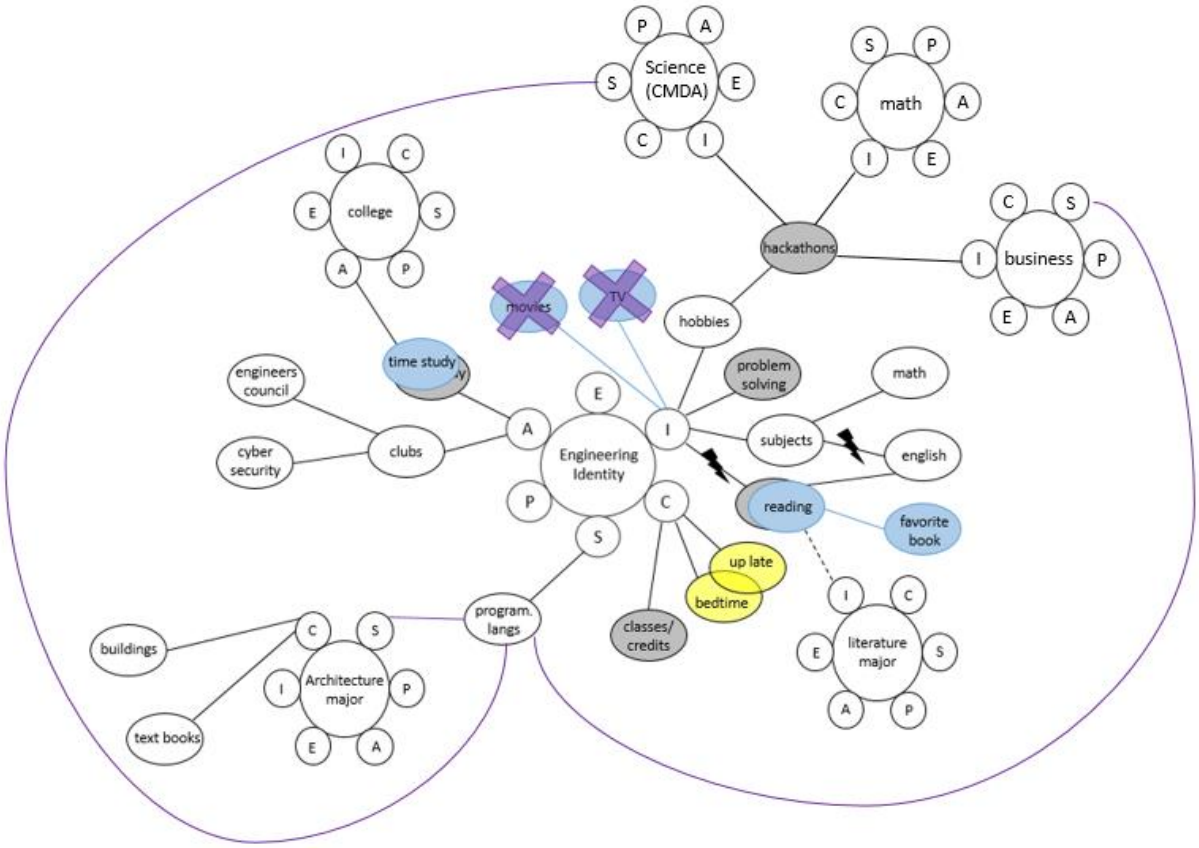

Figure 23: Participant 18 Mind Map 8

After waffling around a few other unhelpful categories, participant 18 comes back to say that

programming languages is not a fruitful criterion for engineering membership. This is in stark contrast with his original claim, which was nullified because of the competing associations for interpreting the relationship between programming and engineering mentioned earlier. Moving on, participant 18 explains, using the example of math, that in addition to a topic being able to relate to various fields it can also relate to various subfields, namely engineering branches, with various strengths. This adds another dimension to our mind map, the strength of an association.

18A9: "If I had to guess - okay I would say at the moment that they're not an engineer. Because anyone can know a programming language a lot of people do now."

18A10: "A couple hours a week - I don't know I've heard horror stories about how hard some of these upper classes are but then again a couple hours a week most colleges should have to spend… (What are your thoughts on the procrastinating versus getting it done immediately?) Uh the reason I asked if they were procrastinating immediately was 'cause if they get it done immediately but they still have to stay up late I'd assume they have a lot of work to do... they study a couple hours a week, I could see that actually. If they go to class and pay attention that doesn't count as studying. Then they got just have to review what they know and then -"

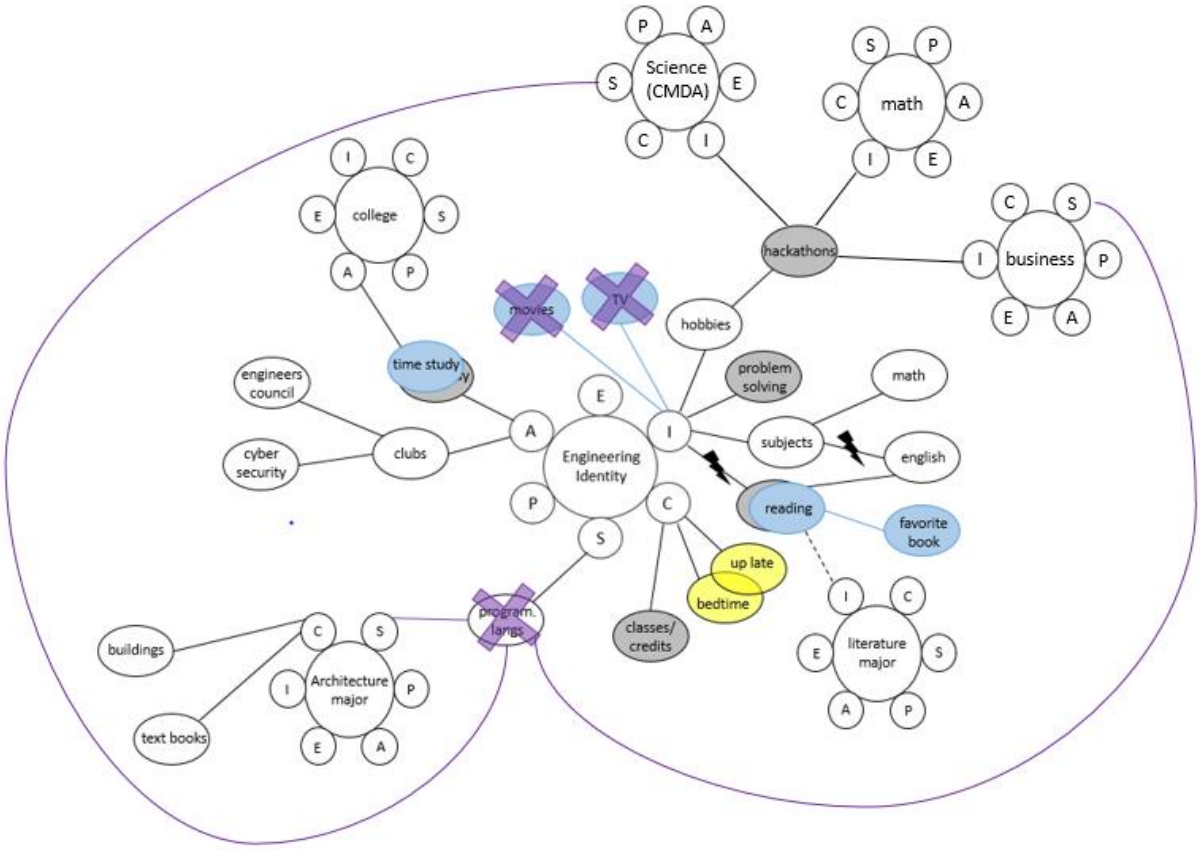

Figure 24: Participant 18 Mind Map 9

Moving on, here we see participant 18 officially reject programming as a telling criteria for

engineering, based on his goal of finding traits unique to engineers. Additionally, participant 18 sifts through a cluster of competing associations that came up previously between engineering high workloads and heavy college workloads in general. Earlier, he tried to determine his conversation partner's work load through asking about their routine, explaining that if they get their work done immediately but had to stay up late to do so there must be a lot of work to do. Yet, looking back on his previous notions he then decides that it is possible to spend less hours on work as an engineer, with the right study and time management habits.

*18A11: "... Sorority… Oh well that makes sense actually it's a girl then… I just picked up on that last. *laughs* (So what was giving you the impression of a guy) Nothing really. I'm just - automatic gendering of when it's neutral… It's easier to assume a single like – hey this is the person. I'm pretty sure most guys immediately think of a guy most girls immediately think of girl."*

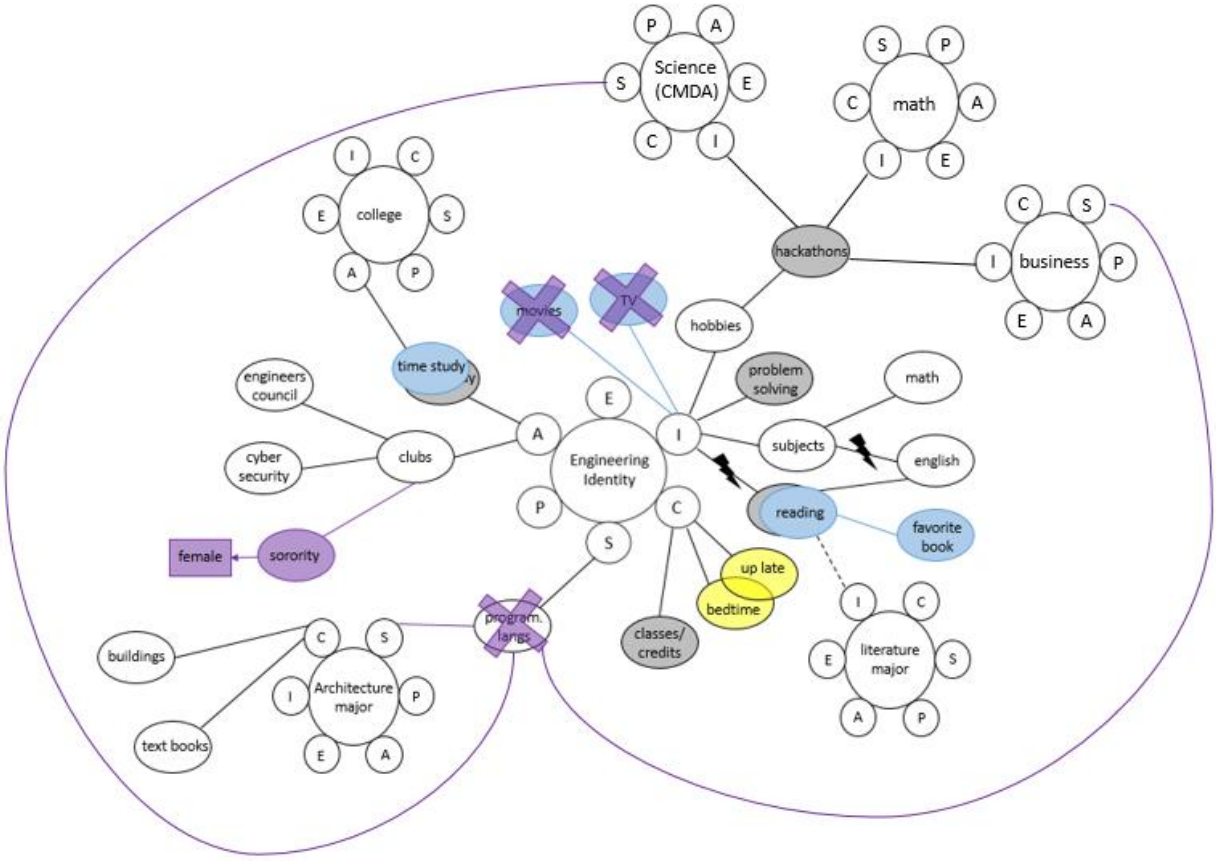

Figure 25: Participant 18 Mind Map 10

Also like participant 5, participant 18 had some intuition about the gender of the person he was talking to. Unlike participant 5, he was wrong. Participant 18 started using 'he' a few times to describe his conversation partner pretty early on during his assessment. Yet, when he came upon the part of the transcript where they divulged their membership of a sorority, he realized his error. Like mentioned earlier, out of all 15 cases where a

participant made a claim about the gender of their conversation partner, this was the only instance in which the participant was wrong.

18FA1: "I'm gonna say they're not in the college of engineering. Primarily - ... Because they know programming languages but anything anybody can know a programming language like a lot of people do nowadays 'cause like I said I have - out of the 4 close friends I have here 3 of them know programming and they're not in engineering."

18FA2: "Um, big thing is the math. They say 'I can do it if I have to' it's kind of begrudging. And that just seems a bit I don't know. And I don't know if I – I mean maybe other people but if I hated doing math I'm not sure I'd be an engineer. (Nice um, when you said um the way they responded to you know do you like math question didn't fit, what would you have expected an engineer to say?) An engineer I would have expected saying 'I enjoy math it's a challenge' or something or more uh - the question exactly was 'how do you feel about having to do math' and saying 'I'm okay with doing math' if they're trying to hide or 'math is alright'. Basically just not saying 'I'd do it if I have to'. Less begrudging."

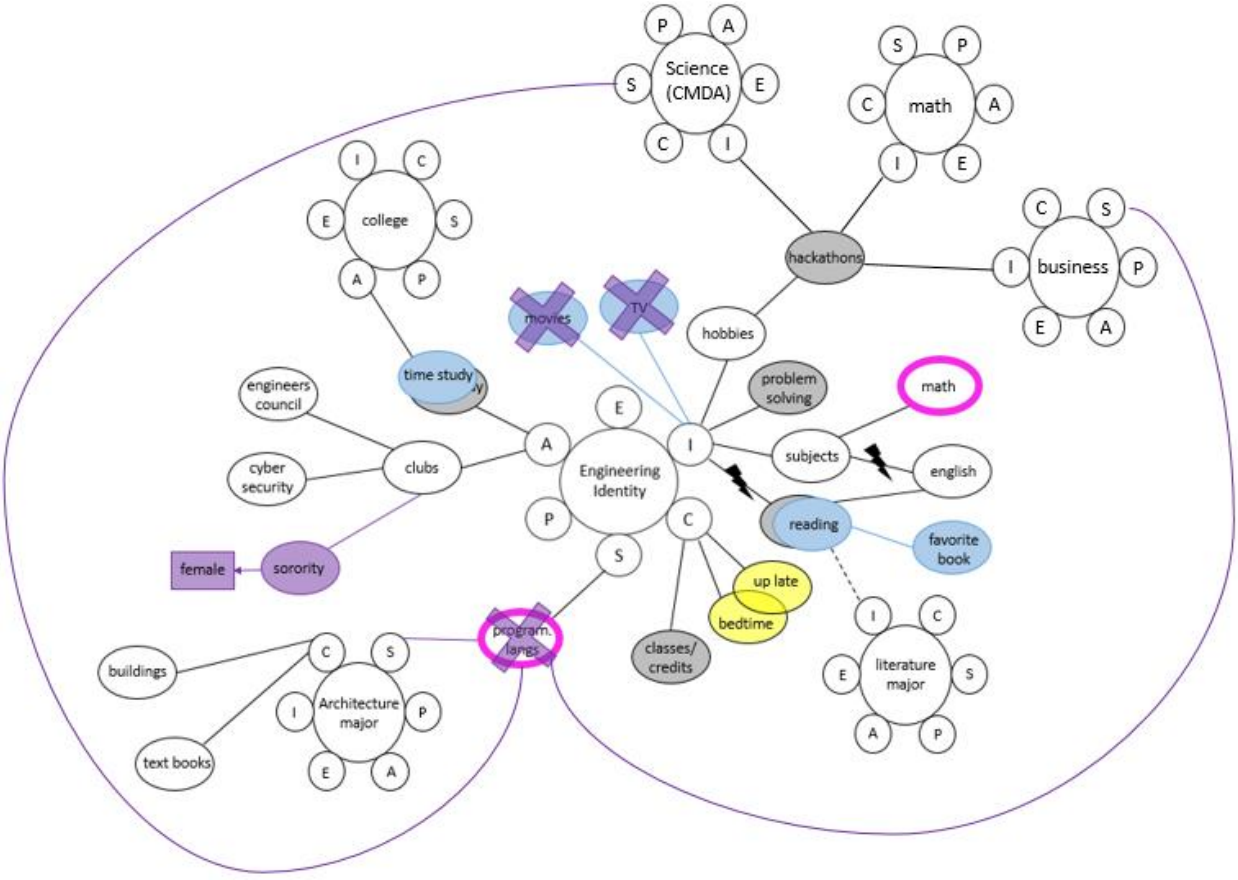

Figure 26: Participant 18 Mind Map 11

To conclude the task, participant 18 explains his final reasons for why he believes his conversation partner is not an engineer -- represented as pink in our mind map. Again, he draws a striking contrast between the work required for a field, and an individual's interest within it. Except this time, participant 18 explains how he does not believe that someone could be a part of engineering and not like math, even though earlier in 18Q20 he stated that someone could major in literature without liking to read. This showcases a glimpse into an interesting ecology of value around participant 18's understanding of how core activities relate to their respective fields in different ways.

4.3.3 Case 3: Conflicts between Associations that lead to Negotiation and Change

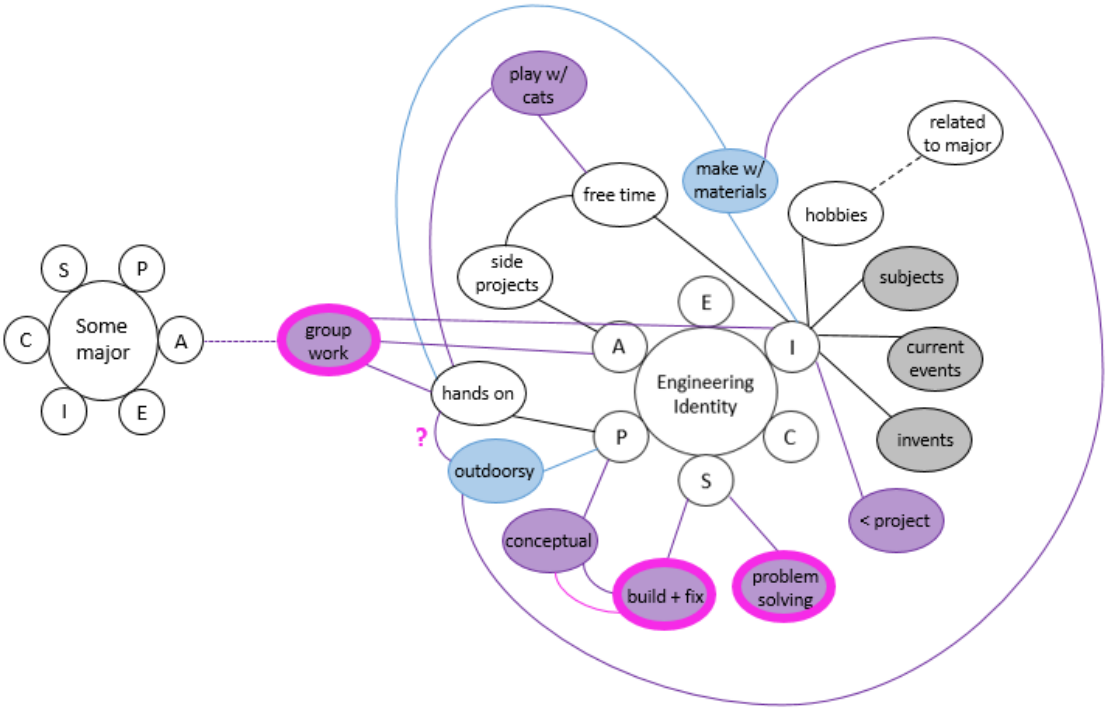

Figure 27: Participant 20's Resulting Mind Map

4.3.3.1 Participant 20: Brainstorming

Moving on to participant 20, we pick up her session at the very beginning during the brainstorming task, where she names a multitude of topics she associations with engineering identity which are represented in our mind map below.

20Q1: "Alright so I guess question number one, um I could ask them about their hobbies."

20Q2: "Something like that. Um, I guess like, if they find themselves… with um… a large amount of free time… What would they do with it?"

20Q3: "(What your thinking behind the first question?) Um the first question I'm thinking that um, maybe their hobbies may relate to what they're interested in, supposedly are studying… Um I mean sometimes hobbies are unrelated but sometimes they correlate."

20Q4: "And then um, my thinking process for the - the free time is like they might have side projects that they're doing or something like that that they do in their free time."

20Q6: "So. Um. Do you consider yourself as a more hands on individual rather than, someone who's not."

20Q7: "Well I was gonna say like what's sorta subjects that they are interested in but I think that that would be on the border. (What about - Are there some subjects you want to specifically ask them what they are interested, in that might be more in line…) Maybe. I guess. Maybe like, maybe - maybe current events maybe?"

20Q8: "I guess, yeah like what sort of current events or what sort of inventions or something peak their interest or something like that…"

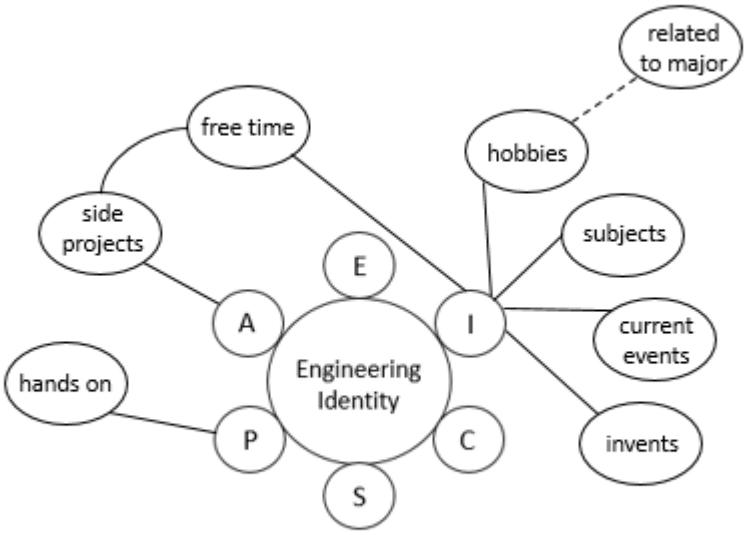

Figure 28: Participant 20 Mind Map 1

4.3.3.2 Participant 20: IRC Conversation

Next, participant 20 asked some of her initial questions, not including the ones about subjects, current events or inventions (represented in grey), along with a few follow up questions (represented in blue).

20C1: <studentguesser> What are some of the hobbies that you are interested in?

20C2: <studentguesser> Oh cool, if you found yourself with a large amount of free time, what would you do with it?

20C3: <mysterystudent> It depends on how much free time I had. If I had a free day to myself, I'd probably go hike McAfee's Knob and picnic up there. <studentguesser> Interesting, do you consider yourself an outdoorsy person?

20C4: <studentguesser> Alright, would you consider yourself a more hands on person as well? Meaning you like to make things with your hands and materials? <studentguesser> or would you consider yourself as someone who likes to create things without the use of actual materials in hand?

20C5: <mysterystudent> I like building Legos, if that's what you mean. But most of the time, no, I don't really consider myself hands-on. I'm much more conceptual. <studentguesser> Can you elaborate on what you mean by conceptual? Do you have any examples?

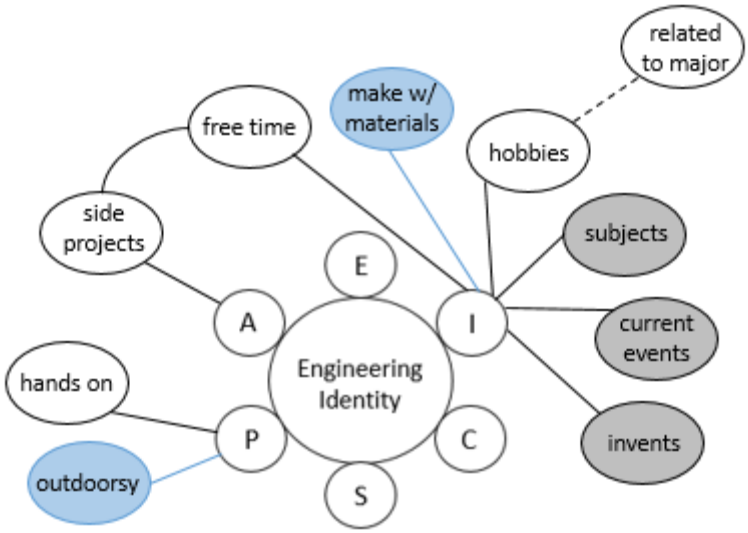

Figure 29: Participant 20 Mind Map 2

4.3.3.3 Participant 20: Assessment

Next, participant 20 begins to think through how her conversation partner's responses do or do not lend themselves to pointing to engineering identity.

20A1: "We also talked about how they enjoyed playing with cats at animal shelters and at first that made me believe like maybe like they are more of a hands on person they like to you know – they're more outdoorsy so they like to um, actually like make stuff I guess. Um with like raw materials or something."

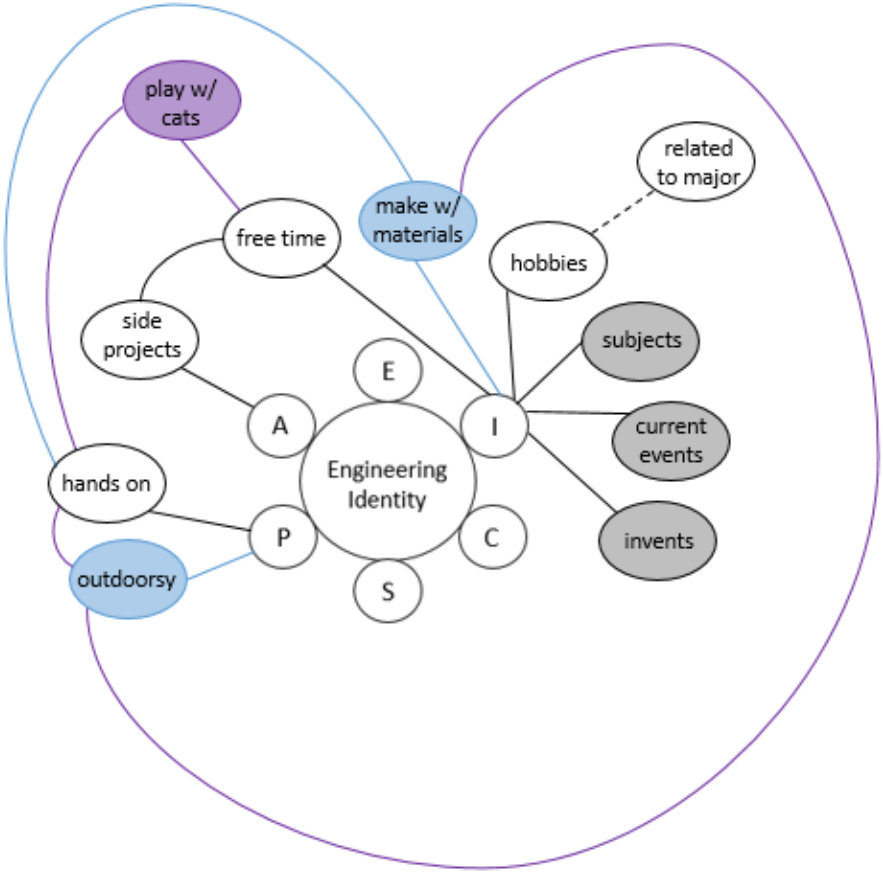

Figure 30: Participant 20 Mind Map 3

To start, participant 20 makes multiple associations between categories, which also all relate to engineering identity. She links playing with cats to being a hands on person, which she also associates with being outdoorsy, which in turn relates to interest in making things with raw materials. Whereas up until now we have spoken about indicators as being one degree away from engineering identity but connected to a trait that showcases it, this model instead proposes even more levels of indirection that both lead to engineering identity, are themselves interrelated, and also all related to engineering.

20A2: "So um, and then… Uh the - the person said that they like to think of things more

conceptually rather than hands on and they gave an example how like they - they would like to build and fix things but they don't think that they have the technical ability to. Which makes me believe that they would like to be hands on person - like they would like to make stuff but they are unsure of themselves and whether not they can do it... So possibly. Um which makes me believe that maybe they are in the – like in the engineering field where they want to study how to actually build things. Since they um, they said they didn't know how to so they - maybe they are going here to learn how to."

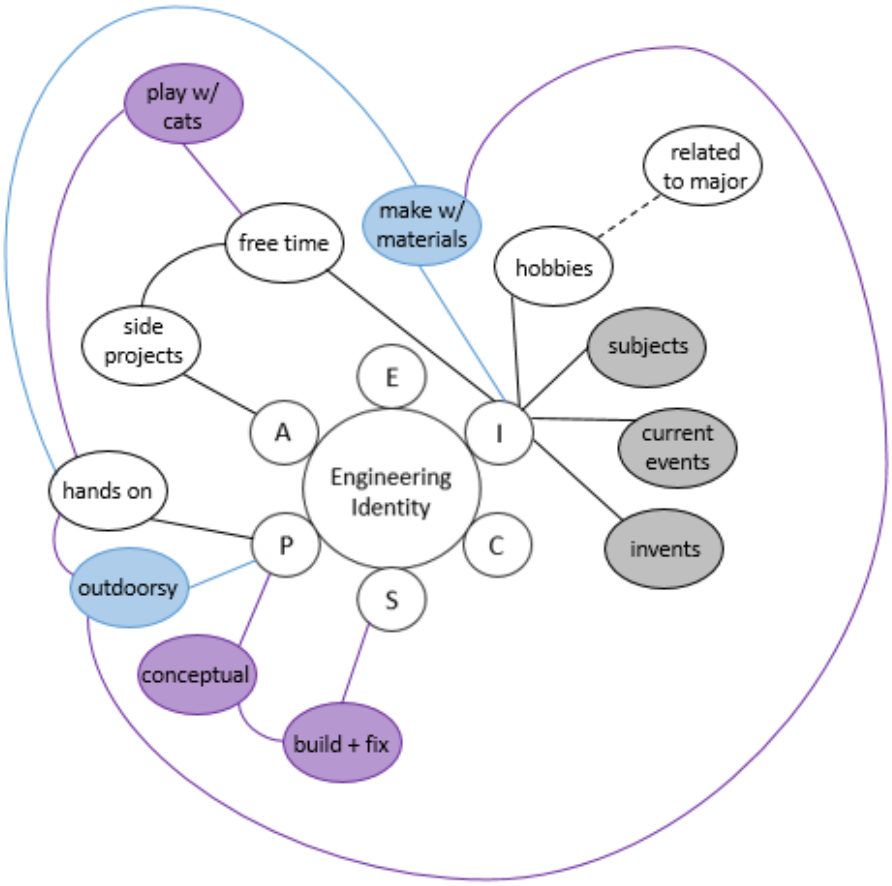

Figure 31: Participant 20 Mind Map 4

Yet, during the chat the conversation partner explained that she is a more conceptual individual. This breaks apart the tightly interwoven associations participant 20 has made around her conversation partner's identity. In responding to this dilemma, we will see participant 20 go on to wrestle with and reconcile these inconsistencies, and bring about new dimensions of engineering identity that both inform our understanding and develop hers. Unfortunately, nuance and development of this level are not represented well with a mind map. Seeing this limitation, we move onto a more powerful form of explaining this finding using stories, in the Stories section.

4.3.4 Critique of Representation: Limits of Showing Change and Alternatives

As a result, these findings on associations critique the notion that people have discrete categories of ideas when it comes to complex entities like identity, along with many design methodologies that rely on such structures. However, the irony here is that this same finding goes on to also expose the problematic nature of modeling associations for design. As seen from this section, associations are too complex to be accurately contextualized and showcased even with representations specifically made for them. Instead, the associations our participants made outgrew the bounds of what mind maps can do to tell their story, leaving little knowledge actionable for design. Even further, going back to object worlds we see how the possibility of different stories existing at once along with the prevalence of dynamic and striking change occurring often, make trying to map associations a futile endeavor. As a result, we move on to the next order of complexity to pursue a better representation for our findings which we will see in the next section.

4.3.5 Summary for Associations

Through mapping the associations of three representative participants, we begin to see the complex networks they have surrounding engineering identity more fully. Specifically, participant 5 and 18 show us how many types of associations interact together to produce overarching ideas, along with how topics may relate to each other as well as engineering, and the kinds of contradiction that can exist within participant's mindsets. Additionally, participant 5 invites us to ask what changing categories for a topic could mean, along with inquiring into the believability of stereotypes. Also, participant 18 shows us a wealth of information regarding engineering's relationship to other fields, that associations can also have varying strengths, and nominally some on how participant's opinions may change during the task. Even further, participant 20 sets the stage to showcase the potential our methodology has to help participants even develop their ideas about engineering identity, along with demonstrating how many levels of indirection and interrelation can occur for any one topic. Thus all of these mind maps contributed to answer our research questions about participant beliefs on engineering identity (RQ1), how they are associated (RQ3A) and some about how they may change during the task (RQ3B). Lastly, through evaluating these mind maps as design representations we see their limitations for showcasing participant development of opinion and consideration of alternatives, and thus must move on to a more complex form of representation that does preserve such complexity.

4.4 LEVEL 3: STORIES

After seeing the sophistication of participants' networks surrounding engineering identity, we came to realize that mapping their associations would not accurately represent the complexity of their worldviews. In order to find a better representation to describe our findings, the best we can do is to move up to another order of complexity by taking on a narrative form. In contrast to associations, these stories do a better job of

preserving context and allowing for the nuances of change and object worlds to take root. Additionally, our progression of levels of complexity parallels the translational stages necessary for design described by many well-known designers, like Hartson and Pyla.

In their 'UX Book', Hartson and Pyla explain that contextual analysis (CA) is performed through aggregation and then narration. Specifically, CA first takes place through breaking down all findings about a user domain into discrete self-sufficient data points which are then built up into an aggregate called a Working Activity Affinity Diagram (WAAD) using grounded theory aspects that also show hierarchical relationships among components. Then, this large structure is traversed multiple times in search of information that relates to specific aspects of the domain, which are used to create Design Informing Models (DIMS) -- some of which have many of the same general forms as mind maps (nodes and links). These DIMs are then studied and iterated upon to learn more about the domain, and eventually produce narrative forms of description like storyboards and scenarios [19].

Even further, we see this same evolution from aggregation to narration in the 3 Paradigms of HCI. In the first paradigm centered around Human Factors, we see the initiative to take many disparate pieces of knowledge and fit them together in a way to unite man and machine. However, the second paradigm which concerns itself with Human Information Processing instead considers a distributed approach, where the mind of the human works in conjunction with digital technology to produce a network of complex information transformations. Lastly, the third paradigm built from Phenomenology professes the deep contextual nature of the lived human experience and values worldviews that take care to see situations holistically [18].

Thus, in a nutshell our progression of showcasing our findings first using initial categories, then associations and now stories, is following the same pattern as many well-worn design methodologies. From both our work, Hartson and Pyla's and the 3 Paradigms, we see first an aggregate emerge from discrete entities, that then is annotated to describe networks of relationships, and lastly results in stories. As a result, we have confidence that our last level of complexity presented here, which also relies on some previous notions we showcased earlier, does indeed strongly represent the complexity surrounding participant's understanding of engineering identity. In turn, we also expect our stories to touch upon all of our research questions in some way.

4.4.1 Story 1: Engineering Status as Adding Value to the Field

Picking up where we left off, participant 20 had articulated some of her associations with engineering that were in conflict with what her conversation partner was actually like. Specifically, participant 20 believed that playing with cats would point to a hands on nature, which would also link to being outdoorsy and enjoying making things which was symbolic of engineering. Yet, her conversation partner said that they were more conceptual.

20A1: "We also talked about how they enjoyed playing with cats at animal shelters and at first that made me believe like maybe like they are more of a hands on person they like to you know – they're more outdoorsy so they like to um, actually like make stuff I guess. Um with like raw materials or something. "

20A2: "So um, and then… Uh the - the person said that they like to think of things more conceptually rather than hands on and they gave an example how like they - they would like to build and fix things but they don't think that they have the technical ability to. Which makes me believe that they would like to be hands on person - like they would like to make stuff but they are unsure of themselves and whether not they can do it... So possibly. Um which makes me believe that maybe they are in the – like in the engineering field where they want to study how to actually build things. Since they um, they said they didn't know how to so they - maybe they are going here to learn how to."

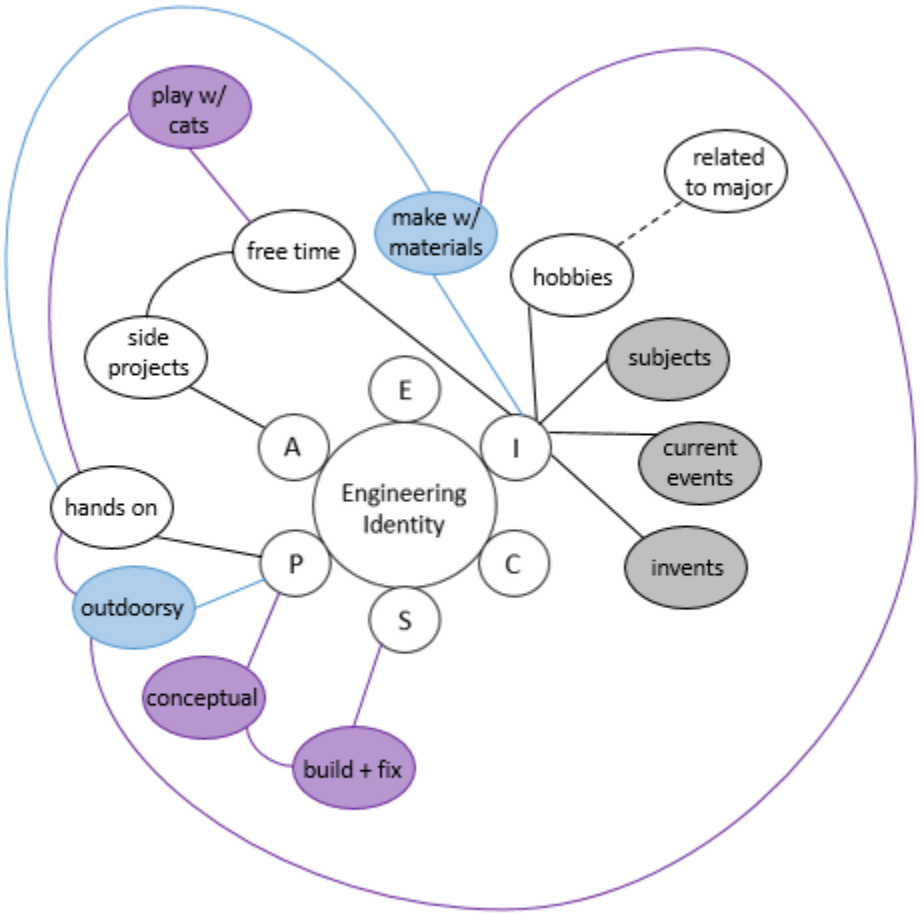

Figure 32: Participant 20 Mind Map 4

To rectify this, participant 20 moves from talking about what is, to speaking about what could be based on desire and intention. She points out that since her conversation partner wants to build and fix things, perhaps they are currently learning how to acquire these

skills through the engineering curriculum. Still, this conflict does not get fully resolved here.

20A3: "Um and then this last thing they said the only time that they think they're hands on is when they are working with people. Much rather talk through problems and solve interpersonal issues than let them fester. Um… I guess with that information they like… they like to work with others more than by themselves so like in groups which is kinda like what the engineering field does its lots of group work. "

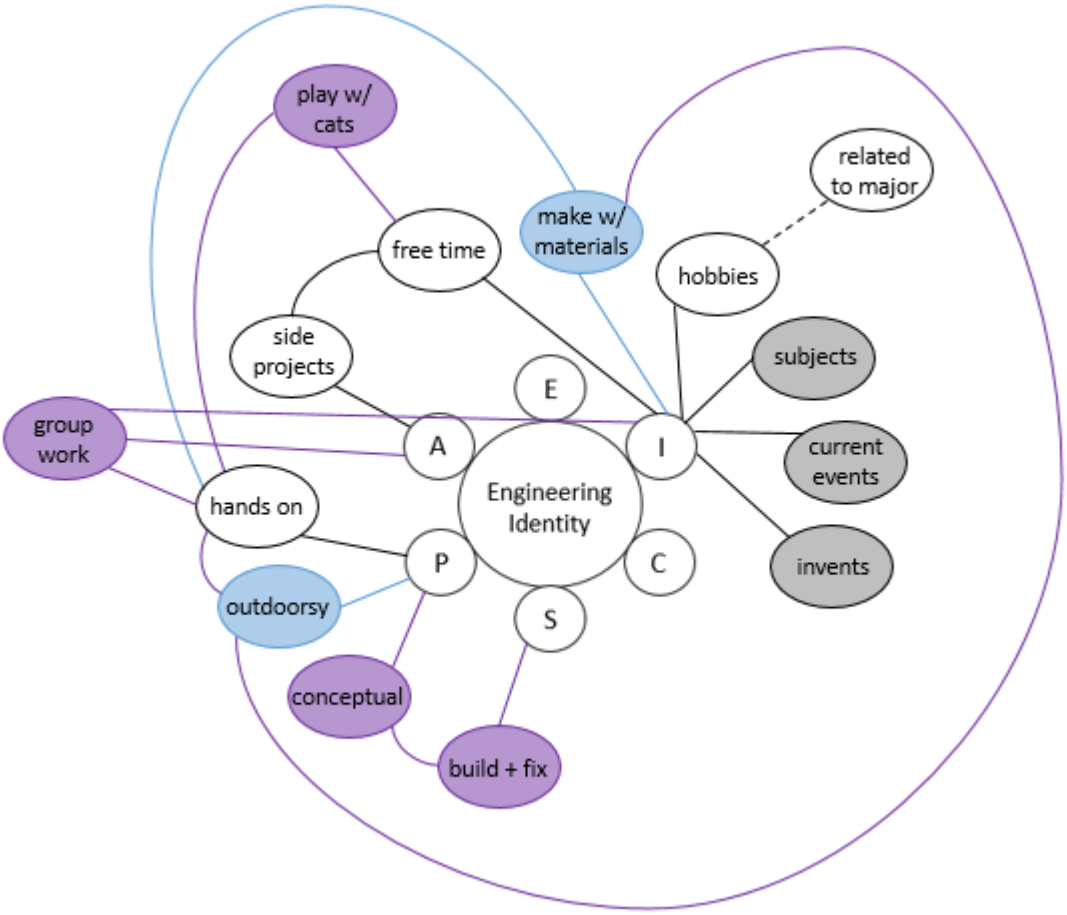

Figure 33: Participant 20 Mind Map 5

Moving on, participant 20 brings up her conversation partner's association of hands on to working with people. It is not entirely clear if participant 20 accepts this association at face value, or only moves forward with the fact that the conversation partner likes to work with others. In either case, participant 20 goes on to explain how this tendency fits well into an engineer's personality based on what the required work of the field.

20A5: "Well I was first considering that they were an engineer, just because of how they are outdoors..."

20A6: "And they like to work in groups. But then they start talking about um they'd much rather talk through problems and solve interpersonal issues. So like I'm thinking maybe like um any issues involving within the group rather than the actual project. Possibly? So um, I feel like they - I don't know - I'm not really sure..."

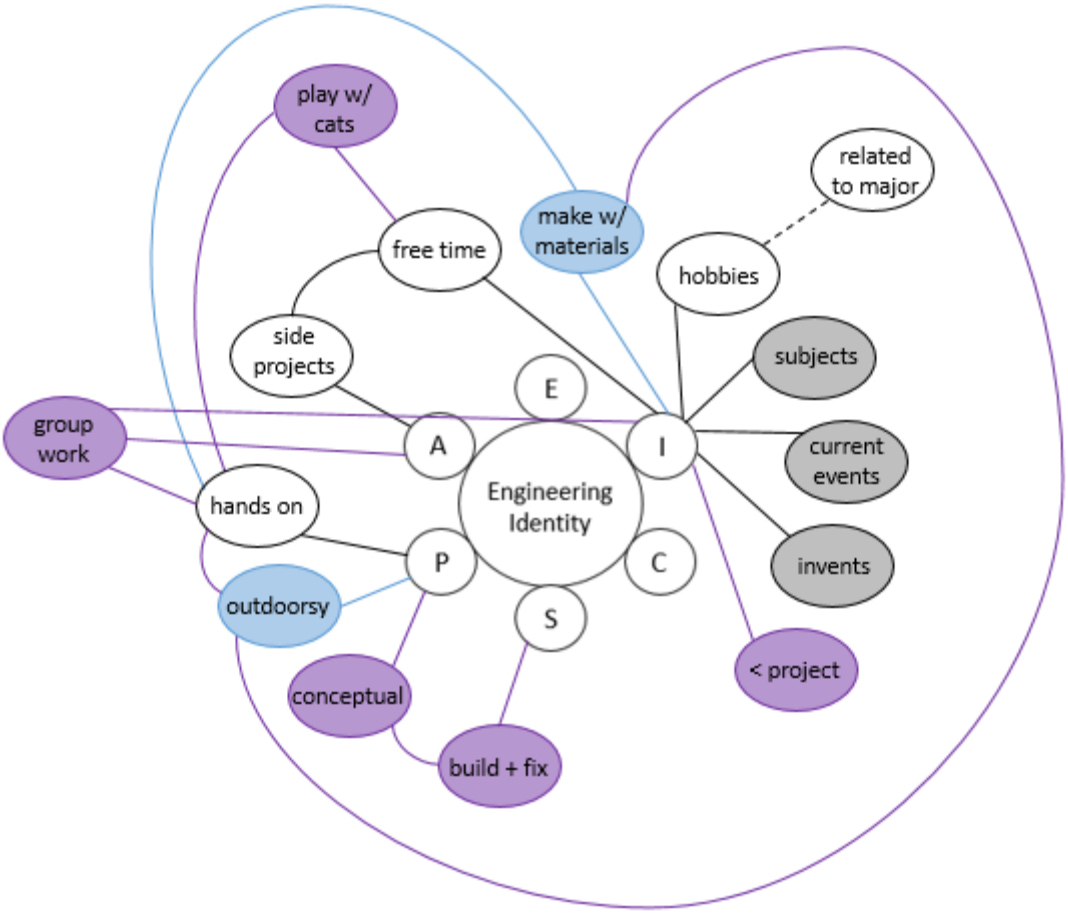

Figure 34: Participant 20 Mind Map 6

Then again, participant 20 comes up against another conflict. As she considers the extent to which her conversation partner likes teamwork, she realizes that it is possible that they like teamwork more than the actual project.

20A7: "so, I'm trying to think like if they weren't an engineer what sort of… Um, I guess field they would be in if they weren't. Let's say - because I'm not really sure who else would be in like group oriented projects that worked only on like interpersonal issues. "

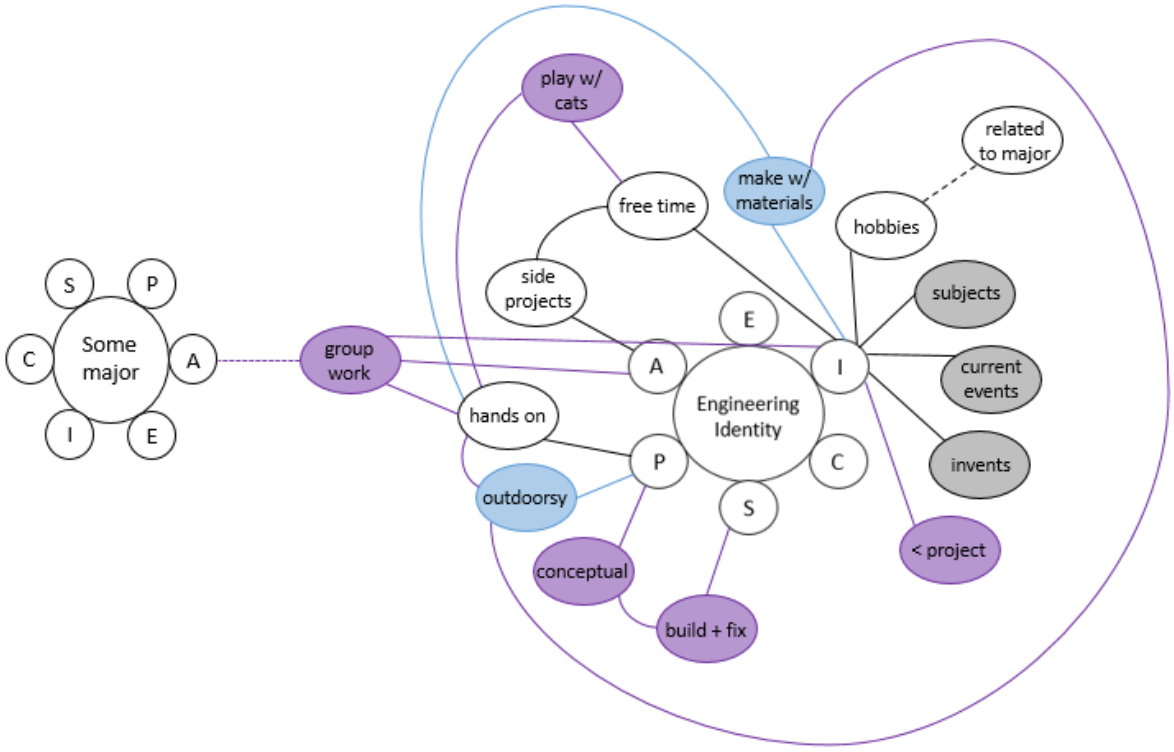

Figure 35: Participant 20 Mind Map 7

Her next comment seems to suggest that participant 20 is skeptical that engineers could exist who value the dynamics of working with others over the actual engineering content of what they are working on. In response to this conflict, like participant 18, she tries to think of another major that would better suit her conversation partner based on their preference for working through interpersonal issues. Specifically, participant 20 tries to think of one where the main work is interpersonal issues, that still involves group work. Yet, participant 20 is limited in her imagination about other fields and cannot come up with any academic majors that would spotlight this topic.

20A8: "Okay. So they – they're talking about how they would like to build or fix things. But then, they say - they can figure out what's wrong with it but they wouldn't be able to fix it. So I'm thinking that they could like - but maybe they are in engineer based off of that, just because um they can see the problem and they can figure out what's wrong and they can tell the group about it? Possibly. So I think - I think my final decision is that they are an engineer that's what it is."

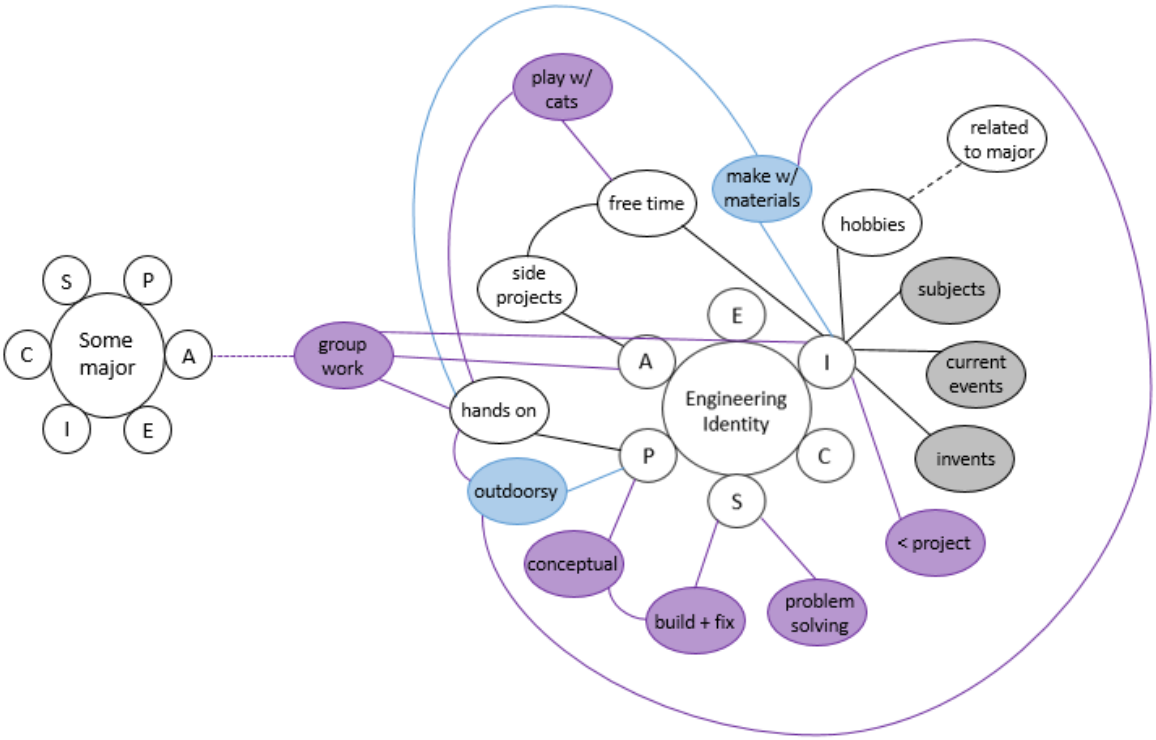

Figure 36: Participant 20 Mind Map 8

Then, to reconcile both the conflict over a hands on vs conceptual nature, and the conflict of seeing teamwork as an end rather than a mean, participant 20 combines the two to imbue her conversation partner with value for the engineering field. Here, she explains that if her conversation partner has good problem solving skills from her conceptual nature, then even if she cannot fix the technical issues on a project she can help figure out how to solve a problem, and because of her open communication with team members she can notify them and they will do the technical work to implement the fix. In this way, her conversation partner would still prove to be an asset for the engineering field and thus qualify for engineering membership, and participant 20 would avoid contradicting either her or conversation partner's associations. Thus, it now seems that participant 20 believes that just having desire and intention to join engineering is not enough to prove membership, but that bringing value to the field in some fashion is necessary, though not required in its full force pre-graduation.

20FA1: "Um I'd say - I think the biggest part of the transcript would be when they said that they would like to think of things that they could build or fix. And they - they thought it would be really cool if they could make something. "

20FA2: "And then they also said that um that like when they are thinking of building something or they're thinking of fixing a problem and stuff they can – they – it says that they figured magnets would work to create a flying car. So they have - if I believe that they have the problem solving skills to figure out what's wrong or like how they should go about building something, but they – they just don't have the technical abilities yet."

20FA3: "Um, they said that they are hands on when they're working with people so like – I was thinking like group projects which the engineering field has a lot of. And um they could talk through problems and solve interpersonal issues within them which is a really good skill to have in group projects as an engineer."

20FA4: "Um. I'd say like when I was thinking before when I said that they seem to be more of an outdoorsy person possibly, but I believe that their answers from that kinda muddled the playing field a little bit. (Can you talk about that? Maybe – yeah maybe talk about some of the places in the transcript that, swayed you into maybe thinking they weren't an engineer?) Um Some of the things that like made me believe they weren't would be that um - well they did say they're outdoors but then they said that they didn't consider themselves as a hands on individual. And so that kinda – that's kinda iffy because at first maybe - I thought maybe they are part of an engineering field where it's more like - maybe like computing and a - ... thing rather than actually making stuff."

20FA5: "But then um, they start talking about um, how they - they like to think of – they started talking about how they'd like to build stuff but they don't have the technical abilities so from them saying that they didn't have – that they didn't think their hands on and then going into they would like to be hands on made me think they may not be an engineer, but I think what swayed me was that they want to build stuff. You know like that's what they want to do. "

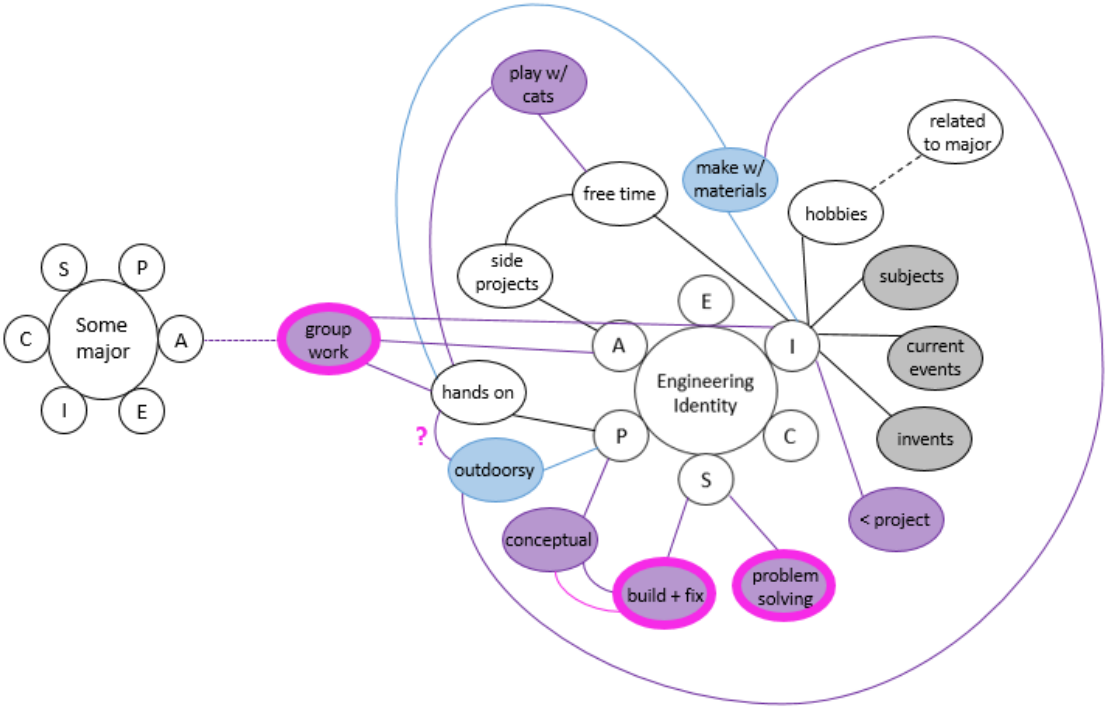

Figure 37: Participant 20 Mind Map 9

During final assessment, participant 20 repeats and solidifies her earlier sentiments. She looks to the future again, explaining that not having technical abilities yet does not disqualify her conversation partner, and that desire in its place is enough for this stage. Notice here though in 20FA5, that participant 20 does not mention adding value to the field through either problem solving skills or working with team members like she had earlier. Thus, it is not entirely clear whether participant 20 backtracked on her previous statement that engineers had to add value to the field in some way, or if she is just briefly omitting this aspect here to focus on desire. Regardless, from this we see temporary weights on certain qualifications, namely that in certain stages it is okay if a budding engineer does not have certain skills, but that what is important is generally adding value to the field (or possible just even having the desire to do so).

20FA6: "(Cool um - and can you just clarify one thing. So the outdoorsiness did that fall on either side for you or that was - just 'cause you said it 'muddled'. Um. But I didn't know if it – if it muddled because it was pulling you one way or the other or it just was a confusing characteristic to deal with?) I think it was more of a confusing thing because um it was kind of like a way for me to like lead into a different - another question that could have cleared up a little bit but then it just kinda made it more confusing. So I was trying to like lead in from outdoorsy to 'oh maybe your hands on' kinda thing but then they said that they didn't consider themselves hands on. And so it's kinda like, this is kind of weird."

20FA7: "(Okay. Can you - Can you tell me a little bit about how um outdoorsiness and hands on relate to each other for you?) So I consider um, I guess in the outdoors there's nature and they mentioned hiking so like they're climbing they're walking they're exercising they're um - I guess there's a lot of physical activity with that, and um I guess that correlates with hands on sort of things because they're doing a lot of physical activities if they're making things with their hands. That sort of thing."

Lastly, participant 20 explains that a full reconcile about the relationship between hands on and outdoors did not occur during the study, but she does go on to explain more about why she associates these two topics together. In conclusion then, participant 20's story provides us a lot of insight into how our participant's conceptions of an engineer may change during the task, helping us answer our research question about change (RQ3B).

4.4.2 Affordances of the Methodology: Helping Participants Develop Beliefs about Engineering Identity

What we learn from cases like participant 20, is that the methodology did not only allow participants to articulate their associations to us, but in doing so their own networks became more apparent to them. In turn, this allowed participants to develop their own conceptions of engineers, particularly when two associations were in conflict with each other. This makes sense when considering people's cognitive tendencies, namely the inherent desire to have coherent beliefs. Adding to this, participants were not only notified of conflicts within their beliefs and the world, but also were asked to use that belief system to complete the task. As a result, participants experienced another thrust of

motivation to have a complete set of rules to work with to perform the task. Thus, when the participant's associations surfaced with conflicts, they had to reconcile their discrepancies to put them to use for the task. Again harkening back to object worlds, negotiation like this is a natural part of designing, and considering that our participants were designing their own conceptions of engineering identity during the study, it makes sense that this behavior would emerge.

Some examples of this behavior include nuancing and reworking. Nuancing occurred when participants would recognize and speak to more of the complexity in the topics they were working with as they progressed through the task, though they did not change their overall opinion. A good example of nuance comes from when participant 16 initially decided to ask her conversation partner if they liked math. Her prevailing assumption was that students who are good at math will like the subject and feel confident to pursue the engineering field.

*16Q4: "I think engineers - can I ask about like math? Like what they think about math?... Um what's your view on math? *laughs* "*

16Q7: "(Um can you tell me a little bit more about um your thoughts behind 'what is your view on math'?) Yeah. Um I don't know I feel a lot of – um a lot of kids get scared if they don't like math in high school there like 'Oh I can't do engineering'… Like yeah so usually when they're engineers they're like yeah I was really good at math in high school I was doing well. So."

Yet, later after her conversation partner answers with a mediocre interest in math, participant 16 realizes that she is not always enthusiastic about math either. Instead, her feelings on the topic change depending on how well she is doing in the class. Notice though that participant 16 does not do away with the association of math and engineering all together, but rather explains how there are more dynamics around the topic, and using this criterion to sort out engineering membership is not as simple as asking "Do you like math?".

*16A11: "Um 'Are you a fan of math?' 'I don't hate it but I wouldn't say I love it either' I mean that could be anybody *laughs* … Yeah she doesn't like hate it then um she doesn't love it. I mean I could say that about myself right now I'm having hard time. So like um I don't hate it either but I'm not like 'Yes! let's go to math class now'."*

Moving on, sometimes participants changed their ideas about engineering all together during the task, which we call reworking. Change like this can span all the way from making simple tweaks on opinions to debunking quite complex patterns of belief. For instance, participant 8 first wanted to ask his conversation partner if they would rather live in the city or on a farm to help weed out the prevalent agriculture majors at Virgini Tech.

8Q1: "Um so… Do you like the outdoors?... Would you rather live on a farm, or in a city? (What's your thoughts behind some of these questions?) Um well I know that uh

Virginia Tech has a lot of agricultural study programs. So I feel like some people's answers might be revealing to uh answering those questions."

Yet, after the IRC chat participant 8 realized that such a preference had no real bearing on engineering identity. However, in this case -- what we cannot determine from the study is if participant 8 initially really believed that living preference had much to bear on engineering identity, or if this was just a haphazard association he threw together for the task.

18A1: "Okay so my initial questions I realize were kind of useless. Um because honestly anyone could wanna live on a farm like - ... for any reason."

For a more sophisticated example, participant 10 reworked two of her initial criteria for engineering membership. During the brainstorming session she first explained that she believed engineers are creative, and do activities related to engineering during their free time.

10Q2: "Um then probably like creativity or like do you consider yourself creative."

*10Q9: "(Mm. Can you elaborate more on your questions about creativity and artistic-ness? If that's a word. *chuckles*) Um. Yeah so like the creativity, like maybe - like do they like to invent things? Um or like come up with like not normal ideas. (In what kind of situations are you imagining this happening in?) In like brainstorming for like anything, like problem solving. I don't know. Um Artistic I don't - I don't really know where I was going with that."*

10Q5: "Um… I don't know. Maybe like motivation? Like - I don't really know what I mean by that… Like they'll go out and do things like related to the major for fun."

However, during the assessment session participant 10 gave up both of these prior notions because of how they did not align with her own experiences. For instance, she explains how she herself is not creative, and thus her conversation partner that also identifies as non-creative should not be excluded from being considered an engineer. She then goes on to explain that creativity is used for invention, but that there are other types of engineering practice that focus more on improving what already exists or innovation.

10A3: "Um… She says she's not really creative when inventing something. But I feel like that doesn't exclude her from like engineering careers 'cause a lot of people just aren't – like I know I'm not. Um..."

10A8: "(Okay. Can you elaborate a little bit on uh - you were going over, what was it, um the creativity when it comes to inventing something and then you identified - you said 'Oh well I'm not very creative either when I identify – when I invent things', can you elaborate a little bit on that and what you meant by that?) Yeah. So like some people are really good with like coming up with new obscure ideas out of nothing. But um, but like a lot of people including me or more like 'Oh there's this thing that already exist and it has

like this one specific problem let's like update the thing'. So like more innovation as opposed to invention. Like they're both engineering type things but I feel like um invention is more like specific. Like I had a friend who would just like create all these super weird like prototypes for stuff. And I'm like how do you even think of that like?"

10A9: "Like no one needs this! It's just some random thing you came up with. And like I don't know I don't - I'm not capable of doing that I need like something already there for me to like improve upon. (OK. When you say - you also just said 'Nobody needs this'. Is there - do you have perceptions then on need as well as innovation versus invention?) Um not necessarily like related to engineering, like a lot of people just create stupid things for fun. Um and like a lot of the things the person I was talking about made like, it was a need to him, it just was like something really dumb. He made like a cereal cup so that all this cereal wouldn't get stuck at the bottom... When you eat cereal out of a cup without a spoon, and I'm like how many people in the world eat cereal out of a cup without a spoon?!"

Additionally, participant 10 drops her original criteria of engineers doing things related to their major for fun. Instead, she says that engineering is so much work that motivation actually works against doing things related to the discipline for fun when engineers finally catch a break.

10A6: "Um… she says she's in two clubs but like doesn't do stuff for fun. Um I feel like that's understandable though 'cause we don't have a lot of free time to begin with. Um - (Why don't engineers normally have a lot of free time, in your opinion?) Um. I don't know I feel like like we have just like - I don't wanna say more intensive classes 'cause that's like not really true, but like a lot of our stuff is group work so you have to do a lot of stuff outside of school. So that kinda like eats away from your free time. Um I don't know also like more long term projects I would say. So that's like I don't know - you're less motivated to like do other engineering things when you have like a long term project looming over your head."

In summary, nuancing and reworking both involve externalization of beliefs in a way that also allowed participants to reflect on these beliefs. As a result, many participants took this opportunity to also elaborate on the strengths and shortcomings of those beliefs, because of human desire to have coherent beliefs (and thus bring their own ideas in line with the realities of their conversation partner). Thus we also see that in effect, our methodology allows for participants to critique their own biases -- those initial assumptions they had about engineers.

Furthermore, this is why for many participants the belief that the task was a reasonable one, namely that engineering status could become known, started to break down. Seeing the contradictions in their own associations made participants begin to wonder if it was possible to merge their conflicting ideas, or if a finite description of engineers even existed. For example, towards the end of his assessment session, participant 23 came to the conclusion that he should make his decision almost entirely on what computer his

conversation partner had, for this was the only criteria that would not widely vary between engineers.

23A7: "On- that's kinda like I don't know like everything else is like I met a lot of unique people in like engineering so like they're all kinds of all over the place with like everything else is kind of like doesn't really narrow it down as much but I feel like that part they have a MacBook it's like, I haven't seen anyone with a MacBook in engineering I feel like that's like – and the engineering specifically says like 'Hey don't get a MacBook'. I feel like that's kinda, the most concrete proof I have that they are not an engineer."

Similarly, participant 25 started her assessment session off by explaining that she had come to the realization that engineers are so diverse, that her conversation partner could have answered every question differently and still fit into the discipline.

25A1: "OK. Um. So a lot of the answers that she gave me where what I was looking for – for like if they were an engineer. But now I'm realizing that - I mean the engineering spectrum is so broad that she could have answered everything the exact opposite way and still be an engineer."

4.4.3 Story 2: Disciplines as Extremes and Computer Science as 'Other'

In order to compare participant's conceptions of engineers to reality, we decided to look into how often they accurately guessed the engineering status of their conversation partner. Our findings are summarized in the table below.

Table 6: Accuracy of Interrogator Guesses about Conversation Partner Engineering Membership

	Guessed Engineer	Guessed Not-Engineer
Was Engineer	5, 7, 24	8, 12, 15, 16, 18, 21, 22
Was Not Engineer	6, 10, 20, 25	9, 11, 13, 19, 23

At first, this gave us little insight -- besides the fact that the task was indeed a difficult one, with less than half, 8/19 participants, guessing correctly. However, after reorganizing the table to include the actual discipline of the conversation partner, an interesting finding emerged that helped deepen our answers to our research question about conceptualizations of engineering identity (RQ1), along with some details that informed answers to our research questions about consensus (RQ2) and variance (RQ3).

1: Mechanical Engineering Major
(half correct [2/4])

2: Computer Science Major, Business leadership minor
(mostly incorrect [5/6])

3: Physics and Political Science Double Major, Minor in Spanish
(mostly incorrect (mostly incorrect [4/5])

4: Multimedia Journalism Major, Minor in Appalachian Studies
(always correct [4/4])

Table 7: Interrogator Guesses along with Major of Conversation Partner

	Guessed Engineer	Guessed Not-Engineer
Was Engineer	1, 2, 1	1, 2, 2, 2, 2, 2, 1
Was Not Engineer	3, 3, 3, 3	4, 3, 4, 4, 4

Specifically, participants always guessed the journalism major as not engineering (correct), half the time placed the mechanical engineer as engineering (correct) and 4/5 guessed the science major as engineering (incorrect) and 5/6 placed the computer science major as not engineering (incorrect). From this, it seems that participants knew how to respond to some extremes that lived within stereotypes, but not how to interpret related but differing concepts surrounding engineering.

Looking at the participant's final decisions, we see that even if they were not always accurate they were almost always cohesive with the collective mental model of engineering that participants used and built during the task. Below we have a few other tables that detail the reasoning of why participants made the decision that they did -- also described using their own words along with direct quotes to preserve their perspectives.

Table 8: Reasons for Final Assessment of Mechanical Engineering Conversation Partner

Mechanical Engineer – Engineer
Wrong Guess: 8, 22 ● 8: high likelihood of going out, little workload ● 22: Out of state but many friends outside of engineering
Right Guess: 5, 24 ● 5: like me they branch out, left brain, movies, plays video games

- 24: likes creating things, would rather make something than buy it, likes math and science

To start, we can see that the mechanical engineer was placed in the non-engineer category for a few reasons that did not match the majority understanding of engineering identity. For example, according to participant 8, this conversation partner was not an engineer because of their high likelihood to go out, and small workload. This can be explained by the fact that this conversation partner was only taking 3 credit hours during the semester in which the study took place, and thus is somewhat of an outlier. Additionally, participant 22 believed this conversation partner was not engineering because they had many friends outside of engineering, which was not likely considering that they were out of state and many engineers surround themselves with other engineers. This sentiment about engineers sticking with each other socially was also expressed by participant 15.

15A11: "What clubs have they done - in a sorority. So I don't know that doesn't sound super, from what like a lot of my friends who are engineers I've like talked to them and they're like 'oh sororities'. I don't know but for some reason they don't like the idea of sororities but again engineers are all really different so it's hard to tell... (Can you go - Can you elaborate more on your friends who don't like um - who are engineers and don't like sororities, like do you - do you know why they don't like them or…?) A lot of them just - a lot of my friends are like just being in a sorority or frat-fraternity is like a waste of their time in college and they – I mean like I'm sure they like to party but like I don't know, they'd just – they'd rather be in their own little group of engineers."

Table 9: Reasons for Final Assessment of Journalism Conversation Partner

Journalism - Non Engineer
Wrong Guess: 0
Right Guess: 9, 13, 19, 23 ● 9: Does not like math, did not take math and science APs in high school, does not see high value in science ● 13: Not good at working with their hands, favorite subject is history ● 19: Role Models are not engineers, likes to read historical fiction, only sometimes likes problem solving ● 23: does not have a heavy homework load, has a MacBook

In contrast, the journalism major was always placed as not an engineer because the characteristics they professed were antithetical to those associated with engineers. What is interesting here, is that these notions about engineering identity were not only articulated by these participants -- but many others who received different conversation partners during the task. For instance, liking math being a prerequisite for engineering was mentioned by twelve other participants than just participant 9, and seeing high value in science was mentioned by one other than participant 9. For participant 13, five other

participants talked about engineering's relationship to hands on, and two others expressed negative valence specifically towards history including participant 19, though many more expressed negative orientation towards humanities in general. Problem solving was a highly valued criterion not only for participant 19 but also seven other participants. Lastly, for participant 23, eight others spoke to the nature of heavy workload in engineering and two others explained that Mac Books are not allowed by the College of Engineering.

Table 10: Reasons for Final Assessment of Computer Science Conversation Partner

Computer Science – Engineer
Wrong Guess: 12, 15, 16, 18, 21 ● 12: no interest or ability to build ● 15: not hands on, in a sorority, does not like sci-fy ● 16: not actively involved in engineering related activities in high school, had an internship with many meetings, classes teach with slides instead of demonstrating material ● 18: does not like math enough ● 21: does not like the application of math (things like sci-fy, documentaries and puzzles)
Right Guess: 7 ● 7: is a girl and has eclectic taste, studies alone, dedicated to school, external thinker, a mix of extraversion and introversion like me, studies at night

Next, the reactions to the computer science major were primarily that they did not belong in the engineering field. Looking at our table, the reasoning that participants had for this conversation partner not being an engineer do describe some of the main differences between computer science and other engineering branches -- like not involving physical building or being hands on, teaching the field through discrete slides rather than working out problems on the board, and involving a different type of math. Comparing these with the reasons participants in general asked if they should consider CS as engineering, we see they include much of the same.

15Q: "(Mm. When you - I - I um - I didn't quite pick up what you said. Did you say 'Is computer science engineering' or…?) Yeah would that count as engineering? (Um. The person you're talking to is um a student here at Virginia Tech… And computer science is a Department under the College of Engineering) ... Is there – so - so by that definition you could consider them an engineer. Do you - is there something about computer science that makes you kind of waiver?) Uhh I feel like computer scientists a little bit different than most engineers. (In what ways?) Um they're more like… There - 'cause they - I mean like computer science is much more like a thought process like this - then this. And they're a little less hands like -... - mechanical and stuff I feel like ",

16SI: (Do you have any family members or older close friends who are engineers? … For some of these people you say engineer, and others you call them CS. I was curious why

you made the distinction in your answer?) I know that CS is not in the engineering college at other places. I don't think CS is as science and math based, like they don't do the 2306 course. (Can you elaborate on that last point?) Some of the courses they don't have to take, physics, they don't take statics or dynamics, which is the meat of other engineer disciplines. I have done some CS programming. It's more problem solving than based on science and math, which is a different kind of problem solving.

20FA: "Um Some of the things that like made me believe they weren't would be that um - well they did say they're outdoors but then they said that they didn't consider themselves as a hands on individual. And so that kinda – that's kinda iffy because at first maybe - I thought maybe they are part of an engineering field where it's more like - maybe like computing and a - ... thing rather than actually making stuff."

Even further, these explanations overlapped with the reasons all participants who identified themselves as going into CS gave when describing the degree to which they saw themselves as engineers. As seen below, all three of these CS candidate participants identified with interest in the conceptual rather than concrete nature of engineering.

10SI1: I enjoy most of the work in the discipline, designing stuff and using math…

10SI2: ...but I feel like I am more focused on math than the engineering part. Like I am very happy to sit down and do equations all day but not create or improve anything.

18SI1: I don't really enjoy working with hands, I do enjoy problem solving. Basically I don't like building models. I prefer software.

*20SI4: (Do you consider yourself to be a hands on person? Something you focused on a lot in your assessment.) I want to do CS fields, so I would not say that I am hands on but I do like to create something without materials *not with hand motion*, and make it a finished project.*

Lastly, during the task many participants went on to also talk about how computer scientists struggled more with social skills than their engineering counterparts, as mentioned earlier. This adds on another facet that treated computer science as "other" among the engineering branches.

6FA: "A lot of computer engineers I've met, this is a stereotype that is kind of held true, um are very like antisocial so – and like kinda like recluse. So the fact that they go out with their friends I'd say probably not that… Um going out and enjoying nature I've found is not something that's typical of computer engineers so I can rule that out."

7FA: "Um… And then - yeah I think like um the environmental and civil engineering are generally pretty social but they know how to work on their own and they get things done individually. (Hm. What makes you say that) Um just cause like in comparison to um people I've met from computer science or computer engineering compared to like environmental or civil or like even like mechanical, um they just seem to be more open to

like working with other people. Than um people who are very self-driven, and like computer and electrical and uh CS."

23SI: There was only one question I did not ask which was about introvert/extrovert – but thought about it a bit more and I have met a lot of different types of people [in engineering]. Some stereotypically ones stay in their rooms with video games but there are also extraverted ones that walk up and talk to people. Major specific – computer.

*25Q:"*writing* Hm maybe… I think engineers - well somewhat there's a lot of engineering majors - but I feel like for the most part its very much about furthering technology and humanity. But then there's computer science and computer engineering which is still – but I feel like it's less - you don't feel like you have to have good people skills to be an engineer so maybe I should concentrate on that? he could and it helps. Um… maybe, how comfortable are you with, working with people. 'Cause engineers have to work with people.*

Taken together, we see a cohesive understanding of computer science as being outside of engineering form from multiple angles. Firstly, ⅚ participants identified the computer science conversation partner as non-engineering. Secondly, their reasons for doing so were mainly founded upon the heightened digital rather than physical underpinnings of the field, which were also echoed by other participants during the task at large. Next, participants who identified themselves as going into CS all had similar diverging traits from their engineering counterparts, and two of these participants even expressed concern that this made them less engineering. Lastly, participants by and large professed beliefs that though being antisocial was an untrue stereotype for most engineers, it was valid when it came to computer scientists.

Table 11: Reasons for Final Assessment of Physics and Political Science Conversation Partner

Physics and Political science - Non Engineer
Wrong Guess: 6, 10, 20, 25 ● 6: has hobbies like me, heavy workload, 20 credits, in general like me ● 10: likes math, is detail oriented ● 20: hands on with people, has a desire to make, likes teamwork ● 25: organized, practical and creative, values giving back, likes seeing new perspectives with reading, likes the things I do, dedicated to school, is busy
Right Guess: 11 ● 11: has a Mac Book, parents job is more social science, favorite math is entry-level, likes reading and writing, maybe 20 credits

Moving on to our last conversation partner, unfortunately, no overt patterns emerged from looking at the final decisions of participants for the physics and political science major.

Switching gears, though participants were not highly successful in deciding whether or not their conversation partner was an engineer, they did have an uncanny ability to assess their conversation partner's gender. As mentioned earlier, the majority of participants often tried to consciously or unconsciously place the gender of the person they were talking to, and in all cases but one they were correct (15/16). This level of accuracy was much higher than guessing whether or not the conversation partner was an engineer (8/19), even though it was not the main task. Even further, some participants (5/16), did not even consciously recognize that they were placing the gender of the person they were talking to and surprised themselves.

Table 12: Accuracy of Interrogator Participants Guesses of Conversation Partner Gender

	Thought Male	Thought Female
Was Male	5, 19, 22, 23, 24	
Was Female	18	7, 10, 11, 12, 15, 16, 20, 21, 25

4.4.4 Story 3: Engineering Identity as Progression of Schooling and Confusion around Divergent Interests

Another aspect of the study that we have only touched on briefly, was asking participants about their own membership within engineering. From this emerged two interesting findings -- seeing engineering identity as a progression of schooling and diverse interpretation about what it meant to have interests outside of engineering. Both of these help further answer our questions about participants' conceptions (RQ1), consensus (RQ2), and variance (RQ3) on engineering identity. To recap, the self-identification portion of the study took place after the task at the very end of a survey inquiring about participant's general experiences within engineering. Specifically, we asked participants the following question along with their reasoning. Our findings are summarized in the table below, though the focus of our discussion will be on quotes from participants' which better explain their conceptions around engineering identity.

> To what degree do you identify as an engineer in general?
> 1 2 3 4 5 6 7
> (1 - I do not identify as an engineer at all, 7 - I completely identify as an engineer)

Table 13: Interrogator Participants' Self-Identification as Engineers on a Numerical Scale

Scale	**Participant**	**Total Number Participants**
1		0
2		0

3	25 (hinted at it)	0
4	9, 16, 18, 25	4
4.5	6 (4 or 5),	1
5	7, 8, 11, 13, 15, 21, 22, 24	8
5.5	23 (5 or 6)	1
6	5, 10, 12, 19, 20	5
7		0

From this, we can see that no participants identified themselves as fully engineers, but also no participants identified themselves as complete non-engineers either. Most participants were somewhere in the middle range, with the data set having a mean of 5.05 and a median of 5. However, looking at participants' reasoning for the scores they gave, 10/19 of them spoke about identity as a progression of schooling. For instance, participants 5, 9 and 15 talked about maturing in an identity like a road that you walk along to journey closer to engineering over the years in college.

5SI: 7 is kind of extreme, maybe next year I will be a 7. I am a freshman so I am still figuring things out.

9SI: 7 is you are done with college, have a job. 4 – I am on the road there.

15SI: I am working towards being an engineer.

Still other participants explained that they felt less like an engineer because they had not yet taken some of the advanced courses offered by the curriculum, but that once they had they would be more engineering like.

19SI: The reason I say 6 and not fully an engineer is because right now I am a freshman and I have not taken all of these advanced courses and specific class about certain types of engineering, so I don't have the full knowledge yet. Right now I am in those general classes that don't always stimulate my mind and thought process.

Participant 16 in particular also talked about the necessity of the maturity that comes with fully embracing the stage of life within college as the criteria for which she would see herself more as an engineer in the future.

16SI: I still feel like a high schooler. I am struggling with some courses like math and stuff. And I have not gotten into engineering courses yet.

Others also expressed maturity as a criterion for furthering engineering identity, but from the perspective of developing skills. Participant 25 spoke about learning more about the

field so that she could be an asset to her teammates and not rely on others to teach her. Still, participant 20 explained that she had good problem solving skills but needed to develop it more to rank herself more highly as an engineer.

25SI: Just cause like I am not an engineer until I start working on engineering projects. I am working on class projects right now but I have no idea what is going on. We are doing aerospace and drones. I always have to catch up – I don't like that. I am learning how now but until can do project like this without teammates having to explain to me why we are doing this, then I will be an engineer.

20SI: Also, I did not put a 7 - I do believe I have good problem solving skills but to a point. I need to develop it more.

Additionally, participant 7 and 20 both explained how in the absence of skill, pursuing engineering via just doing the curriculum was an important measure of being an engineer.

7SI: I do not have every single skill yet to be an engineer, but I think I am because I am in the engineering program, so I am pursuing engineering and I have a passion for it. I have analytical and technical skills to build on and become an engineer.

20A: "So um, and then… Uh the - the person said that they like to think of things more conceptually rather than hands on and they gave an example how like they - they would like to build and fix things but they don't think that they have the technical ability to. Which makes me believe that they would like to be hands on person - like they would like to make stuff but they are unsure of themselves and whether not they can do it... So possibly. Um which makes me believe that maybe they are in the – like in the engineering field where they want to study how to actually build things. Since they um, they said they didn't know how to so they - maybe they are going here to learn how to."

Lastly, participants 8 and 24 talked about how they felt less like an engineer because they had not yet identified the specific branch of engineering that they wanted to join. Instead, they would declare their major at a specified time after their first year of General Engineering. Thus, this can be considered an aspect of progression of schooling because the decision to join a branch is indeed a milestone in the school curriculum and monitored by the university.

8SI: "I am definitely not a 7 because I did not come to VT knowing exactly what wanted to do as engineer. I did not know what engineers did so I could not be really engaged in it. I feel disconnected from people who are gung-ho about engineering."

24SI: But I am first year student and I don't even know what type of engineering I want to go into yet.

Additionally, within these responses about why participants felt they were a certain degree of engineering, we also saw a lot of diversity around what it meant to have interests different from engineering. First, however, let us recap on our earlier findings

we presented in the Initial Categories section about how participants drew lines in the sand around certain topics in general. Compiling some of our initial results from earlier, we can see that participants considered math and science as engineering subjects, and that reading, writing, English, and humanities were not.

Table 14: Frequency of Participants Bringing up Antagonism between Math, Science and the Humanities

Subjects	Number of Participants	Majority Valence
Math	13	Positive
Science	10	Positive
Reading, Writing, English	7	Negative
Humanities	7	Negative

A few participants even claimed that a person can be in either of these two camps, but not both, because they were natural opposites and sometimes even "othered" by each other. For example, participant 22 crafted the question below like a binary, asking her partner if they were more of an English or math person.

22C7: <studentguesser> That's super cool. Are you more of a math person or English person?

Even further, participant 11 explained that science and math people did not like writing because of its fundamental nature of being more open ended.

*11A2:"Um. Maybe not so much the writing part. I feel like that's not typical of like science math people *laughs*."*

11FA1:"Um. The writing - like reading and writing. Like I like to read but I don't really like to write. (What do you not like about writing?) There's no like definite answer. That's why I like math.

Yet, academic subjects were not the only topics participants expressed opinions on in terms of engineering identity. During the study, many participants made claims about what it meant to have general interests outside engineering. Some like participant 5, believed that having interests other than engineering was an important part of being a well-rounded student.

5FA1: "It's something I've always loved to do, 'cause I like I don't know when it comes to right brain left brain I like to bounce it out because I don't wanna lean too far one way. So like I always took art classes like I've been taking music classes since I was 5 like playing the piano and like in choir and stuff. (confident) So um - and also that's another thing like especially as a Virginia Tech student in engineering most of them are very like, um what's the word… Uh they've been involved in all kinds of things you

know... I think that's like a very common thing they uh yeah… like not just one thing because I think that something they look for in admissions, like wide spread interests but also like a skill set in specific areas."

In contrast others like participant 6, felt that unrelated interests had no bearing on engineering membership in either direction.

6A6: "Um my roommate likes to - she's in choir and she sings and I have a friend on the 6 floor of my dorm who also is also in choir there's a few of them. So I don't think that's particular to engineering I just think there are engineers in choir rather than - all the, it's not mutually exclusive is what I'm trying to say."

Even further, a few participants pointed to interesting dynamics where certain demographics, like gender, and unrelated interests intersected. Participant 7 and 15 specifically pointing out that it was female engineers who were more likely to branch out from engineering interests.

*15A9:"... fiction and then when she said sappy romantic novels I'm like you're a girl. *chuckles*... (At one point I remember you said 'this is so much harder because she's a girl'. (during the IRC conversation)) Yeah. (Could you elaborate on that?) Yeah so, the girls in engineering I feel like tend to be much more diverse in what they like. The guys tend to be much more straightforward like - a lot of the girls are tomboys but a lot of the girls aren't. A lot of girls are like to dress up and a lot don't. Like if you see me... Um my roommate and I are really similar in like the kinda person that we are but we also have very different likes. So it's really hard to like tell. I feel like with a guy it would be easier to tell. Um, I don't know girls are just more abstract. *chuckles*"*

Still, others used the indicator strategy mentioned earlier, to mine engineering traits from seemingly unrelated activities their conversation partners may be involved in.

7Q3: "What they like to do outside of class that doesn't really have to do with school... (What your thoughts behind asking that?) Um well even though it's not really gonna indicate whether or not there an engineer, 'cause I know for me my activities aren't directly related to engineering um. It'll kinda indicate what kind of skills they have, like depending on what they do - like teamwork. Um, 'cause like I know I'm in choir so teamwork or like working with other people or if it's more like an individually based task so."

These sentiments about the relationship between unrelated interests and engineering identity continued into the self-identification section. Specifically, 6/19 participants mentioned during this part of the survey some way in which their interests were either unrelated to or divergent from engineering. Furthermore, in analyzing how participants reflected on themselves we found a spectrum on development and confidence around whether participants thought that other engineers liked topics unrelated to engineering, and sometimes whether it was okay to do so. Some participants strongly believed that

their identity encompassed more than engineering, and intentionally picked a lower score on the scale to reflect this.

21SI1: I just don't think I am just an engineer and that's just all I am. I am a lot of other things. I have not gotten a degree yet but engineering is a big part of who I am and the reason why I am interested in all the things that I am interested in. (5)

One participant even went so far to say that no one could rank themselves as a 7 and have their entire identity rest on engineering.

23SI3: but no one can completely be an engineering. Like I am trying to do a minor in business. I like math and science, but I like other stuff like theater class is fun. I have different interests not in line with engineering per say [and that makes me not a 7]. (5 or 6)

However, on the other end of the spectrum, there were participants who expressed concern around having other interests. For participant 22, this even went so far as to make her wonder if she did not belong in engineering for this among other reasons.

22SI1: So well first of all, I wonder if I shouldn't be in engineering.

22SI6: (Can you elaborate on what you mean by you wonder if you shouldn't be in engineering?) Sometimes I wonder if I am smart enough.

22SI7: Also I like other things - I did well in English and history in high school. Sometimes I think I should branch out but I don't know what I would do. (5)

4.4.5 Summary for Stories

Moving up a level in complexity and contextualization, we see some of our initial findings mentioned earlier culminate into the most interesting stories of our research. Specifically, in this section we detailed the affordances provided by the methodology that allow for participants to not only articulate, but develop their understanding of engineering identity through showcasing participant 20's journey during the task. Additionally, we pointed out interesting relationships among the conversation partner's majors which showcase a spectrum of 'likeness' to engineering within fields, along with a persistent rejection of computer science as an engineering field. Lastly, from the self-identification section we come to see how participants considered engineering identity as a progression of schooling, as well as their diverse opinions about what it meant to be an engineer but have interests outside of the field.

In terms of our research questions, showcasing development with participant 20's story helped us answer our question about change (RQ3B) and helped answer our question about associations (RQ3A). Also, our discussion about the accuracy of participants' guesses of the membership of their conversation partner along with results from the self-identification section helped us answer our research questions about conceptualizations (RQ1), consensus (RQ2) and variance (RQ3).

5. CONCLUSIONS

5.1 Engineering Identity

5.1.1 Summary of Findings that Answers Our Research Questions

Through our study, we learn about the many ideas entry level engineering students have about engineering identity, and thus answer our research question about conceptualizations (RQ1). Specifically, in our Initial Categories section, we saw that participants had high overlap for some topics, but more diverse opinions for others, which helped us answer our research questions about consensus (RQ2) and variance (RQ3). Even further, we pointed out some of the topics we believed were missing from our findings (intelligence, and gender as a strategy) along with some of the tensions participants pointed out between dynamics of engineering during the task (balance between creative and practical, teamwork required for a field that has many independent members, beliefs that computer scientists are not engineers but that engineers knowing programming languages is important, and deep antagonism between math and science and the humanities). From the former we learn that as researchers we have our own biases and expectations on what engineers think, while for the latter, we and participants learn about the complexity of engineering identity. As such, our study not only helped participants articulate engineering identity, but walk through that landscape and realize how complex it was, along with helping us as researchers recognize our own assumptions.

Moving on to our Associations section, we continued to learn the many ways that engineers' conceptions may vary which helped us answer our research question about variance (RQ3), along with the kinds of networks they were forming which contributed to answering our research question about associations (RQ3A). First harkening back to strategies, we saw that the participants had a wealth of beliefs on ways engineering can become known. Some of these included overarching techniques like categorization, fluidity between categories, indication and intuition. Still others pointed to smaller tactics, like consideration of time, similarity to self, comparison to peers, confusion over diverging interests in themselves, acceptance of extrinsic notions, and avoidance of stereotypes. From these strategies, we also learn about participants' beliefs on what entities are valid to draw on to construct a notion of engineering identity. Specifically, for this notion, we see that participants' by and large considered themselves as valid examples of engineers and often used their own identity as criteria for engineering membership.

Then, creating mind maps allowed us to demonstrate these strategies along with the topics from Initial Categories in context, furthering our inquiry to answer our research question about associations (RQ3A) and change (RQ3B). Specifically, participant 5 and 8 helped illuminate some of the interesting ways that strategies can combined to form complex ideas about engineering identity, along with the potential for topics to have relations to each other and not just engineering identity, as well as how contradiction can

live inside a participant's conceptions. Specifically, for participant 5, she raised the question about how our study interacts with the validity of stereotypes. In contrast, participant 18 showed us how engineering can have many different kinds of relationships to other academic fields, along with the possibility of varying strengths of associations and nominal amounts of change. Ending with participant 20, we see the potential for a participant's conceptions to have many interrelated levels of indirection.

Lastly, our stories help further our pursuit to understand student's conceptions of engineering identity to answer all 5 of our research questions. Beginning with participant 20's journey through the study, we learn about how she sees the intersection of skill, desire and adding value to the field come to bear in engineering identity. Additionally, we discover more about the temporal nature of identities, which evolve overtime into stronger manifestations of engineering qualities. As a result, we deepen our answers to our research question about conceptualizations (RQ1), along with providing more data on how participants associate topics to engineering identity and how their opinions may change during the task which answers our questions about associations (RQ3A) and change (RQ3B).

Moving on, the other stories we tell from our findings again speak to participants' beliefs about engineering identity, which answer our conceptualization question (RQ1), along with some about how these ideas merge and diverge, answering our questions about consensus (RQ2) and variance (RQ3). Specifically, we learn that participants see engineering identity as a progression of schooling, as well as other academic fields' ties to engineering also as a spectrum. In addition to this, looking at self-identification we find that there was a large amount of diversity and sometimes confusion on what participants believed it meant to have interests unrelated to engineering. Lastly, through the whole body of our work and culminating in stories, we see participants' strongly held sentiment that computer science is not an engineering discipline.

In conclusion, through our research we learn about the many different kinds of complexities that exist around engineering identity. Firstly, there are many different sources that inform the formation of what an engineer is like. Participants created their ideas about identity through what they observed about themselves and their peers, and even sometimes through extrinsic authorities like the school system. Even further, sometimes these different sources would have conflicting views on what an engineer is, which further complicated participants' beliefs on identity. Additionally, engineering membership is not black and white but rather grey – a spectrum of belonging rather than a binary. Many of our participants identified this through pointing out how people have engineering, non-engineering, and neutral traits, thus identity is not about only ensuring engineering traits but rather about how all of these traits interact together. Parallel to this is the relationship that the engineering field has with other academic fields, complicating the endeavor to define what is uniquely "engineering" when the field at large shares many traits with other disciplines. Also, from these points we see how the engineering field comes to influence the idea of an engineer, which is also why many participants described engineering identity not only in terms of the realities they were exposed to but also through thinking about what would be ideal for an engineer to be like. Like the

different sources that inform identity, there also existed a tension between this real and idea image of an engineer. Lastly, engineering identity is further complicated by the ways it varies with the manifestations of its associations and with time. From our study, we can see the many different ways participants associated the same traits to engineering identity, along with how they pointed to it being demonstrated over time through asking about high school and treating engineering identity as a progression of schooling.

5.1.2 Problematic Phenomena that leads to Future Work

Thus through our study we learn about the many engineering and non-engineering sentiments around engineering identity from our participants. What our research is pointing to then is not just the complexity around engineering identity but a deeper question around the use of engineering identity, especially for our students who recognize and hold non-engineering traits. Specifically, we wonder "Can someone be an engineer without an engineering identity?". Though this question goes unanswered in our work, and thus prompts us to call for further study, it is foreshadowed by our participants who explain the ways in which they diverge from engineering. For them, what will these divergent traits mean for how they engage within the field -- and will they have limitations to the amount in which they can acculturate themselves into the role of an engineer? Will they be considered as "other" by their peers, or even by themselves? Is there a significant difference in belonging or productivity between people who "do" being an engineer and those that "are" engineers? In fact, if engineering is truly a spectrum like our research suggests, how much engineering-ness must someone have to qualify themselves as an engineer (assuming that identity is what makes someone an engineer)? Questions like these hold particular significance for our students who have un or non-engineering traits, some of which surfaced in our research like development of skill, divergent or unrelated interests, and computer science membership in which we elaborate on and call for further study below.

To start, for some the last point from participant 20 about how engineers develop engineering traits overtime might seem like a cop out. Yet, at the same time this perspective is a powerful one that is often dismissed in academia. Many expect students coming into a major in college to already have acquired many of the skills necessary for it. However, this poses a real challenge for the students who come from school districts around the nation who do not have access to a variety of academic disciplines. Specifically, the problem we would like to draw attention to here, is not one concerning infrastructure but rather human perspective. Taking our findings beyond the context of the study and into the classroom, we can see potential for the desire to have well qualified engineers from the beginning of college to actually marginalize others' sense of belonging -- an important human need on the way to self-actualization or self-fulfillment [25]. Even further, these sentiments could not only exist for professors, administrators and other stakeholders, but also possibly exist within a student's very own peers or themselves. As such, these ideas could pose barriers to entry for many engineering candidates which can dissuade them from joining the field altogether. In response, we believe there should be more research into the prevalence of such beliefs in the student body along with the impact they are having on individual's feelings of belonging and other aspects of well-being and productivity.

Additionally, our participants also expressed a lot of confusion and sometimes even concern around what it meant to have unrelated or divergent interests from engineering. From this we see potential for students to grow in their understanding of themselves and each other, and thus believe this finding holds implications for Engineering Education work. Specifically, perhaps through incorporating more interdisciplinary aspects of engineering into the curriculum, students might get the exposure they need to better understand what their diverging interests mean for themselves and the field. Our concern for letting this confusion go unaddressed is twofold. Firstly, confusion may result in students having a poor assessment of their belonging in the engineering field and thus dissuade themselves from remaining within the major. At a time when siloed projects across the country are moving towards a more interdisciplinary approach, loss of students like these would be particularly damaging for the field. Secondly, prevailing negative views of unrelated interests could also impact students sense of belonging within the field, creating barriers for achieving a general sense of well-being mentioned earlier. Yet, to know for sure the prevalence and impact beliefs like this have on students we must first engage in more research.

Lastly, we see that engineering students by and large consider computer scientists as "other" when it comes to the engineering branches. This causes us to question whether the Engineering College is the best home for the CS Department. In some ways, this fit allows for the Department to benefit from many different resources and exposure provided by the College. Yet, this deeply entrenched conception of CS as "other" produces challenges for computer science students to also maintain a status of belonging within the College. In turn, this could create many of the same ill effects explained earlier for engineers with few skills and divergent interests. In conclusion then, as a field we must continue efforts to unearth the frequency of this belief and the impact that it is having on our computer science students.

5.2 Methodological Considerations of our Results

Through our study, we also learn about the affordances of our methodology. Specifically, that our method of comparison of a student through conversation allows for articulation and development of engineering identity. Articulation includes two important behaviors – 'adding' and 'projecting'. 'Adding' occurs when participants continue to bring up more membership criteria as the task wears on because of the progressive nature and stages of the task that help participants onboard and acclimate. In contrast, 'projecting' occurs when participants read engineering characteristics into the responses they receive from their conversation partner, because of human cognitive processes. Development on the other hand includes behaviors like 'nuancing' and 'reworking'. Essentially, because of intrinsic human motivation to have cohesive beliefs, participants were drawn to change when there were conflicts between their thoughts on engineering identity and the realities of their conversation partner. As a result, they recognized the complexity of the topics they were talking about in more depth ('nuancing'), and often even changed their opinions all together ('reworking').

In turn, we see that articulation allowed us as researchers to see into participants' conceptions of identity. Yet, development allowed us and participants to realize the complexity of their beliefs. Thus, our methodology did not only provide research findings, but also opportunities for participants to learn and grow. Specifically, through performing the task, participants grappled with whether engineering status can actually become known, and became aware of and critiqued their own bias. The first can be seen through looking at the orientation of participants to the task, and specifically the doubt participants cast upon the task. The second occurred as participants began to try and reconcile their beliefs with the responses from the conversation partner. As they looked back on the ideas they professed in brainstorming, they began to also point out their shortcomings and move towards a more complete image of engineering.

What is powerful about these actions is that the motivation to embrace alternatives, along with the actual alternatives themselves, are both driven by the participant. In turn, the kinds of changes that take place during the task, are more strongly held and long lasting. This points to the uniqueness and strength of our approach that achieves both of these things through supporting reflection in the stages of the task. As such, we believe that this methodology can be repurposed for other topic domains to help people see their own biases, and have the opportunity to wrestle with them, and perhaps even change.

Still, our methodology is not without its flaws. When it came to implementation we had several limitations that in turn weakened the depth of some of our findings. Firstly, we conducted the study in the fall in the first few weeks of the participant's freshmen semester because of IRB scheduling problems. Ideally, we should have conducted our study in the spring semester after our participants had more time to acclimate to the field. Additionally, we had a shortage of male students as participant in the study, which means our findings have the potential of not being representative of the field considering that males are in the majority. We also were hoping to get more opinions from different ethnicities. As for procedure limitations, we did not consistently ask participants to explain the reasons behind why they wanted to ask a question during the brainstorming session, so we missed some data that could have revealed more of their opinions and better informed our efforts. Lastly, one shortcoming of the methodology is that it does not make clear how much participants actually changed during the task, rather than just not wanting to live into stereotypes and other generally frowned upon ideas in a semi-public setting. For this last point, we would like to call upon additional efforts to discover better ways to understand the amount of sincerity that existed within participants who indicated they changed their opinions.

Generally, though, due to the success in using our methodology as a tool for research, along with the benefit of helping participants learn and grow as well, we believe that more studies should utilize and expand upon our approach for inquiry. This includes more research on engineering identities, but can also be extrapolated to inquire about any social group. Specifically, for our context we believe there should be more research on using this methodology to learn about the conceptualizations of identity from other points in time during engineering student's collegiate journey, and from other stakeholders (other majors, professors, working engineers, industry employers). Through this we could

continue to learn about the state of these understandings which can inform Engineering Education work, as well as help these different groups of people progress in their own opinions. Additionally, considering the many conceptualizations of engineering as a spectrum, we should investigate the benefits of changing the main task from answering 'Are you talking to an engineer or not?' to 'Rate your conversation partner to the degree you believe they are an engineer on a scale 1 - 7', similar to the procedure of Berman and Bruckman mentioned earlier [4]. In this way, we may come to better understand the strengths of associations to engineering, along with its relationships to other fields. Lastly, this methodology should be augmented to also inquire into the differences among engineering branches.

5.3 Design Considerations of our Results

Additionally, our results help us better understand how we might represent their knowledge to be actionable for design. To do this, we have shown the progression of how different forms can communicate the context and complexity of our results. Starting with initial categories, we see that though they point to some interesting findings and small amounts of sophistication, they are inaccurate when considering the ways people truly negotiate entities, like identity, through looking at object worlds. Thus, we also must reject representing findings this way for design, as they will misinform the ways in which participants see identity as well as mask some of its content. Moving on to associations, we find that they better showcase the complex and varying relations our participants have over different objects, and preserve context through considering an individual participant at each stage. Yet, this form proves limited when trying to represent change and multiple opinions on the same topic, as well as almost unreadable when trying to account for a wealth of detail. As a result, associations are also an incomplete and limited representation for design because they fail to retain certain kinds of knowledge and are sometimes hard to digest. In the end, we settle on stories as an appropriate representation of knowledge for our study, as it preserves both context and complexity through its narrative form.

Seeing the advantages of narration over other types of representation, we believe that other kinds of research results should also consider and investigate using this form as well. In this way, we can continue to strive for data that is a strong asset to designers and result in more informed designs for users. Currently, many kinds of narrative forms exist like ours that can be used for these efforts. Some of which may not have even been recognized as such. Take for example the Analyze Spoke of the UX Life Cycle by Hartson and Pyla. Their progression of understanding comes from aggregating discrete entities into a large diagram of relations, that they study to pick out interesting anecdotes to translate into scenarios and storyboards [19]. Even further, we see the same journey occur in the 3 Paradigms of HCI: the first paradigm aggregates disparate pieces of information to unite man and machine, then the second paradigm models the network of information transformations between humans and computers, and lastly the third paradigm considers the deeply contextual aspects of lived human experience [18]. As such, both of these follow the same progression from aggregation to narration that we do, and as a result have aided countless designers in their efforts to understand their domain.

Therefore, taking our cues from narration, we can see the latent advantages in many of the research techniques that exist today, and should continue to investigate them so that we may have a more complete understanding of the people we design for.

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APPENDIX

Appendix A: Demographic Questions and Responses

A.1 Original Survey Questions for Interrogator Participants

1. What is your age?
2. What is your gender?
3. What college are you currently enrolled in?
4. Do you intend to stay (or be) in the engineering college?
5. What is your intended major? What is your intended minor (if any)?
6. Have you had any professional work experience (e.g. internships)?
7. Have you had any relevant classes for engineering prior to coming to Virginia Tech?
8. Have you had any relevant extracurricular activities for engineering prior to coming to Virginia Tech?
9. What college are your roommates currently enrolled in?
10. Do your roommates intend to stay (or be) in the engineering college?
11. What is your roommates' intended majors? What are their intended minors (if any)?
12. What percentage of your friends are in the college of engineering (you can give a rough estimate)?
13. What are your parents' occupations?
14. What are your parent's highest level of degree?
15. If college level – what were your parent's majors?
16. Do you have any family members or older close friends who are engineers? If so, list your relationship to them, age, gender and their engineering discipline.

A.2 Revised Survey Questions for Interrogator Participants

1. What is your age?
2. What is your gender?
3. What is your ethnicity?
4. What college are you currently enrolled in?
5. Do you intend to stay (or be) in the engineering college?
6. What is your intended major? What is your intended minor (if any)?
7. Have you had any professional work experience (e.g. internships)?
8. Have you had any relevant classes for engineering prior to coming to Virginia Tech?

9. Have you had any relevant extracurricular activities for engineering prior to coming to Virginia Tech?
10. What college are your roommates currently enrolled in?
11. Do your roommates intend to stay (or be) in the engineering college?
12. What is your roommates' intended majors? What are their intended minors (if any)?
13. What percentage of your friends are in the college of engineering (you can give a rough estimate)?
14. What are your parents' occupations?
15. What are your parent's highest level of degree?
16. If college level – what were your parent's majors?
17. Do you have any family members or older close friends who are engineers? If so, list your relationship to them, age, gender and their engineering discipline.
18. To what degree do you identify as an engineer in general?
    1 2 3 4 5 6 7
    (1 - I do not identify as an engineer at all, 7 - I completely identify as an engineer)
19. What qualities about yourself make you feel that way?
20. Were there any questions during the task that you had but did not feel comfortable asking?

A.3 Summary of Interrogator Participants Responses to Survey

		IDs	# of participants
		5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 18, 19, 20, 21, 22, 23, 24, 25	19
All Freshmen, All intend to stay in the College of Engineering			
Age	18	5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 18, 19, 20, 21, 23, 24, 25	18
	19	22	1
Gender	Men	8, 9, 18, 23	4
	Women	5, 6, 7, 10, 11, 12, 13, 15, 16, 19, 20, 21, 22, 24, 25	15
Ethnicity	Indian	5,	1
	Cacausian/White	6, 7, 9, 10, 11, 12, 13, 15, 18, 20, 21, 22 (American?), 23, 24	14
	Hispanic	8,	1
	Asian American	16,	1
	Asian	19,	1
	African American and Caucasian (co	25,	1

Future Major	Mechanical	5, 16, 23	8 (debating between), 13 (probably this or)
	Civil	11,	8 (debating between)
	Structural	25,	
	Industrial Systems	12, 21, 22	8 (debating between)
	Enviromental	11,	
	Chemical		8 (debating between)
	Material Science	15, 19,	
	Aerospace	9,	
	Biomedical	6, 7	
	Biosystems		13 (probably this or)
	Electrical		
	Computer Science	10, 18, 20	
Future Minor	Minor in Math	10, 19	
	Minor in Cybersecurity	18,	
	Minor in CS	16,	
	Minor in Green Engineering	8, 13	11 (or enviro or both)
	Minor in Enviromental Science		11 (or green or both)
	Minor in ESM	7,	
	Like biomed but not the new one	15,	
	Minor in Biomedical	5,	
	Minor in Nanoscience		
	Minor in Meterology		
	Minor in Business Leadership	19, 23	
	Minor in Bussiness	21,	
	Minor in English	5,	
	Visual Arts		
	International Studies	13,	
	Foreign Language		
	No Minor	9 (I've not thought about minors yet), 22 (I don't have one right now), 24 (currently I am trying to study abroad, so there is no room for minors. But if it doesn't happen I'd do one in a non-STEM field like history. I'm also very much into humanities side.)	
Family Members/Close Friends t	Dad	9 (M Civil), 13 (M Enviro Sci- not engineer by practice but wanted to be), 16 (M EE/CS), 22 (M Civil)	4
	Mom	10 (F ME and systems), 13 (F CS - not really consider engineer)	2
	Brother	16 (M 5 years older CS), 22 (M older grad Civil)	2
	Grandfather	10 (M Civil), 21 (M ME), 24 (M EE)	3
	Cousin	5 (F way older ME), 5 (M way older CS), 5 (way older eng?), 7 (2nd cousin eng?), 15 (8 cousins in eng), 16 (M eng?), 16 (M eng?), 20 (M CS/IT)	8
	Aunt	5 (F eng?), 16 (F CS)	2
	Uncle	5 (M eng?), 7 (M Nuclear), 16 (M eng), 18 (M CS/EE)	4
	Church Leader	25 (team leader eng?)	1
	Older Close Family Friends	6 (M VT grad in 2016 ChemE), 20 (M VT student interested in CS but going into Neurosci), 23 (junior ME), 24(recent WPI grad EE/CPE)	4
	Older Neighbor	11 (F 4 years older Enviro), 11 (F about 40 years old Civil)	2
	Older VT Students	8(F mult sophomores, juniors and seniors ME), 22 (None of my close friends outside of VT are engineers)	2
	Confused…	10 ([any others?] I would not consider them close friends), 19 (I don't think so (family/engineer) – lots of people in computer and computer science.),	
	None	12	1
Degree Consider Self Engineer	1		0
	2		0
	3	25 (hinted at it)	0
	4	9 (7 is… I'm on the road there), 16, 18, 25	4
	4.5	6 (4 or 5),	1
	5	7, 8, 11, 13, 15, 21, 22, 24	8
	5.5	23 (5 or 6)	1
	6	5, 10, 12, 19, 20	5
	7		0
	Mean Average Degree	5.052631579	

Appendix B: Some Deliverables from Analyzing Data

B.1 Merged Codes Along with Reference to Old Codes

Super Code	Code	Sub Code	Ref to Old Code

People in the Field			
	Compare/Contrast Engineers with Other Majors		
		Engineers vs/sim STEM Majors	C24
		Engineers vs/sim Other Majors	C23
		Engineers vs/sim Sci Majors	C25
		Engineers vs/sim Math Majors	C26
		Engineers vs/sim Bus Majors	C27
		Engineers vs English Majors	C28
		Engineers vs/sim Art Majors	C29
		Engineers vs/sim Ag Majors	C31
		Engineers sim to Architecture	C30
	Like Engineers		
		Like Me	B17
		I'm not like engineering	B19
		Like People I know	B18
		We	B16
	CS and Diff Bt Eng Branches		
		CS	B34
		Engineering Branches	C32
	Stereotypes about Engineers		B21
	Nature of Engineering		
		Demonstrative Nature of Engineering	B271
		Teaching Math is Demonstrative	C177
		Teaching Sci is Demonstrative	C188
		Learning	B270
		Rel bt Math and Engineering	C167
		Rel bt Science and Engineering	C179
		Nature of Engineering/Engineer is PS	C97
	Demographics		
		Freshmen	B11
		Guy Girl Diff	B10
		Gender	B9
Personality Traits			
	Best Trait		B47
	Practical		B60
		Thinking thru relevance of a problem	C89
		Staying on Task	C90

	Likes Specifics/Detail Oriented		B141
	Learning Type		B67
		Vis Learner	C133
	Efficient		B77
	Introvert vs Extravert		B50
		Library vs go out -> Introvert vs Extravert	C51
		Outside -> Extravert	C52
		Group Work vs not -> Extravert vs Introvert	C53
		Go Out	B210
	Thinker/Objective	Emotional Intelligence vs Obj	B57
		Objective	B59
		Informed	B58
		Thought Patterns	B99
		Thinker	B56
		Intentional	B78
		Methodical	B55
		Analytical	B54
		Analyze	B100
	Challenge		
		Makes vs Buy	C113
		Independent/Challenge	B82
		Headstrong	B83
		Perfectionist	B72
	Organized/Structure		B74
		Consequences for Inorganizedness	C75
		Motto -> Organized	C76
		Habitual	B73
	Perseverer		B79
		Persevere	C80
		Motto -> Persevere	C81
	Creative		B61
		Brainstorm/Implement Ideas	C64
		Generate Ideas	C63
		Seeing other POV	B62
		L or R Brain	B66
Engineering Mindsets and Skills			
	Uses Materials on Hand		C114
	Makes/Creates/Invents		
		Makes	C112

		Wants to Make/Learn How to	C111
		Doubts Ability to Make	C110
		Likes to Make and Has Ability to Do So	C109
		Likes to Make/Create	C108
		Inventing	B139
		Invention vs Innovation	C140
	Problem Solving		
		Does PS	C96
		PS Ability	C 92
		PS Ability and Approach	C91
		Likes 'Fixing' Nature of PS	C95
		PS Ability > Technical Ability	C93
		Likes PS	C94
		PS Approach	C88
	Build and Fix		
		Propensity and Ability to Build	C105
		Wants to Build/Learn How to	C104
		Wants to Fix/Learn How to	C102
		Propensity and Ability to Fix	B101
	Ability <,>, = Desire?		B86
	Experimentation		B98
	Draws		C138
		Not Expect Drawing	C137
		Likes Drawing	C136
		Doodles	C135
		Artistic	B65
	Teamwork		
		Likes/Comfortable with Team Work + Contradictions	C148
		Sees the Value of Teamwork	C149
		Likes People > Likes Project	C150
		Experience w/ Teamwork	C151
		Roles within Teamwork	C152
		Frequency of Teamwork	C153
		Does Teamwork	C155
		Communication	C156
		Lack of Face to Face Interaction	C157
		External Thinker	B68
		Work Alone vs Groups	C267
		Where Study -> Alone/Groups	C268
		Long Term Projects	B158
	Service Work		B142

		Responsibility/Consequences of Work	B146
		Gravitates toward Vol w/ Eng Chars	C143
		Likes Helping People	C144
		Work is About Helping People	C145
	Spatial Vis Ability		C132
		Spatial Vis Approach	C131
Academics			
	STEM		B165
	Science		B178
		Likes Science	C180
		Climate Change -> High Value/Trust in Science	C187
		High Value in Science	C186
		Fave Subj is Science	C181
		Likes Physics	C182
		Based on Science/Sciency	C183
		Takes Science	C184
		# of Sci Classes HS Offered	C185
	Math		B166
		Fave Math	C168
		Highest Math	C169
		Likes/Interested in Math	C170
		Fave Subj is Math	C171
		Good at Math	C172
		Based on Math	C173
		Likes and Good at Math	C174
		Takes Math	C175
		Music -> Math	C176
		Reads Math and Sci (or not)	C225
		Math (and sometimes Sci) vs English (reading)	B189
	Programming Experience		B197
		Knows Matlab -> Engineer (rather than Java)	C198
	English/Read/Write		
		(Dis)likes English	B190
		Doesn't Find English Valuable	C191
		Writing	C192
		Reading	B218
		Not Like Reading	C219
		What Read/Like to Read	C220

		Hasn't Read Recently	C224
	Humanities		B194
		History	B193
		Social Sciences	B195
		Reads Historical Fiction	C221
		Knows Another Lang	B196
	Research		B234
	Internship/Co-op		B235
Interests			
	Hobbies/Free Time/Do		B214
	Engineering Related Hobbies/FreeTime/Do		C215
	Music		B206
	TV Show/Movie		B203
	Documentaries		C205
	Video Games		B207
	Involved in Activities/Clubs		B228
	Involved in Engineering Activities/Clubs		C229
	Summer Activities		B227
	Greek Life		C232
	Mostly Engineer Friends		B35
	Sports		B213
	Do Puzzles		B209
	Play with Legos		B208
	Like Outdoors		B211
	Science Fiction		C204
		Reads Fiction	C223
		Reads Non Fiction	C222
Development			
	Parents Occupation		B248
		Parents Occupation Engineering	C249
	Childhood		
		Way Think as a Kid	C247
		What Wanted to Be as a Kid	C246
		Childhood Hobbies	C245
		Fave Subj as a Kid	C242
		Fave Toy as a Kid	C243
		Played w/ Leggos as a Kid -> Eng	B244
	Inspiration/Motivation		

		Money	B258
		Current Events/Inventions	B253
		Inspiring Material	C256
		Model of Inspiration	C255
Effort			
	Building is Work Intensive		C106
	Dedicated to School		C70
	Out of State -> Dedicated to School		C71
	Team Projects are a Time Sink		C154
	Stressed Out		B238
	Engineering Activities and Clubs are Labor Intensive		C231
	# of activities/clubs will -> engineering		C230
	Been Tutored		C264
	Credit Hours		C280
	Workload		C261
	Study		C262
	Time		C263
Univ Context			
	Computer		B282
	20 Credit Hours		B279
	Performance for Admissions		B278
		Well Rounded	B281
		Balanced	B43
	Out of State		B283
Routine… Maybe Effort			
	Where Study		C266
	When Study		C265
	Stay Up Late to Complete Work		B274
	Procrastinate vs Not		C269
	Bedtime		C273
	Morning/Night Person		B272
Place in Larger…			
	Myers Brig Personality		B49
	Why VT?		C257
	Double Major		B161
	Parent Relationship		B250
	Subjects		B162

	AP Courses Took		B164
	Favorite Subj/Class		C163
	Drillfield Sidewalks		B276
	Ride Bike to Campus		B275
	Fave Color		B201
	Fave Store to Shop At		B202
	High Grades -> Engineer (external Voice)		B199
	Indicators can come from Clubs/Activities Involved In		C233
	Baking		B216
	Play Instruments		C217
	Gone Backpacking		C212
My Thoughts			
	Preparation?		A286
	Inherent vs Learned		B48
	Past and Present		B237
	Extrinsic vs Intrinsic		A285
IDK (Common Behavior and Unique Opinions)…			
	Conversational		B13
	Unsure about Rational/Expectations		B36
	Intuition		B20
	Combination		B40
	Questions I should've asked		B37
	Diverse		B41
	No Dead Give Aways		B39
	Lims of Imagination about Fields		B33
	Identity is Known		B44
	Could be Great Engineer		B42
	Thoughtful		B14
	Grammar		B15
	"Real" Questions		B38

B.2 Case Studies of Participant Attitudes and Behaviors around Change

Case 1: Participants who already had very open expectations and did not want to create any concrete definitions of engineers (either because of reluctance or really believed in diversity)

Participant 6: comes in introspective, recognizes a lot of diversity and willing to wrestle with, did l/p/n/a: 2
This participant did recognize a lot of the diversity in engineering - she decides that some of her categories could not truly lend either way - extravert/introvert, research. She also added some nuance to other categories like doing service work -> liking service work, but that some engineers are selfish. She also picked up on new topics she did not talk about before like 20 credits emotional intelligence vs objective, which did not sway her final decision.

Participant 18: comes in scrutinizing, hesitant to claim anything during whole thing, do away with all (at least rationally) except math
This participant was very contentious of the overlapping relationships of other majors with engineering, and how things he asked could be answered positively by engineers and others. He is very hesitant to say that anything points to engineering or not engineering, and in the end his evidence mostly rests on them not liking math (which he did nuance before deciding it was evidence for not an engineer). And decided that all else could be possible for an engineer (lighter study load, programming - could be yes or no, hobbies don't matter and neither does TV).

Overlapping Case 1A: Very reluctant to make claims during assessment (like 8)

Participant 8: mostly expect -> yes, not -> no, lots of partial information, but reluctant to claim during assessment, 1 change
This participant was pretty reluctant to call things out as no - usually had gut reaction to say no but then in the end said something like "that's that". He did rethink outdoors - very overtly stating that anyone could like it, decided a lot of things were inconclusive because he needed more information to use them as evidence (internship/co- op), some things he said he was unsure about - but it's hard to tell if he was reluctant to categorize them as 'not engineering', forgot about them, or no longer believed they mattered (some AP, English, wanting to know more about credit hours). Most things he stuck with his initial thoughts (family in manu/eng, taking many AP sci in HS, designing something, going out to parties infrequently, high SAT, high study workload).

Overlapping Case 1B: Gave up almost all criteria because of diversity, except work load and computer (like 8)

Participant 23: in many ways expect -> yes, not -> no, but then devolved it all to computer and work load was the only concrete evidence to use, unsure about 1 beforehand and gave up
This participant sort of stuck with his expectations for math/sci, #clubs/engineering work as laborious at the beginning. They were already hesitant about asking about introversion and extraversion, and though they still asked a related question - they came to the conclusion it did not matter, but did not come down on a conclusion for doing work in groups. When it came time to talk about the computer, the participant realized that he's seen diversity in almost all of his other categories, and so decided that this and workload were the only two that truly factored into his assessment that they were not an engineer.

Case 2: Very little change, stuck with previous notions (though some did not receive a participant who lived outside their expectations, meaning they did not have the opportunity to challenge themselves)

Participant 12: expect -> yes, not -> no/no comment
This person asked a lot of questions in the conversation that they never put to work in the assessment. They stayed very close to their original ideas, and pretty clearly articulated their ideas before the conversation that engineers are people who gravitate toward building and fixing, and we can possibly assume that by asking about spatial abilities they already believed that engineers were good at them. When the student replied in ways counter to that, they decided they were not an engineer (problem solving approach and in general build/fix gravitation). However, we are not sure what happened in the participant's mind for all the content that they didn't comment on in assessment. Though it was interesting that they didn't make a final call on which way 'okay' spatial abilities leaned.

Participant 22: expect -> yes, not -> no, unsure 1
The conversation partner fell into a lot of the assumptions that the participant had - liking math more than English, having a parent in a related field, but because he was from out of state and had a lot of friends outside of engineering - the participant decided that it was unlikely he was engineering. She also was not sure what to think about him having time to rock climb.

Participant 11: expect -> yes, not -> no, some partial info/unsure (2), did l/p/n/a: 2
This participant mostly stuck with her ideas coming in. There were a few topics that she was unable to full sort out because of competing evidence - like whether this person was an introvert or extravert, and whether that pointed to an engineer or not. She did say that she felt like engineers were introverts, but that she was not. Some other pieces did not fully flesh out in a way that allowed her to use them like going to bed late. There were some characteristics that were like engineering - like sports -> math and science, but there were many more characteristics unlike engineering (computer, programming langs, parent's occupation, Fave HS math). Additionally, she lifted 2 characteristics from the conversation - reading/writing and 20 credit cap.

Participant 24: expect -> yes, not -> no (mostly unchallenged), did l/p/n/a: 2
The conversation partner for this participant mostly lived into their expectations - they like problem solving, liked creating things, and liked math and science. In the conversation, the participant expanded on these things - asking if they were a perfectionist and wanted to persevere to get things right, and also if they liked making things themselves instead of buying. For both of these the conversation partner gave a hesitant yes with some caveats. The participant ended up only using the criteria where the convo partner fully lived into her expectations as evidence (liking to make things - applied, liking math/sci, and being creative - the later she perceived from the conversation).

Participant 7: expect -> yes (mostly unchallenged), not -> unsure (and nuanced these unsure), did l/p/n/a: 1
This participant did live into most of her original expectations, all the things that were like her/she expected contributed to yes, and there were a lot of them, and all things that were not like her or engineers she said leaned no but mostly unsure. It was interesting that she did not say no to these traits, and actually did add more thought to these characteristics that were not in line with her expectations - saying things like maybe having a smaller study workload was possible if her conversation partner was not counting the breaks. Also, the one thing she ended up doing projection with was the gender. Originally she was going to relate it to something else, but ended up talking about the eclectic tastes.

Case 3: Participants who changed their ideas without challenge, making the bar to entry more exclusive

Participant 13: did change 2, didn't project, added more barring (to hands on)
This participant did let go of some ideas mostly explaining that they did not have a lot of credit to push one way or another - video games, and that it was okay that this person didn't mention anything technical or hands on for free time, didn't project on things that came up (hiking, outdoors, music, best quality), and decided that being able to recover from mistakes didn't lean either direction. This participant also added to liking to work with hands the ability to do so, and since this conversation partner did not have that ability, that was one of the 2 biggest pieces of evidence working against them. The other was that their favorite subject was history - which this participant does say they liked history, but it was not their favorite and that engineers' favorite is math and science.

Participant 21: added more barring (to math), increased value of 2 interests, unsure: 1
This participant actually re-worked a lot of her assumptions about engineering. Originally she said that engineers favorite subject being math and being good at it would be indicative of an engineer, but then even after confirming this about the conversation partner - she felt that her conversation partner was not an engineer because though she liked math, and things like puzzles and playing an instrument, she didn't like the application of math. She also at first felt that not liking science fiction and documentaries was not super significant, but later decided that it did point to them not being an engineer. She was not sure how to parse out being a hands on and visual learner but not being able to doodle during class.

Case 4: A large amount of change, almost completely reworked their ideas in the face of challenge to them

Participant 20: changed pretty much everything in some way, did l/p/n/a: 1
This person allowed for reconsidering some of the aspects of what she was proposing. Originally, she said that she thought that engineers would do things in their free time/hobbies related to engineering. She also said that she expected engineers to be hands on. At first she wanted to connect being outdoors to being hands on, but that association

fell through. Instead, she projected hands on to playing with cats. However, the conversation partner said that she was most 'hands on' when working with others - this was a definition that the participant was willing to accept. She was also wrestled with whether it was problematic that the conversation partner did not have the technical abilities to build/create/fix. She eventually decided what was important was that the conversation partner could be an asset to the group with their problem solving abilities, and that they qualified as an engineer because they had a desire to build/fix/create, that would be matched with technical ability after going through the engineering curriculum. This participant also lifted teamwork as an engineering characteristic from the conversation.

Participant 10: changed all ideas that were challenged except 1, did not change others that were unchallenged, did l/p/n/a: 2

This participant seemed really willing to change a lot of her ideas going in, she originally said that engineers would do something related to their major for fun - but then believed that some wouldn't for lack of stamina/time, she said that they would be creative, but then realized she doesn't conceptualize herself that way and so would not want to hold that criteria against other engineers. There were other preconceived notions that she was not willing to do away with altogether - like liking math (and some others that fell into her expectations so she did not have to confront compromising - like detail oriented for new instructions, and OS because she felt she got partial information). She also lifted some characteristics from what the conversation partner said about themselves - like seeing unique work arounds to problems, teamwork.

Case 5: Participants who received almost no challenge, and instead talked about how everything was like an engineer, and heavily projected on and interrelated that space

Participant 5: everything is like an engineer, lots of nuance and projection

A lot of what participant 5 said they wanted to ask, they did not clarify which direction an engineer would respond with. Afterwards they said that a lot of it was engineering like, but we will never know if they thought that going in. Pretty much saw engineering in everything they said (ETSJ, math/sci and performing arts/choir, analytical, left brain, Star Wars/action/thriller/scify, plays video games) - yes to all of it and a lot of projection (seeing well balanced, and thinking through more connections to music and what should have asked). She also related a lot to the convo partner and said he was like her in a lot of ways.

Participant 25: everything is like an engineer, some rework, lots of nuance and projection

This participant added a lot of nuance to her categories through the conversation. She first said that creativity was important, and that engineers would seek after opportunities to utilize it instead of just doing engineering for the money. She also said that teamwork was important. Later, she expanded that engineering is both practical and creative, and that not only was teamwork important but she projected that this conversation partner enjoyed it (not only because she said so but also) because she liked to read and thus see other perspectives. She also originally said that she expected an engineer to have hobbies

that inspired them to do the work of engineering, which would could say either led to her projection onto the reading or she was able to drop. She also at first was unsure if being dedicated to school came in conflict with doing a lot of clubs, but came to say that this was possible because the conversation partner was very good at time management. The whole time this participant, believed that being an engineer meant being organized/structured, creative, good at teamwork, dedicated to school, and pressed for time. She also lifted from the conversation the notation of responsibility. However, this participant also explained that: "OK. Um. So a lot of the answers that she gave me where what I was looking for – for like if they were an engineer. But now I'm realizing that - I mean the engineering spectrum is so broad that she could have answered everything the exact opposite way and still be an engineer. "

Case 6: Generally hard to follow participants and contradict themselves (3A participant 9 also entertains other perspectives in all aspects but then sticks with previous notions)

Participant 9: entertain, but goes with original ideas, a little hard to follow/contradiction

Seems like this participant was willing to try to see other points of view during assessment - and even calls out some stereotypes/biases he doesn't want to live into, but then in the end went with some of his original ideas - takes AP courses in HS, trusts science, and for the others left them at unsure or possibly didn't affect but leaned no = likes math/sci, grades in HS. He also contradicted himself (9A6->9FA8: thinking this person was in science, but then disqualifying him as an engineer because he didn't value/trust science; 9A2 -> 9FA4: saying that he felt that sports were not relevant but later saying that they were a lot).

Participant 15: did change about 1 (unconsciously?), some contradictions, did l/p/n/a: A LOT, combination

This participant did change her mind a bit. At first she said that engineers don't like to read and write, but then when her convo partner liked to read, she asked her about what she liked to read and then went on to say it sounded 'sciency' to like fiction and baking/outdoors (though earlier she said that liking outdoors was just a VT thing). But then at the end when she reflected on movies and said that since this conversation partner liked comedies for movies and romantic novels for books, that was evidence against being an engineer, since it wasn't scify or fantasy. Her conversation partner likes to draw, so she did not compromise that belief. The other places with conflict were volunteering with ties to hands on and being in a sorority. Also the participant brought up new topics like backing, favorite store to shop at, knows another language and checks horoscope - the conversation partner fit in line with knowing little language and treating their horoscope as a joke, but decreased the level of belief they were an engineer because they do not do backpacking and do shop online. This participant was also able to project how engineers like music, because it is related to math and could connect many engineers, and that no one factor was deciding but all pushed her towards the answer together. She also brought up an interesting dynamic that we have seen once before with women engineers having more eclectic tastes than men. In the end she decided that some categories like liking video games did not lean either direction.

Case: I don't know

Participant 16: did change 1, needed more info, did not change 1, did l/p/n/a: 2
This participant did come to decide that some of what she saw was not telling of an engineer - like always liking math and science, or that she needed more information to make a call - like asking if someone has been tutored rather than asking if they tutor. She stuck to her original assumptions about being involved in something engineering related in HS. Besides that, the other things she used for evidence she lifted from the transcript - namely meetings and slides.

Participant 19: expect -> yes, not -> no, changed tiny 1.5, did l/p/n/a: 1
This participant did give up some questions as more about preferences rather than an engineer or not - like being a morning or a night person. They also mentioned that everyone is sort of a mix of introversion and extraversion. Though this person did live into the participant's expectations for an engineer on some accounts (introvert, organized, problem solving approach, an accomplishment that shows desirable engineering traits), they deviated on others (no STEM role models, reading historical fiction, only says sometimes likes problem solving). So in the end the participant chose not an engineer - though they also decided that engineers would do different kinds of problem solving approaches so maybe the information derived from that conversation was not as helpful. This participant also talked a lot about teamwork which was a new topic for them that they projected onto the Eagle Scout accomplishment.