CAREER: Actualizing Latent Diversity in Undergraduate Engineering Education

Dr. Allison Godwin, Purdue University at West Lafayette

Allison Godwin, Ph.D. is an Assistant Professor of Engineering Education at Purdue University. Her research focuses what factors influence diverse students to choose engineering and stay in engineering through their careers and how different experiences within the practice and culture of engineering foster or hinder belongingness and identity development. Dr. Godwin graduated from Clemson University with a B.S. in Chemical Engineering and Ph.D. in Engineering and Science Education. Her research earned her a National Science Foundation CAREER Award focused on characterizing latent diversity, which includes diverse attitudes, mindsets, and approaches to learning, to understand engineering students' identity development. She has won several awards for her research including the 2016 American Society of Engineering Education Educational Research and Methods Division Best Paper Award and the 2018 Benjamin J. Dasher Best Paper Award for the IEEE Frontiers in Education Conference. She has also been recognized for the synergy of research and teaching as an invited participant of the 2016 National Academy of Engineering Frontiers of Engineering Education Symposium and the Purdue University 2018 recipient of School of Engineering Education Award for Excellence in Undergraduate Teaching and the 2018 College of Engineering Exceptional Early Career Teaching Award.

Ms. Brianna Shani Benedict, Purdue University

Brianna Benedict is a Graduate Research Assistant in the School of Engineering Education at Purdue University. She completed her Bachelor's and Master's of Science in Industrial and Systems Engineering at North Carolina Agricultural & Technical State University. Her research interest focuses on interdisciplinary students' identity development, belongingness in engineering, and recognition.

Ms. Jacqueline Ann Rohde, Purdue University at West Lafayette

Jacqueline A. Rohde is a third-year graduate student at Purdue University as the recipient of an NSF Graduate Research Fellowship. Her research interests in engineering education include the development student identity and attitudes, with a specific focus on the pre-professional identities of engineering undergraduates who join non-industry occupations upon graduation.

Ms. Dina Verdín, Purdue University at West Lafayette

Dina Verdín, PhD is an Assistant Professor of Engineering in the Polytechnic School of the Ira A. Fulton Schools of Engineering at Arizona State University. She graduated from San José State University with a BS in Industrial Systems Engineering and from Purdue University with an MS in Industrial Engineering and PhD in Engineering Education. Dina is a 2016 recipient of the National Science Foundation's Graduate Research Fellowship and an Honorable Mention for the Ford Foundation Fellowship Program. Her research interest focuses on changing the deficit base perspective of first-generation college students by providing asset-based approaches to understanding this population. Dina is interested in understanding how first-generation college students author their identities as engineers and negotiate their multiple identities in the current culture of engineering. Dina has won several awards including the 2018 ASEE/IEEE Frontiers in Education Conference Best Diversity Paper Award, 2019 College of Engineering Outstanding Graduate Student Research Award and the Alliance for Graduate Education and the Professoriate (AGEP) Distinguished Scholar Award. Dina's dissertation proposal was selected as part of the top 3 in the 2018 American Educational Research Association (AERA) Division D In-Progress Research Gala.

Mr. Aaron Robert Hamilton Thielmeyer

Aaron Thielmeyer is a mechanical engineering undergraduate student at Purdue University.

Mr. Herman Ronald Clements III, Purdue University at West Lafayette

H. Ronald Clements is a postbaccalaureate research assistant in the STRIDE lab at Purdue University and an incumbent graduate student for the 2020-2021 year. He works on the project titled "CAREER: Actualizing Latent Diversity: Building Innovation through Engineering Students' Identity Development," assisting with narrative analysis and interviews, helping to understand the identity trajectories of latently diverse students. He received his Bachelor of Science in Psychology at Harding University with honors, where he participated in the Beyond Professional Identity (BPI) research group, studying frustration in first- and second-year undergraduate engineering students. He also served as the BPI lab manager during 2017-2018. He is also a Society of Personality and Social Psychology Undergraduate Research Fellow, through which he studied in the Stereotypes, Identity, and Belonging Lab (SIBL) at the University of Washington during the summer of 2018.

Zhihui (Sherry) Chen

CAREER: Actualizing Latent Diversity in Undergraduate Engineering Education

Introduction

Cultivating a culture of inclusion is critical to engineering education. The environment in which students learn shapes not only their competencies but also who they become or their identities as engineers. Developing an engineering identity has been found to be important for a number of different outcomes including academic and personal development [1]–[5] as well as retention [6]–[8]. Students form their engineering identity in relation to the ways of being, thinking, and knowing that are valued in engineering culture. As a result, students who do not align with the cultural values in engineering may experience a lack of belonging [9], [10], which can ultimately lead to negative experiences and even attrition. For example, one of our participants, Mark, expressed that he loved studying mathematics, but he felt that "there wasn't much room for creativity in engineering". This mismatch in his goals and values led him to switch out of engineering to major in business. Ultimately, he felt that this change allowed him to be exposed to more diverse ways of thinking about problems in business applications.

Mark's experience highlights how creativity is "drummed out of engineering disciplines by rigor gatekeepers" [11, p. 251], which is not something that materializes without being cultivated through early engagement in the curriculum [12]. Instead "creativity depends on our life experiences" and "without diversity, the life experiences we bring to an engineering problem are limited" [13, pp. 8-9]. This example is just one among many reasons why students' who do not feel supported in their ways of thinking may leave engineering or feel pressure to conform to the norms of engineering. Research has shown that the process of educating engineers results in homogenized approaches to problems, ways of thinking, and attitudes [14]–[18]. Hence, concerns regarding creativity and innovation motivated this work to investigate how students with varying ways of being, thinking, and knowing, in this work termed *latent diversity*, navigate their pathways into and through engineering and how engineering culture affects their development as engineers and abilities to engage in innovation [19]. This executive summary describes the progression of the research project focused on narrative interviews with students over three semesters to understand their experiences in engineering education and development over time.

Project Overview

The fundamental goal of this research project is to characterize how latently diverse students experience the culture of engineering and negotiate their identities as engineers. As such, the earlier stages of this research involved developing a survey to measure latent diversity among a nationally representative sample of first-year engineering students ($n = 3711$) and characterize latent diversity using Topological Data Analysis (TDA) [20], [21]. The results of this prior work have been reported in detail in our prior work. This analysis resulted in six data progressions of latent diversity, highlighting distinct underlying differences among the students attitudes and beliefs about their STEM role identities, belonging, motivation beliefs, personality, and epistemic beliefs [20]. These data progressions were used to recruit 25 latently diverse students to participate in longitudinal narrative interviews to understand their experiences and development throughout their undergraduate engineering education.

This CAREER project examines latent diversity through a national survey and longitudinal narrative interviews to answer three research questions:

1. What kinds of diversity in attitudes, beliefs, and mindsets (i.e., latent diversity) are present in engineering students?
2. How do undergraduate students with latent diversity form engineering identities within an engineering community of practice over time?
3. What support, both inside and outside of the classroom, can be provided to promote inclusion of students with latent diversity in engineering?

Currently, this project is collecting data to answer the second research question through longitudinal narrative interviews. The first round of interviews was designed to understand students' background and pathways into engineering. The second round of interviews involved asking the students to complete a journey map to guide the interview focused on understanding their identity trajectory. This journey map documented the "high points" and "low points" of a student's experiences over the previous semester and was used as a reflective tool and data collection artifact to guide the narrative interviews. The third round of interviews continues to use journey maps and students' stories to understand their development in engineering.

The interviews were used to develop "restoryed" case summaries. A restoryed case summary is a short version of each student's pathway and highlights. In addition to these narrative constructions, we also compiled a conceptually clustered matrix that tracks patterns in participants' developing narratives over time, which allows the researchers to make contrasts and comparisons among the students within the themes [22]. This matrix includes students' personal information (i.e., group membership, major, and life changes), identity-building experiences, specifically aligned to the identity trajectory strands, agency, belonging, and unique elements or connections among participants. This paper describes the methods used to construct the restoryed case summaries of each participant, featuring two participants: one participant in group A who persisted in engineering and one participant in group B who decided to pursue a different academic major. Only two participants were selected for this executive summary, due to the lengthy nature of narrative work. A brief description of the trends observed throughout the narratives and future work follows each narrative.

Narrative Constructions

Narrative analysis is an emerging research methodology used in engineering education research to capture the richness and complexity of individuals stories [23], [24]. This set of methodologies allows the researcher to focus on the nuances of an individual's unique story, as opposed to using a generalized approach detaching the story from the theme observed [24], [25]. In this research study, we constructed restoryed case summaries using a naturalist perspective to capture the "rich descriptions" of the students' life experiences as a way to make connections between their past, present, and future, as it relates to their pathway into and throughout engineering. We constructed the narratives from a first-person point of view, primarily including direct quotes from the narrative interviews [24]. Extra text was included to provide clarity of the narrative, shown in italics.

In constructing restoryed narratives, we "smoothed" the stories as narrative interviews are often disjointed recollections of the students' experiences rather than thought out and complete stories ordered chronologically [26]. Using this approach for constructing restoryed narratives has several methodological strengths by prioritizing the participants voice, which ensures credibility and reliability; however, the reader may perceive this approach as "messy", in comparison to a third person approach to narrative construction in which the researcher narrates the larger story [24].

Identity Trajectory Theory

In these narratives, we use the framework of Identity Trajectory Theory to understand how three different strands of identity development happen over time: intellectual, institutional, and networking. Developed by McAlpine and Amundsen [25] to understand graduate student pathways, this project has adapted this framework to understand undergraduate student development. The intellectual strand includes, "Developing, drawing on, and effectively using subject matter expertise in ways that others acknowledge and ultimately make some sort of contribution. Consists of past experiences, individual ability, personal responsibilities, and identity to understand the impact on learning and being recognized within engineering" [27, p. 2]. "Institutional structures, resources, and responsibilities that influence students' identities within their academic institution and engineering as a career," [27, p. 2] describe the institutional strand. The networking strand encompasses, "Present, past, and historical relationships, organizations, and collaborations that individuals develop and draw on that contribute to professional identity and ability to succeed; these include both inter-personal (contemporary) and inter-textual (contemporary and historical networks)" [27, p. 2]. Together, these interconnected strands provide a rich, ongoing understanding of identity development at multiple levels including intrapersonally, interpersonally, and within a student context. For a more detailed description of this framework see [25], [27].

Results

Our results from this work include rich stories from 25 different students. While there are some common themes that have emerged from these stories, we have intentionally kept each student's story as a unique contribution to understanding individual pathways in engineering. Of the 25 participants, three students left engineering (two students left in the timeframe of the first interview and one left in the timeframe of the second interview). We have continued to interview these students as they provide rich information on how engineering culture may push them out of their originally intended pathway or how competing interests outside of engineering may pull them away from cultivating their engineering identity. As such, we decided to present two restoryed case summaries to illustrate two pathways that emerged throughout data collection.

The following sections describing Anna and Hilda's stories include a brief description of each students' initial latent diversity profile as characterized from a national survey (described in [20]) as well as presenting their individual restoryed narratives interview one and two (a one-year period in their second year). Anna's narrative represents a student who decided to continue pursuing engineering, while Hilda's narrative represents a student who decided to leave engineering to study

health data science. Following the narratives, we describe underlying themes observed throughout each narrative.

Restoryed Case Narratives of Anna

Anna is an electrical engineering student at a large northeastern institution. Anna's incoming attitudes and beliefs aligned with individuals characterized as Group A in our study [21]. Individuals in Group A are generally motivated by intrinsic and extrinsic factors, strong interest in mathematics, and strong beliefs about their abilities to understand and do well in physics. These students also indicated moderately high responses of belonging broadly in engineering and in the engineering classroom.

Interview 1. From kindergarten until middle school I went *to* an alternative school which had 40 kids in total, grouped by rough age groups and the school was project-based learning so instead of sitting down teaching us ABCs, numbers, counting, they gave us a project, assembled us into rough groups of kids of different ages and told us to go. It was very loose, not formal at all. I didn't learn much academic knowledge from that time, but I did learn really well how to work with other people, how to be a part of a team, how to sort of self-direct and do what I wanted to do. I spent a lot of time reading. I spent a lot of time playing with LEGOs. I got really good making friendship bracelets. I had a lot of fun and then in fifth grade, my parents started getting worried about me academically being able to make it in the real world, so they sent me to a private middle school which was very academically focused.

Before I transitioned to middle school, I learned six years of math in two weeks. *This school required* uniforms, homework, quizzes, *and* tests up the wazoo. If I got a grade less than a 95 my parents would sit down with me and have a talk, "What are you doing? What's wrong? How can we fix this?" So, I went from having no academic structure to *an academic institution that was very* structured. *This exposure to a highly structured academic program, prepared* me to go to a *public* vocational high school but *I* had to apply to get in.

I *attended* a high school *that had* a structured curriculum *centered on* science and technology. *It is one of the top 15 high schools in the northeast*. There weren't a lot of options for electives or classes. All of the science classes that we took were marine science classes, *including* one technology class each year. For example, my freshman year I took technical writing and my sophomore year I took AutoCAD. *Also, during* my senior year I took a research class in which I participated in a year-long research study that hasn't actually been done before and will be published shortly about Microplastics on the *East* Coast, and that was an amazing class. My teacher treated me like an adult, a scientist, I was responsible for my own deadlines and due dates, and her attitude towards the class and towards my responsibilities in that class really made me want to work hard for it. I really latched on to some of the better teachers, which lead me towards engineering because they staffed really good teachers for my systems engineering class, that was so much fun. In that class, we did a bunch of hands-on engineering projects, we built a Balsa bridge. We made a Rube Goldberg machine which didn't work but it was a lot of fun to do. We made that fishing lure, I still have the website, which I documented my results on and a bunch of other smaller projects and concepts about system balances, and, I don't know, engineering design. The curriculum of my high school also tried to incorporate these kinds of projects into other

classes. In my physics class, we made a physical model of *a northeast barrier*, it has sort of a trench in it and we used sound to map it.

Retrospectively, I think that it has been worth it because it's made me a lot more adaptable and it made coming to college actually really easy because I already knew what it was like to start out with no friends, no one, to have to adapt to a completely different set of rules and standards and to just go from the start. *For example, since my high school focused on science and technology,* I really had that opportunity to sort of become a scientist. But, what I realized when working senior year on my research project is that scientist[s] spend their whole lives delving into a problem, laying it out, describing it, but they don't solve it at all, and I don't think I would be able to live such big issues on my shoulders that I could do nothing about. I feel like engineering is related to science in that you use science to solve problems. I absolutely live for the moment where you solve the problem. I couldn't do that with such pressing matters like microplastics, oh my gosh, it's absolutely crushing to have to think about that sort of stuff all the time. Although my mom still thinks that I should be a scientist, it's just not for me although I really do value the experience of being able to try it out. She has made it very clear that she sort of sees me more as the scientist type then the engineer type. She also doesn't love that I'm in a career that's mostly men, but I don't really care about that because anything they can do I can *do* better. She really pushed me to be the best I could and be as creative as I could. I think she's definitely the one who made me a bit of a perfectionist. As for other influential people in my life, definitely my senior research teacher. The best teacher I've ever had, really an amazing woman.

In high school, *I also* took a AP Physics course which was centered around electricity and magnetism and for the first half the year we learned about electricity and the second magnetism and then at the very last minute, like three weeks before the end of the year my physics teacher started teaching us about light and how it's where electricity and magnetism come together and that's the moment that it clicked for me and physics sort of fell into place and I had that brilliant aha moment. It made me really feel like an expert and I saw classes like electricity and magnetism in my college curriculum *and* was like, *I want to study* engineering because that's where science and design and math and technology all meet up. I feel like it's such a varied field you can do whatever you want with it.

*My mom pushed me to take piano classes for several years and to be creative. However, u*nfortunately, the downside of being in such a science and technology-heavy high school held me back from other things that I'm good at like English and Art. There were no art classes, there were no music classes, the English curriculum was not very good at all. *That's why* I've been trying to make up for that in college by taking fun Gen Eds *like theatre, anthropology, cooking, and public speaking*.

My freshman year I didn't really take any electrical specific classes, *instead* I took general classes *that* seemed applicable to every other major *such as* English, Math, *and* Science. The only really exciting engineering part *during* freshman year *was* Engineering Design Lab. *During the first term, w*e made a Rube Goldberg machine. I made the Rube Goldberg machine with my ex-roommate and ex-friends then I moved on to a better group and we made a LEGO robot that performed a series of specific tasks. The idea was you set the robot down in *an* arena and it went around, and it picked up different canisters based on what color it was, it put it to different corners of the arena.

During my last freshman term, I chose to do a self-directed project instead of a typical class where they give you all that instruction. So, me and my two group members, who were also my group members for the robot, we chose a mentor who's an assistant teaching professor at *our Northeastern institution*. We decided that we would be making a set of solar powered window blinds that raise themselves and lower themselves, powered by solar panels that are on the windows. One of my group members was responsible for the mechanical design of the gear system and the blinds and that ratio. My other team member was responsible for the solar panels and their integration into the circuit. I was responsible for the circuit, the controller, and programming the controller. During that project, I taught myself C++, which was very difficult but also a good thing to know. We just very barely got it to work by the end of the project when we were supposed to present it.

At the end of my freshman year, I *decided to declare my major as electrical engineering*. I looked at the curriculums for *each* major. I read the descriptions of the classes and I felt pulled toward the more electromagnetism classes, *along with courses focused on* computer architecture and digital logic design. I still don't really know what I want to do as an Electrical Engineer. I have a lot of time to figure it out and develop that career path, but I really did like working with the hardware in front of me as I was trying to type out the software. I'm really hoping that my first co-op will give me sort of more insight into what there is out there because I don't really know. *My first co-op starts in April at a steel mill and m*y first project is going to be I guess assembling, installing, and coding/setting up a robot arm which stamps steel-plates with their identification number.

In Anna's first interview, she reflected on childhood and high school-aged experiences that led to her choosing engineering as a major. Although she enjoyed her early experiences in science and was recognized as a scientist by her mother, she identified a differentiation between science and engineering based on an ability to actively solve a problem. Anna expressed how she was not given the opportunity to be creative through the arts in high school; however, she appreciated the opportunity to take general education courses that fostered creativity and expanded her knowledge beyond STEM.

Interview 2. Below, we provide Anna's journey map used to elicit her experiences during the Spring semester of her second year, where she discussed half of the semester in classes and preparing for her co-op position at a steel mill.

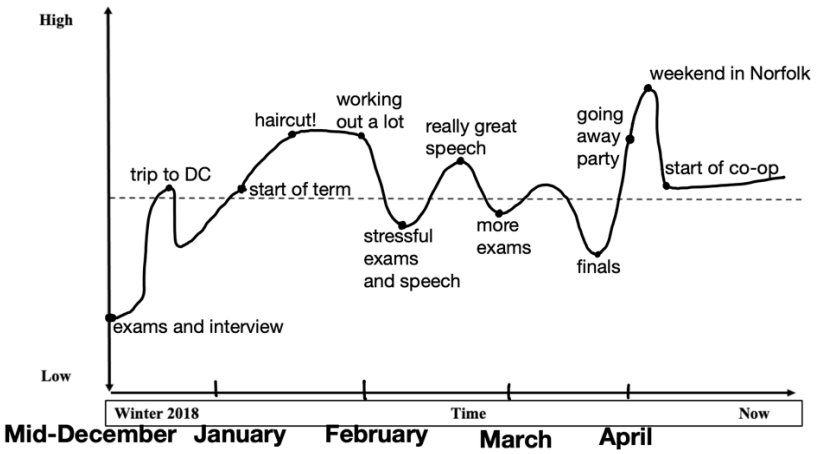

Figure 1. Anna's Journey Map for Year 2 in Engineering.

My program involves six months of school and then six months of work experience for a company. My lowest point during mid-December *was* when I had not only my final exams, but also *applying and interviewing* for *a spring* co-op. That just made me feel really, really stressed out and overwhelmed and confused about my future.

*I was confused about my future during the process of s*earching for *a* co-op *position. This process* made me realize *how* there are so many different paths my life could take, and they all seem so cool. *I thought,* "How are you supposed to decide?" What really nailed that down for me was deciding between two different jobs. One *job entailed traveling* a lot and *working* for a cause that I think is really important, but I would be doing a lot more secretary type work, and I would not be paid very much. But, it was close to home and had a lot of benefits. I feel like if I had taken that job, I could have really gone down the government path and gone more into the Navy side of things, which would have been really cool.

The other job that I was considering *entailed working at a* steel mill. That involved no red tape at all, but also a complete change for me. It's in an extremely rural area, which I had never lived in before. I don't know. It's really weird, right? You don't think of electrical engineering students working in a steel mill, which was scary but also exciting. Since it's private industry, not government, I would make a lot more money. These two potential jobs were really fighting me, fighting each other in my mind. I was really struggling with the thought that I have to choose what path my life is going to take right now, and the choice that I make is going to determine my future, which isn't something that I really had to do all by myself before. *When I was selecting a* college, I got input from my parents *and* friends. But, *when I made a decision about my first internship*, I asked my mom. I was like, "Mom, what should I do?" She's like, "Do whatever you want." I'm like, "That's not helpful!" But, yeah. I really felt torn between two things, and I decided to go with the adventure.

Going on an adventure involved me selecting the steel mill as my first internship. One of my strong values is wanting to live a diverse experience in life, and I want to travel to all different places. I want to really understand different cultures. I had never been south of the Mason-Dixon Line prior to my interview for that job. It is a really big shift for me, which is exciting. Also, I feel like if I

had stayed *closer to home,* I wouldn't have the opportunity to spend as much time trying to figure myself out by sequestering myself down south with no friends or anything. I feel like I have the opportunity to be a little more introspective and learn what's good for just me. Also, financially, the apartment that I was staying in would not have been reasonable for me to stay in with the money I would have made from the government, whereas the place that I'm staying in *for my internship* is paid for by *the* company. That was also a deciding factor.

About a week into January, classes started up again, and everything was normal. I was taking Public Speaking, Circuits One, Complex and Vector Analysis, Dynamic Engineering Systems, which is basically differential equations with a little bit of code thrown in there, and I was taking Physics. *I used t*wo resources, *Koofer and Reddit, to make decisions about courses*. I really like the beginning of term, because you don't have many assignments to do and you can relax and spend time with your friends and do the little homework assignments and set yourself up for the rest of the term. Around that time, I also made a couple lifestyle changes. I cut my hair real short and *started working out daily*. I found this term of school to be pretty straightforward, not especially difficult.

I chose to *enroll in a* Public Speaking *course, instead of Technical writing,* because I felt I could benefit the most from it, and also, I don't like writing essays. I walked into the class expecting it to be an easy A, but at the end of the first class, I realized that my teacher was going to actually try to make us learn something. He really did. He got into the science behind public speaking and gave us really specific rubrics for how to improve. He also taught us about formats of speeches and different ways you can prepare for different kinds of speeches, which was really beneficial to me because everybody always throws around persuasive speeches, but nobody ever teaches you what that is. At the beginning of term, *I was not* a very confident public speaker. Then, *public speaking* turned around for me and it clicked *when I* gave a really great speech. *I prepared for the big speech by* just sitting my roommates down and making them listen to me saying it a million times. When I nailed that speech, it was the pride of my life at that time. I showed it to everybody. I sent *it* to my mom *and* grandparents. I was like, "Look at my speech!" I really enjoyed that class. At the end of the term, my teacher told me that I was the first student to actually earn in points an A plus. I was like, "Yes." *This* course actually really *taught* me something important.

Also, I made a friend *in public speaking* who led me to join two clubs. I was talking *to o*ne student who is in computer science after class and he mentioned that he is on the IT Team for the school paper. *I am responsible for* upgrading the memory for computers and trying to fix bugs on the newspaper website and writing documentation for the different software that we use. It's really nice to have a group of people who are all super nerds like me. It's been really fun. I tried to continue this over co-op, but *my friend said,* "Take the term off."

*M*y Circuits class is kind of interesting. It was run by *a man who is* really old for a teacher. He was very put together, always wore collared shirts and button downs and ties and everything, and his hair was perfectly quaffed. Just like this hair, he wanted everyone's answers to all problems to be perfect. He needed you to write out every single step and every single unit to get full credit. He was very, very meticulous. I have no problem with being meticulous, but a lot of students had problems with being meticulous. *There were three questions on the* midterm, which I thought was extremely easy. He was so specific about, "You need to write out all your positive and negative

signs, all your units, every single mathematical calculation that got you to your answer," which I think is a little unnecessary, but he thought was very important. The meticulousness is what made that class difficult, not the content. He was a very good lecturer and explained things clearly. But he did get really frustrated if you didn't understand it the first time. It almost seemed like he hated his students, which is not ideal. But, ultimately, as long as you did what he told you to do, you could get a good grade, and I did what he told me to do, and I got a good grade. One interesting part of that class was the lab where we actually built circuits and tested them with multi-meters and got to see how they actually worked, which has been beneficial for my current job, because I've had to use a multi-meter, and I've had to know what the different components of circuits actually look like. That was useful. I liked that class, but a lot of people didn't because they thought the professor was *an idiot*.

This was the first term that I actually took a good Physics class. My professor was the first guy who didn't try to shove so much information down your throat every single lecture. He took it reasonably slowly. He used a lot of demonstrations and simulations, and he really seemed to care about his subject and about you learning his subject, which made learning about electromagnetic waves and quantum mechanics a lot easier. His format was almost entirely lectures, and then some demonstrations and simulations. It was easy to not pay attention because he spoke a little quietly and he was a really nice guy. But, if you paid attention, you could really get something out of it. I also found that his homework reflected what was on the tests, which is something that's really important to me. I enjoyed that class a lot.

I looked in my photos, and I didn't really see many for the period of February, basically. I don't think I was really doing that many social events or anything except for hiding from the cold and doing my homework.

In March, I took my final exams, *which was* my lowest of the low points. That's because I take school very seriously, and finals are a massive percentage of your grade. It's really the last thing holding you back from the next thing. I tend to get a little stressed out about it. I'm lucky to have people who actually care enough to be like, "*Anna*, what's wrong?" My boyfriend is super, super supportive. He always makes sure to do little things to make me not feel overwhelmed. My mom is also a really great resource because she provides perspective on things and she is endlessly encouraging. She's like, "Come on, *Anna*. You know you can do this." She's like, "You're here for this. You're so good at it." Also, I personally cope with stress include not being afraid to have a lazy day, making lists and schedules really makes me feel in control, and setting aside time to do fun things, even when I have an exam in two days. You need to set a little time aside that you don't have to worry. Those things work for me.

I also packed up my entire apartment. I made sure to see all of my friends *before I left for my internship*. I had a going away party, which was really, really cool. I made sure to say goodbye to the city and everything, although I'll be back there in six months.

Moving to my internship location isn't exactly what I expected before I got down *here*. I knew it would be quiet. I knew it would be a little bit lonely. But, I expected that they would expect more of me at my job. Right now, the only thing it seems like they want me to do is just learn, which is difficult when you don't have any objectives or things that you need to accomplish. I haven't been

amazed by my co-op experience, but I'm hoping to utilize it more fully. The first couple days I was there, I was really relying on my boss to tell me what to do. At the end of the week, I realized my boss is a flake and he doesn't care. That's bad in that I don't have really any direction. But, it's good in that it allows me to sort of take control without feeling guilty. On Thursday, I marched into his office, and I was like, "I need three things from you today." I was like, "I need a place to work, a computer to work on, and something to do." And, he provided me with a place to work, that's it. But, that's good enough. Since then, I've been trying to get other people, other employees to show me things that I should be doing. I think I've got a couple projects in the works.

Right now, I'm primarily working on safety training. One of the things that I've found very striking is just how nice and accepting everybody is of having an intern around. They just seem so happy to show me all their stuff and teach me all the things they know, and they answer all my questions, which has been really cool. It's really nice to have nice coworkers. That's a big deal to me. It makes me feel like I belong, which is something that I wasn't sure I would, being a city girl.

Anna's second interview began with discussing her experience applying and interviewing for internships. Her decision to select the internship at the steel mill was independent, whereas her decision about college was informed by her family and peers. Ultimately, she decided to pursue an internship that would expand the ways in which she envisioned the applications of electrical engineering and temporarily relocate to an unfamiliar area. The remainder of the interview focused on Anna reflecting on her classroom experiences, highlighting strengths and weaknesses of her professors. Once Anna completed her coursework in her second year, she started her internship at the steel mill described earlier in her interview.

Restoryed Case Narrative of Hilda

Hilda is a health data science student at a large Midwestern institution. Hilda's incoming attitudes and beliefs aligned with individuals characterized as Group B in our study [21]. Students in Group B had slightly similar characteristics as Group A across several constructs. Individuals in Group B are motivated by extrinsic factors and demonstrate strong interest and recognition in engineering. Similar to Group A, these students also indicated moderately high responses of belonging broadly in engineering and in the engineering classroom.

Interview 1. My dad is an engineer. He's worked for one company his entire life. He actually went to *Midwestern University 1.* That originally was my goal, was to be an engineering student at *Midwestern University 1*, but for a lot of reasons, I decided that maybe *Midwestern University 2* was a better fit for me. I originally wanted to be a doctor for a long time. I found that it wasn't really a fit for me and since my dad was an engineer, I found biomedical engineering to be really interesting to me. I really did enjoy *engineering* for a long time, especially the introductory classes, my intro engineering classes. It wasn't so much that I didn't like engineering. It was that there *were* other things I was realizing I liked better and that maybe I was more talented in certain areas. Specifically, with biomedical engineering, I found that my favorite parts were computer programming and the health part, so my new major is exactly those two things put together, basically.

I didn't really like physics at all, and even though I had a good grade because I had a weird professor, I still didn't feel like I was understanding it and it started to make me really worried. This is an intro physics class. If I don't understand this, I'm not going to understand the next one and the next one and the next one, so it started to scare me a little bit. Whatever the intro biomedical engineering class was that I was going to take the following semester somebody told me it was just the same physics again, except mostly about bones and the friction and that was like, "Okay. I'm not excited for where this path is leading me," so second semester, I pretty much had lost sight of a lot of my goals. I had to really take in stock what I really wanted to do in life, if that makes sense.

Again, when I heard about *my major*, it just sounded like exactly what I wanted to do. It was computer science. It was statistics. It's health related, but it doesn't have to be if I end up changing my mind about that later. It's still a data science degree. I can go anywhere. It just sounded so perfect when I heard about it, like, "Oh my gosh. This is what I was looking for my whole life."

When I got to college, *I took the* intro to *engineering* programming class, I ended up with one of the most difficult professors because instead of doing a bunch of mini projects through the whole semester, you work on building a video game, and since I had a background in computer science and not many of the other students did, I found myself helping them a lot, being able to read and analyze their code and fix it and help them out with that. It made me realize, wow, I'm kind of really good at this. Even in my engineering classes, I really liked the intro class where you do stuff in CREO and you go through the engineering process of making some fake design thing. I found myself always, I don't want to brag, but I felt like my deals were definitely on a different path than most of the other classes.

I mean, I honestly couldn't have given you a definition of engineer until the second half of senior year in high school. A lot of my life, I realized, *how engineering is* science centered, and it was mostly due to my parents. Even though I don't ever realized myself that I wanted to go towards engineering, I think it was something that they instilled in me. I think my dad found biomedical engineering and showed *the major* to me and explained to me what it was, and he was like, "Is this something that you would want to do?" I'm like, "Yeah, sounds close. Yeah." My mom always told me that she wanted us to be beauty and brains, kind of deal. She wanted us to care about how we look and how we present ourselves, but at the same time, understand that just because we want to be pretty doesn't mean we can't also be smart and strong willed and just powerful women, basically.

I was pretty lucky because BME [biomedical engineering] has probably, I think it's the largest percentage of women for any engineering group, so there was definitely a good amount, I think it was almost even amount, of women in my first year seminar, which is pretty good, but obviously, as time went on, that did change. After I left the first year seminar, it was like, okay, now it's all guys.

Another one of the big influences for leaving engineering was also the community, I think, that surrounded it. I found that in engineering, it was going to be maybe a more office-ish job in the future, a very professional workplace. Even the people who are majoring in it, I found that, this is going to sound mean, but they felt like bland. I guess I had programming classes, but I felt the

people were, more diverse in terms of pretty much every sense of the word, even just personality diverse, if that makes sense, and I just felt better there, if that makes sense.

I was really scared to tell anybody about my own personal sexuality and things that I just enjoy *when I was in engineering*. I do think we're nerdy, but they weren't the same kind of nerdy that I was. I remember specifically, we had to do a scavenger hunt for our first year seminar class and we went to the LGBTQ and diversity center and one of the guys in my group, we were supposed to take pictures in front of all the signs, he wouldn't even stand in front of the sign, and I was just like, "Really? You're so against this that you won't even stand near the room? It's just a room." I've already talked to people in my new major about these things. It just feels better. I don't know. It just made me realize that he could be a coworker in the future. Even though I know there's workplace rules and stuff that say you can't do certain things, I just felt like, I wouldn't want to be working in a community with that kind of mindset, if that makes sense.

Hilda's father is an engineer who introduced her to biomedical engineering. She discussed how the biomedical engineering program attracts more women than any other engineering program. However, after her first seminar, which included a good proportion of women, she was reluctant to be immersed into an environment primarily comprised of men. Although she enjoyed her first-year engineering courses and performed well in physics, she decided to pursue a degree in health data science where she could merge her interest in computer programming and healthcare. Hilda also expressed how when she studied engineering, she was unable to acknowledge multiple aspects of her identity; however, in health data science, she was able to establish community unlike in engineering where she described her peers as "bland," and lacking latent diversity.

Interview 2. In Hilda's second interview, she discussed how her spring semester shaped her development and interests outside of engineering.

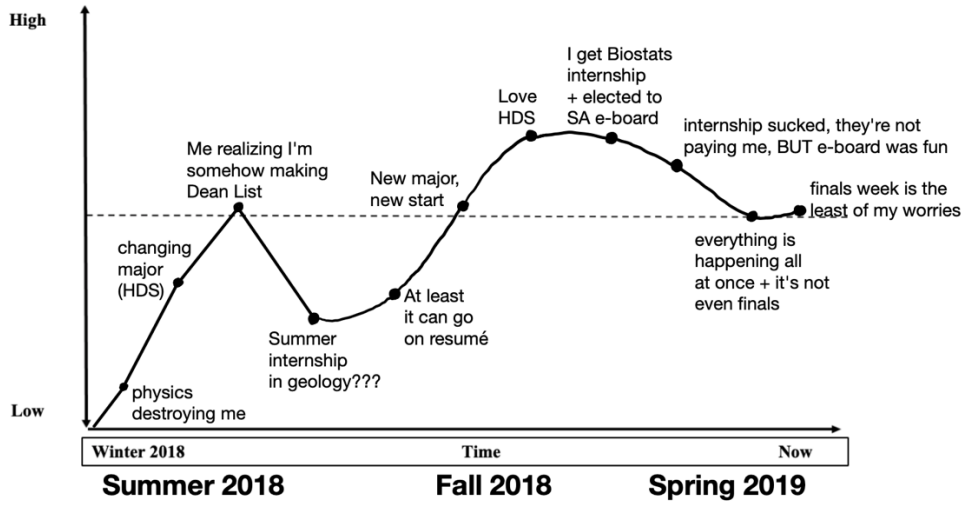

Figure 2. Hilda's Journey map for Year 2

Physics was destroying me. I honestly think physics was one of the classes that really made me want to change my major. Just because I was struggling, and it seemed like a lot of other people

really understood *physics* intuitively. That kind of made me realize, “Maybe engineering isn’t really for me.” Just because it seemed to *come* natural to other people, and it’s not as natural to me. Then I decided to change my major to health data science. That was definitely higher up, because it felt like I suddenly had a future, where I enjoyed what was going on. Then I somehow ended up making the Dean’s List. That was kind of a nice thing. It turns out the physics class, he was not super concerned about grades, so he gave us a bunch of extra credit and everything. Even though I had a good grade, I think I was able to take a step back and realize, "I got good grades, but I don’t really understand any of this.”

The physics professor attempted to let us do a lot of group work. Which is nice, because it helps us see what other people are doing and *learn* the correct processes for things. But it also ended up being two or three students who knew how to do everything, because they took this class in high school, leading the group and not really slowing down to explain everything. During this time, I *did not* know *what* I was smart in. I understood material. I *believe I* was smart *because* I understood how to use the system to my favor to get good grades. I’m in the honors college, so it’s not really an option for me to fail classes and stuff like that. Just because if I do, then I lose my scholarship money. Yeah, I consider myself smart, but not necessarily in physics. No, not smart in physics. *Also, during freshman year, I didn’t feel comfortable asking my professors questions* because I didn’t know how to write emails. I thought they were going to say, "Oh, this is unprofessional the way that you’re writing this". I mean, they didn’t. But that was definitely a fear in the back of my mind. During recitations it was always very much, like my physics recitation is when we did the group led stuff. The professor wasn’t even really taking questions. He was just assuming that we as a group would figure it out. I feel like that’s something similar I felt with a lot of my more STEM heavy classes. The *STEM* professors are more concerned with seeming smart rather than actually teaching, if that makes sense. I don’t mean that all professors are really bad about this. But, definitely it was, they just assumed we understood what they said. *For example, in* my calculus *2* class, I remember the professor didn’t really explain any of the concepts. *He* would just kind of assume that we knew how to do them, and wouldn’t slow down, and was just more concerned with, “Oh. Here’s what I know how to do.” I don’t know how to describe what I’m saying. It seemed that they were all really incredible at the subjects that they were teaching, but they weren’t teachers. You know? They’re professors. They’re not teachers. But they didn’t have the kind of teaching skills that I thought were necessary. They definitely seemed like they would rather be doing something else. I mean, I don’t know a lot about what the PhD program is like. I don’t know if they have teaching classes that they have to take. But teachers, you think, yes, they learn the subject that they’re teaching. But they’re also learning skills to convey information to you. I don’t know necessarily that some professors have those skill sets. Like I said, they’re incredible at the subject that they’re teaching, and it’s very obvious that they know exactly what they’re talking about all the time. But they don’t necessarily know how to convey that information to students. That’s not exclusive to engineering. Though I do think I felt it more there, just because it’s more STEM heavy.

Also, when I was still in engineering, I was *studying* biomedical engineering. I wanted internship experience in a lab, *so I learned about the internship through the* multi-disciplinary undergraduate research internships *program*. The only real lab work internship that was available at the time was in geology. Over the summer I had a geology internship that was not at all relevant to anything that I wanted to do. But I didn’t know how to back out. I was like, “You know, I’ll just do this. At

least it can go on my resume," and that helped a little bit. But, it was still, the summer was definitely kind of a bad time for me. I feel that I made the right choice in changing majors. Because that was my goal with BME, was to do clinical lab work. Being in a lab, it made me realize I don't actually like doing lab work. I was actually really excited for the summer to end, because I wanted my fresh start or whatever for my new major. I found that I really did like health data science a lot. That was basically how fall went. I had a lot of fun classes that I really enjoyed, like epidemiology. A lot of public health stuff that was a lot of fun. Then at the very end of fall, I had a bunch of stuff suddenly on my plate. I had more credit hours in the next spring semester that I was going to be taking. I actually ended up with a bio stats internship, and I was elected to the LGBTQ+ student alliance E-board, or the executive board. I am still currently the vice president of that organization. But as *it turns* out, the internship kind of, I don't want to say they lied. But they said it was through an organization, and then they didn't fill out the proper paperwork to make it actually go through that organization. They were having me intern for them, saying it was through an organization that it wasn't actually through. Therefore, they were not paying me. That was awful, so it put me down a little bit because I had to quit on the second day, which is not great.

Reflecting back on when I initially chose biomedical engineering, I don't think I understood completely what the major itself would entail. I knew it was math and science and engineering. But I don't think I understood the level of learning that was required for it. It was harder than I thought it was going to be, long story short. But, there were definitely elements that were, I don't want to say easier, but more fun and more interesting to me. I just kind of combined all those elements together and realized that health data science was those parts of BME that I liked, and none of the parts that I didn't like. I heard about the major just by chance. I was volunteering and somebody brought it up to me. *Also,* I remember very early on in engineering, I *took* a biology class for BME *and they* gave us a presentation on bio-informatics as a major. *I discussed the bioinformatics major with my* engineering advisor, *and s*he said, "I don't think this is what you think it is. But I'll help you keep an eye out if you really feel like BME isn't what you're wanting to do." I really appreciated that, because it was clear that she was motivated to help me as a student and as a person, and not help the engineering department.

I never even considered public health before. But now that I'm in it, I learned that, epidemiology especially is something that I really enjoy learning about. That's definitely the area that I want to go to with my data science. Tracking disease, and the end goal is to work for the CDC. But, I don't know about that one. Yeah, it's definitely the coursework. I really like the people in *my new major*. *There are* I think eight or nine of us. That means our main core class of bio-stats is really small. I like that a lot, because it means that it's more personal. I definitely feel like I have a relationship, not like *a romantic* relationship, but a relationship with will all the students.

It's definitely easier to see how the learning will be applied, compared to where I was in engineering. It was like, "Yeah. I know I have to learn physics and calculus. But I don't really, I don't see the vision." But with bio-stats it's like, "It's bio-stats. That's what I'm doing." I think that a lot of our professors are also like, they work in the industry because that's just kind of the nature of any kind of computer work. That you'll also have side hustles and whatever. They have a lot of firsthand experience.

In bio-stats, there's a lecture, and then there's some kind of interactive lab. We'll apply the concepts that we just learned about in, not a real world example, but with real world data, and do some analysis on that. Then generally, we'll have one or two exams per semester. Those are generally just the same things that we've done in class, but we have to do it *independently* now.

Also, I really enjoy epidemiology. A lot of my public health classes I feel like are really nice. Then kind of unexpectedly, I took an elective in medical humanities. I feel like that's really helpful. It's mostly geared toward more so pre-med people, and pre-nursing and such. But, I think it's a really good thing for STEM majors who are going into a health field to take. Even if I was still in BME, I think I would've really wanted to take this course. It would have been a lot beneficial to me. About big companies with data issues. Honestly, I haven't ever really paid attention to those. But now that it's becoming more and more relevant to what I'm doing, maybe I will. Yeah. But now, we don't have any internal coursework dedicated to data ethics. I'm writing a paper on this, so I have lots of examples I could give you. But one in particular I think is disease modeling. Or, well just kind of a predictive model for, let's say clinical research that a doctor's going to use. It takes the data that is already available in electronic health records, and then uses that to model future outcomes for current patients. One of the biggest issues with that would be, it only represents people who are already represented in the healthcare system. Especially marginalized populations that can't necessarily afford healthcare or are just less likely to be represented well in a hospital, or spoken for or anything like that, are less likely to be represented well by this model. That definitely struck a chord with me. Because it's very possible for a hospital to say, "Oh. Well we don't want to provide. We have different priorities for people who are lower socioeconomic class than we do people who are higher socioeconomic class" and use the data or the model to reflect that issue. Whether or not they're doing it consciously or subconsciously. That scares me a lot.

My medical humanities course is heavily reading based, because it's a humanities course so it's very liberal arts. You have to read *and* write essays. All that kind of fun stuff. We have a couple of exams. It's a class, is what it is. Reading, lecture, exams. But, I think my experience in it has been very good actually, just because I didn't know that it would be applicable. Honestly, I only took it as a blow off course for my honors credit. But, it turns out that actually, it's more relevant that I thought it was going to be. My experience with it has generally been really good.

The student alliance E-board is a lot of fun. I learned *that* I really like event planning, which is not related to my major, but you know. I have a lot going on. Plus, we were doing a drag show for the E-board, so it kind of put me down a little bit. But, it wasn't nearly as bad as I think winter 2018 with physics. *The student alliance organization* really helped me out *especially since I* didn't have a *support* structure within the queer community *during* my freshman year. That made it very difficult for me to survive in this environment that was predominantly straight White male. When I went and then started getting more involved in this community, it gave me a support system. Even though now health data science isn't necessarily more diverse than engineering was, I still have that support system. Getting elected to this made me feel that, "Oh. Now I'm empowered." I have a power and a voice within my community, and it doesn't matter where I work and who I work with. Because I know who I am. Yeah. It doesn't directly correlate to my major or anything that I'm doing in there. But it still is I think a necessary support system for me to have.

Hilda's second interview reiterated experiences during her first-year in engineering and provided confirmation on her decision to change her major to health data science. Specifically, Hilda recalled her experiences in Physics where she experienced difficulties with understanding physics and making connections between how physics and calculus informed biomedical engineering. Unlike the health data science courses, where she understood the value of biostatistics and its applications to health data science throughout the progression of the course.

However, despite her difficulties in physics, Hilda's physics professor was not concerned with grades which resulted in her passing the course without having a grasp on the material and ultimately led to her changing to health data science. Hilda showed a change in her outlook, affect, and experiences after changing her major from engineering. She described that she felt like she belonged more and even felt "empowered" through her decisions and networks developed in her new major. Below, we describe how these restoryed case summaries are informing our understanding about identity trajectory theory, belonging, and agency in undergraduate engineering education.

General Trends Among Participants

This research project employs mixed methods to provide a holistic understanding of how students navigate engineering and develop their identities as engineers. Throughout this project, we are using two approaches to measure engineering identity formation. The initial measurement was embedded in the survey where we measured latent diversity with several constructs, including a specific quantitative instrument for measuring engineering identity along three sub-constructs (i.e., interest, performance/ competence beliefs, and recognition) [20]. In addition to a quantitative engineering identity instrument, we used identity trajectory theory as a complementary methodological tool where we were able to capture a longitudinal perspective of student experiences that contribute, stagnate, or pivot their development as engineers. Likewise, identity trajectory theory operated as a powerful construct to provide a deepened understanding of individuals past, present, and future experiences that inform their learning and development by situating identity as an ongoing, continuous process, instead of viewing one's experiences and roles as disembodied contributions to who the person is or is becoming [25]. This analysis of longitudinal restoryed case summaries afforded a way to highlight how their past and present experiences inform their identity development across interrelated constructs such as belonging, agency, and learning.

Our work focuses on how identity trajectory theory can be translated to an undergraduate context by adapting descriptions that were initially defined to understand early career researchers and graduate students. The three strands are defined as follows [27]:

a. The intellectual strand demonstrates how students develop and draw on engineering-related knowledge to make contributions towards their learning and projects in engineering.

b. The institutional strand involves a variety of structures, resources, and responsibilities that support their identity development.

c. The networking strand represents the recollection of past and present relationships, organizations, and collaborations that inform their identity development.

Both students expressed strong interest, recognition and performance/competence beliefs in physics or engineering, which was cultivated through their pre-college exposure to STEM learning (institutional and intellectual) and parental support (networking). However, despite strong interest, performance/competence beliefs, and recognition in engineering, Hilda decided to pursue an alternative career path in Health data science where she could merge her interest in computer programming and healthcare, instead of remaining in biomedical engineering where she would be required to engage in the aspects of engineering that did not make her feel recognized as an engineer. This finding supports prior literature that discuss how performance/competence beliefs are not sufficient to sustain an engineering identity; instead, identity development should be mediated with interest and recognition by themselves and others [2], [28]. Further, this lack of recognition and belonging in engineering was facilitated by her experiences in physics and engineering where she described her peers as "bland" and engineering as lacking latent diversity, unlike her new major where her peers were inclusive of her multiple identities (networking). Interestingly, Hilda perceived her STEM professors as knowledgeable individuals in STEM subjects, but not as "good" teachers. However, although Hilda transferred to health data science for a multitude of reasons, she expressed how she still draws on engineering knowledge from the design process when approaching coding, as well as how engineering taught her how to be resourceful (institutional and intellectual). A combination of institutional, intellectual, and networking supported her decision to leave engineering, but continue to support her while learning data science.

Together institutional structures and intellectual development contributed to Anna's identity development during pre-college and college experiences. She felt recognized as a scientist when she engaged on a research project during high school; however, based on her perception of science, she decided to pursue engineering due to her ability to readily apply solutions with her engineering knowledge (institutional and intellectual). She described how her first-year engineering project required her to learn C++, since she was responsible for programming the controller to her groups solar powered window blinds (institutional and intellectual). This experience supports the value of students engaging in lifelong learning to facilitate their development, in addition to the structures provided by their institution [29]. Unlike Hilda, Anna was able to establish a sense of belonging and enact agency during her internship at the steel mill. She attributed her colleague's willingness to teach her as a factor for belonging (institutional, intellectual, and networking). Also, Anna was able to draw on her knowledge from her circuits course during her internship when operating a multimeter, which relates to her strong performance/competence beliefs in physics and engineering (institutional and intellectual). In addition to drawing on past and present experiences, both students described how their present decisions influence how they envision their future selves as an engineer or data scientist. These narratives illustrate how their experiences influenced their identity development, belonging, and willingness to exercise agency to enhance their experiences to foster learning. Positioning learning as agency situates students with authorship in their participation, identity development, and learning trajectory [30].

Future Work

In this paper, we described how we are using constructed narrative analysis to establish order and meaning to the data collected in two narrative interviews for 25 students. Recently, we conducted the third round of narrative interviews where we asked students to complete a journey map and describe their experiences in the third year of their engineering program (or non-engineering program for students who are in different majors). These students were also asked to verbally respond to a second version of the survey where we asked about their STEM role identities, belonging, and motivation beliefs. We will use these responses to identify how students' membership in one of the six groups changes or remains constant. Furthermore, we will construct restoryed case summaries for each participant and track patterns across categories described earlier, including pedagogical practices that contribute to students feeling included or excluded in the classroom. The longitudinal narrative interviews will continue throughout the Spring and Fall of 2020 to contribute to our understanding of how students form their identities over time. The results of this work will provide educators with empirical evidence of how to create supportive learning environments where students with non-dominant identities and mindsets will feel a sense of belonging and recognize multiple ways of thinking and knowing as an asset to engineering.

Acknowledgements
This work was supported through funding by the National Science Foundation CAREER Grant No. (1554057). Any opinions, findings, conclusions, or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation. The authors wish to thank the STRIDE research team and participants for their participation in the study.

References

[1] A. Godwin and G. Potvin, "Fostering female belongingness in engineering through the lens of critical engineering agency," *Int. J. Eng. Educ.*, vol. 31, no. 4, pp. 938–952, 2015.
[2] A. Godwin, G. Potvin, Z. Hazari, and R. Lock, "Identity, critical agency, and engineering: An affective model for predicting engineering as a career choice," *J. Eng. Educ.*, vol. 105, no. 2, pp. 312–340, 2016.
[3] A. Jocuns, R. Stevens, L. Garrison, and D. Amos, "Students' Changing Images of Engineering and Engineers," in *American Society for Engineering Education Annual Conference and Exposition*, 2008.
[4] H. M. Matusovich, R. A. Streveler, and R. L. Miller, "Why Do Students Choose Engineering? A Qualitative, Longitudinal Investigation of Students' Motivational Values," *J. Eng. Educ.*, vol. 99, no. 4, pp. 289–303, 2010.
[5] R. Stevens, K. O'Connor, and L. Garrison, "Engineering Student Identities in the Navigation of the Undergraduate Curriculum," in *American Society for Engineering Education Annual Conference & Exposition*, 2005.
[6] A. Godwin and G. Potvin, "Pushing and pulling Sara: A case study of the contrasting influences of high school and university experiences on engineering agency, identity, and participation," *J. Res. Sci. Teach.*, vol. 54, no. 4, pp. 439–462, 2017.
[7] O. Pierrakos, T. K. Beam, J. Constantz, A. Johri, and R. Anderson, "On the development of a professional identity: Engineering persisters vs engineering switchers," *Proc. - Front. Educ. Conf. FIE*, no. 2, pp. 1–6, 2009.

[8] A. D. Patrick, J. Borrego, and A. N. Prybutok, "Predicting persistence in engineering through an engineering identity scale," *Int. J. Eng. Educ.*, vol. 34, no. 2a, pp. 351–363, 2018.
[9] B. A. Danielak, A. Gupta, and A. Elby, "Marginalized Identities of Sense-Makers: Reframing Engineering Student Retention," *J. Eng. Educ.*, vol. 103, no. 1, pp. 8–44, 2014.
[10] C. E. Foor, S. E. Walden, and D. A. Trytten, "'I wish that i belonged more in this whole engineering group:' Achieving individual diversity," *J. Eng. Educ.*, vol. 96, no. 2, pp. 103–115, 2007.
[11] S. A. Atwood and J. E. Pretz, "Creativity as a Factor in Persistence and Academic Achievement of Engineering Undergraduates," *J. Eng. Educ.*, vol. 105, no. 4, pp. 540–559, 2016.
[12] D. Riley, "Rigor/Us: Building Boundaries and Disciplining Diversity with Standards of Merit," *Eng. Stud.*, vol. 9, no. 3, pp. 249–265, 2017.
[13] National Academy of Engineering, *Diversity in Engineering: Managing the Workforce of the Future*, vol. 12, no. 20. 2002.
[14] L. L. Bucciarelli and S. Kuhn, "Engineering Education And Engineering Practice: Improving the Fit," in *Between craft and science: Technical work in US settings*, S. R. Barley and J. E. Orr, Eds. Cornell University Press, 1997, p. 210.
[15] P. M. Leonardi, M. H. Jackson, and A. Diwan, "The Enactment-Externalization Dialectic: Rationalization and the Persistence of Counterproductive Technology Design Practices in Student Engineering," *Acad. Manag. J.*, vol. 52, no. 2, pp. 400–420, 2009.
[16] T. Becher and P. R. Trowler, "Disciplinary Socialization," in *Academic Tribes and Territories*, McGraw-Hill Education (UK), 2001, pp. 47–54.
[17] K. J. B. Anderson, S. S. Courter, T. Mcglamery, T. M. Nathans-Kelly, and C. G. Nicometo, "Understanding Engineering Work and Identity: A Cross-Case Analysis of Engineers within Six Firms," *Eng. Stud.*, vol. 2, no. 3, pp. 153–174, 2010.
[18] M. Lumsdaine and E. Lumsdaine, "Thinking preferences of engineering students: Implications for curriculum restructuring," *J. Eng. Educ.*, vol. 84, no. 2, pp. 193–204, 1995.
[19] A. Godwin, "Unpacking Latent Diversity," in *ASEE Annual Conference and Exposition*, 2017.
[20] A. Godwin, D. Verdín, B. S. Benedict, R. A. Baker, and T. J. Milton, "CAREER : Actualizing Latent Diversity : Building Innovation through Engi- neering Students ' Identity Development CAREER : Actualizing Latent Diversity : Building Innovation through Engineering Students ' Identity Development – An Executive Summary Introd," 2018.
[21] A. Godwin, B. S. Benedict, D. Verdín, A. R. H. Thielmeyer, R. A. Baker, and J. A. Rohde, "CAREER: Characterizing Latent Diversity Among a National Sample of First-Year Engineering Students," *126th Annu. Am. Soc. Eng. Educ. Conf.*, p. 7, 2019.
[22] M. B. Miles and A. M. Huberman, *An Expanded Sourcebook: Qualitative Data Analysis*, 2nd ed. Sage publications, 1994.
[23] G. Light and J. M. Case, "Emerging Methodologies in Engineering Education Research," *J. Eng. Educ.*, vol. 100, no. 1, pp. 186–201, 2011.
[24] N. N. Kellam, K. S. Gerow, and J. Walther, "Narrative Analysis in Engineering Education Research: Exploring Ways of Constructing Narratives to have Resonance with the Reader and Critical Re- search Implications Narrative Inquiry in Engineering Education

Research : Exploring," *Am. Soc. Eng. Educ.*, 2015.
[25] L. McAlpine and C. Amundsen, *Identity-Trajectories of Early Career Researchers*. Macmillan Publishers Ltd., 2018.
[26] J. Cruz and N. Kellam, "Beginning an Engineer's Journey: A Narrative Examination of How, When, and Why Students Choose the Engineering Major," *J. Eng. Educ.*, vol. 107, no. 4, pp. 556–582, 2018.
[27] B. Benedict *et al.*, "An Early Adaptation of Identity Trajectory to Understand the Identities of Undergraduate Engineering Students," in *Frontiers in Education Conference*, 2019.
[28] D. T. Rover, "Engineering Identity," *J. Eng. Educ.*, no. July, pp. 389–392, 2008.
[29] National Academy of Engineering, *The Engineer of 2020: Visions of Engineering in the New Century*. Washington, 2004.
[30] S. J. Basu and A. Calabrese Barton, "Critical physics agency: Further unraveling the intersections of subject matter knowledge, learning, and taking action," *Cult. Stud. Sci. Educ.*, vol. 4, no. 2, pp. 387–392, 2009.