Tinkerers, Artists, and Athletes: Using Personas to Spotlight Alternative Engineering Identities and Pathways

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Engineering education is typically described using a "pipeline" metaphor, wherein students are shuffled along pre-determined pathways toward a narrow set of career outcomes. However, several decades of research have shown that this pipeline model does not accurately describe engineering trajectories and may exclude students who enter the pipeline at different times and have other career outcomes in mind. Similarly, qualitative studies have shown that normative identities in engineering feature masculine stereotypes such as "geeks" and "nerds" that reproduce technical/social dichotomies. Several studies have suggested that broadening the expected outcomes and identities in engineering to include "alternative" pathways and identities may contribute to a shift to a more inclusive form of engineering education. To make these alternative pathways more visible to faculty and students, we have developed a set of engineering "personas" based on interviews [n=16] with senior engineering students at a liberal arts university. Interviews were coded by three members of the research team using consensus coding techniques to ascertain core elements of the personas: Origins, Identities, and Trajectories. Early drafts of student personas were presented to students, who provided insights into future iterations. We propose several engineering personas using a matrix approach, which allows each persona to be adaptable for various origins, identities, and trajectories. These personas contribute to our understanding of alternative engineering pathways based on real student experiences. We intend to use these personas as pedagogical tools to help faculty recognize a wider range of engineering identities, and to help students see themselves as "real engineers" without sacrificing other (non-technical) core values, identities, and pathways.

Introduction

What does it mean to be an engineer? What do engineers do in the world? Who is and is not recognized as belonging to the engineering profession? Those of us interested in equity in engineering education have pondered these questions for decades as we try to work out how to move the needle toward broadening participation in engineering. We (the authors of this paper) believe that part of the problem is that the status quo understanding of engineering is too narrow. As educators in engineering departments, we are limited by our own experiences in engineering. Those of us who eventually succeeded in engineering found the identities and pathways offered in engineering acceptable, and perhaps after some struggle and practice, we were able to convincingly perform these identities to become established members of the engineering community. It can be difficult for us, from this privileged vantage, to understand the myriad ways in which engineering excludes individuals on the margins of the field. As engineering "insiders", we must work hard to challenge dominant conceptions of "the way things are" and continue to imagine how things might be otherwise. What might a new, expansive, inclusive version of engineering culture look like?

When we speak of the "narrowness" of engineering culture, two prominent conversations are ongoing: identities and pathways. The literature about engineering identities has sought to elucidate what exactly it means to be an engineer and how the boundaries of who is, or is not, an engineer are enforced. It has been well-established that normative engineering identities exclude women and racial minorities, as well as other minority groups. The pathways discussion is more procedural: what is the process of becoming an engineer, and what are the recognized destinations of engineers? The pathways literature emerged as a critique of the well-known "pipeline" metaphor, arguing that underrepresented minorities

often follow nontraditional pathways in engineering and consider a wider range of options after college. These nontraditional paths tend to be invisible and/or seen as not really engineering.

We see these two conversations as linked in important ways: engineering students' personalities, interests, and motivations inform what they consider to be meaningful occupations after college. As we consider how to broaden participation in engineering, it is necessary to expand both our conception of who is recognized as a "real engineer" (identity) and what students choose to do during and after their education (pathways). As we considered how best to transform our own department at a liberal arts university, we settled upon creating a set of "personas" to help us conceptualize the variations amongst the students in our department, which were derived from interview data with two cohorts of graduating seniors. These personas have three levels: 1) Origins, to understand variations in students' backgrounds, 2) Identities, to explore variations in student interests and motivations, and 3) Trajectories, to explore variations in what students hope to do with their engineering degrees. We intend to use these personas within the department to help faculty support non-traditional or "alternative" identities and pathways in engineering. We also intend to use them to help students better articulate what kind of engineers they want to be and to recognize themselves as full members of the engineering profession.

Engineering Identities: Moving Beyond the Technical

At the root of many normative engineering identities is a presumed "technical-social" divide. Engineers are presumed to have a passion, bordering on obsession, with technology. Technology is the central focal point around which engineering culture is organized, and technical knowledge and practice are commonly prioritized over humanistic knowledge and relationships [1], [2]. Furthermore, technical knowledge is often constructed *in opposition to* social knowledge in engineering culture, such that the rejection of the social becomes proof of engineers' commitment to the technical.

Despite the pervasiveness of the "technology-focused, asocial engineer" stereotype, social scientists who study engineers have repeatedly pointed out that this identity does not hold up under observation. Wendy Faulkner finds that despite the pervasiveness of the technical-social dichotomy, both male and female engineers have reasonable people skills [3, p. 172]. She identifies several salient engineering identities in the oil and software industries, such as "nuts and bolts", "football and families", pranksters, nerdy men, shy men, urbane men, etc. [4, p. 14]. While all of these identities were coded masculine, these studies paint a more nuanced portrait of engineering identities than stereotypical accounts.

Engineering identities often exclude women, racial minorities, and other minority populations. Women's presumed association with "social", rather than "technical" knowledge often makes them "invisible" as engineers [3]. Simultaneously, they are hypervisible in feminine identities such as mothers, sex objects, helpless women, etc. [2, p. 57]. As such, their attempts to perform engineering identity are frequently misrecognized by their engineering peers: if they present themselves as women, they are misrecognized as "not engineers"; if they present themselves as "one of the guys" they are perceived as unfeminine and unattractive [2], [3], [5].

Racial minorities are excluded from engineering identities through similar mechanisms. Historically, engineering has been the domain of white men employed in colonial, military, and/or industrial expansionist projects throughout the world [6], [7], [8]. As the term "technology" came to refer almost exclusively to industrial and military machines, the technologies created by conquered nations and indigenous groups were redefined as "crafts", and the people who made them were disparaged as

"primitive" [7]. Rather than creators in their own right, people of color became the targets of "technological progress" as Europeans sought to pressure "backwards" and "uneducated" nations to embrace industrialization [9]. The exclusion of Black, indigenous, and other underrepresented minorities from technology continues today, as students of color face deficit-based assumptions from their peers and professors, implying that they are inferior and underprepared [10]. Students of color work to build positive self-identities, many of which are aided by family members, friendships, mentorships and networks related to their racial identities [10], [11], [12]. However, their racial identities often exist in conflict with their engineering identities: to be hypervisible as a person of color is to be perceived as less competent as an engineer. A more equitable engineering culture would ensure that engineers do not have to sacrifice their racial or ethnic identities in their quest to be perceived as "smart", "objective", "rational" engineers.

One point of hope is that the collective identity of "engineers" is open to reinterpretation. As new members join, they bring new ideas and their participation changes the dynamics and values of the group. By moving beyond strict associations between engineers and purely "technical" knowledge and opening up new ways of being a "real engineer" that include social, political, and context-based knowledge, we can make room for students to bring knowledge and values that correspond with their gender and racial identities in engineering.

Engineering Pathways: Not Lines, but Loops

Another important consideration, as we strive to build a more inclusive engineering culture, involves broadening our understanding of what engineering pathways look like. Student trajectories in engineering are often envisioned as straight lines - pipelines, to be specific. Concerns over retention of students have led to metaphors that seek to keep students "in the pipeline", presumably on their way to the final destination of engineering jobs. This conception of success - who has been retained, who has "leaked" - contributes to notions of who is considered to be a "real engineer". Are students who have engineering degrees but did not end up in "engineering jobs" still engineers? If students choose to pursue alternative pathways after college, is that not also success? These questions are important for educators as we consider whether what we teach is valuable for students who will pursue nontraditional pathways. They are also important for students, who may become entangled in pressures to become a "real engineer" despite having other desires, values, and goals.

The "pathways" literature has attempted to make more room for alternative ways of navigating the engineering profession. Early voices called for greater attention to students who entered the STEM pipeline later than typical students, perhaps not discovering an interest in science until the final year of high school, or after community college [13], [14]. While the "pipeline" model could not account for these students, who were perceived to be "behind" in their education, the pathways model allows for more flexibility in when students enter STEM fields. Similarly, during college, the pathways metaphor is better suited for understanding students who change majors [15], accounting for students who may leave the pipeline and return at a later date.

Finally, after students graduate they may choose occupations that are not "counted" as related to STEM. The comprehensive APPLES survey [16] shows that a majority of engineering students consider a much wider range of occupations after college than expected. Only 30% of the seniors surveyed were considering technically-focused engineering jobs exclusively [16, p. 90]. Seven percent were considering non-engineering occupations exclusively, and the remaining 63% were considering both engineering and

non-engineering pathways. Sheppard et al. observed that for today's graduates, engineering is seen as a "flexible platform for a variety of career options" and questioned whether our degree programs offer adequate support for students who may be considering a much wider array of pathways [16, p. 90].

Occupational flexibility appears to be of particular importance to the question of retaining women and racial minorities in engineering. The NAE finds that underrepresented minorities and women were more likely to be working in non-engineering occupations than their white and Asian male counterparts five years after graduation [17, p. 34]. The APPLES survey revealed similar trends amongst graduating seniors [16, p. 92]. In a smaller, qualitative study, Johnson et al. [18] found that for underrepresented women in STEM, finding a meaningful occupation sometimes meant leaving the well-beaten path of career opportunities. For example, Kathy, a Native American woman in a pre-med program who faced repeated misrecognitions and conflicts between her racial identity and her science identity abandoned the prestigious medical research path in favor of becoming a pharmacist for Indian Health Services (IHS) [18, p. 357]. This position allowed her to fulfill her dream of being in the medical field, avoid being the only person of color in the workplace, and give back to her community. The authors argued that far from being passively "leaked" out of the STEM pipeline, the women of color in their study were fighting to stay in, while trying to reconcile their racial and gender identities with the science identities of their field.

The connection between identities and pathways is clear in the example above. Individuals' identities inform their career choices. Rather than a linear path, occupational decisions are a series of loops, in which individuals consistently make choices whether or not to continue to pursue their areas of interest. Repetitive loops create momentum, or "patterns of acceleration" toward science occupations, which simultaneously result in a "thickening" of science identities [19].

Conflicts between gender and racial identities and engineering identities are commonly cited as sources of low self-efficacy and/or poor outcomes expectations. Outcomes expectations appear to be particularly important for persistence. In her groundbreaking work on women in male-dominated fields, Eccles [20] found that rather than lacking positive self-concept, women were simply making rational choices based on their assessment of the expected outcome. Specifically, the women in this study perceived that they would likely be unsuccessful at climbing the career ladder and face conflicts with their roles as mothers and actively chose to scale back their career goals. Despite being published nearly forty years ago, these conflicts between their professional and social identities continue to be salient among women engineers today. More recently, Johnson et al. [18], stressed the importance of "authoring identity", referring to the ability to forge pathways in STEM that felt authentic. As the women in the study considered their futures in science, they were concerned not only with "fitting in" but with the ability to chart their own paths in science that accorded with their racial identities. Thus, it was not enough just to be recognized as a scientist, but to become the kind of scientist that reflected their values.

This may perhaps explain the higher tendency for women and racial minorities to consider non-engineering pathways after college. It also supports the notion that in order to retain more women and racial minorities "in the pipeline", we may need to consider how to widen the field to recognize engineering occupational pathways that are compatible with a broader range of gender and racial identities.

Personas: Learning to Count Past Two

In an effort to expand the variety of recognized engineering identities and pathways, our research team has created a set of "personas" for use in our department. Social scientists have noted a stubborn

tendency amongst engineers to resort to binary thinking: technical-social, theory-practice, hard-soft, abstract-concrete, etc. [3, p. 175]. There is a need amongst engineers to "learn to count past two" [21], to move beyond dualistic thinking and recognize more heterogeneous forms of engineering identities.

Based on data collected from real engineering students, we seek to capture the variation that already exists but is under-recognized and tends to collapse into binary categories of "technical" and "social". We intend these personas to be used amongst educators to expand their perception of engineering students and their goals, which may result in a deeper understanding of how their work helps students pursue their diverse occupational pathways. This has been successfully implemented in other engineering departments with similar goals [22]. We also intend to use these personas amongst students to help them recognize a wider range of identities in engineering and see themselves as "real engineers".

While we are optimistic about this endeavor, we also acknowledge that there are some important critiques of the use of personas on contemporary design teams [23]. Although it has become common to create personas to characterize user profiles, too often these serve as a substitute for real engagement with users. Personas may be used in early stages of design as inspiration but forgotten in later stages, closer to production. They may also not be based on user data at all; rather, design teams may create personas out of their own imaginings, which serve only to solidify their own prior assumptions [23, pp. 82–83]. This is especially dangerous when designing for minority groups, since designers themselves tend to be from dominant groups, and thus, may reproduce normative patterns and fail to understand the real needs of minority populations. Costanza-Chock emphasizes that there is no substitute for real interactions with users at all stages of design, and for the inclusion of people from minority groups on the design team itself.

We concur with these critiques and have made efforts to ensure that our personas are based on real engineering students. We have sought feedback from students in interviews and focus groups during the development of these personas.[1] Finally, we are committed to including students in future conversations about transformation in the department, rather than simply relying on the personas alone.

In addition, we want to caution that these personas are not intended to be used as personality tests. In contrast to Myers-Briggs or Big-5 archetypes, which are tests of intrinsic psychological traits, these personas should not be considered "universal" classifications. Rather, these personas indicate *social* identities that were developed in a particular context, an engineering department at a liberal arts university. We make no claims that these are the *only* personas possible in engineering. Similarly, we do not wish to constrain students to identify with only one persona. Rather, our hope is that students will see themselves in *multiple* personas as a creative process of identity-building in engineering.

Methods

Institutional Context

Our research team analyzed the origins, identities, and trajectories of students at a small liberal arts college in the Mid-Atlantic region of the United States in an Electrical and Computer Engineering (ECE) department. Engineering within a liberal arts context offers smaller class sizes and enables professors to engage more closely with students on an individual basis. Students who choose this setting, rather than typically larger engineering programs at research institutions, are often well-rounded individuals seeking greater breadth to both their studies and personal identities.

[1] The feedback from the student interviews and focus groups are being reserved for a future journal article.

This university is a prestigious, highly-ranked institution recognized for its exclusivity and privilege. It is an attractive option for elite students from prestigious preparatory high schools. Efforts to increase student diversity include scholarships and outreach programs targeting racial minorities, international students and those from lower socio-economic backgrounds. The motivations for pursuing engineering vary across these distinct student populations, as do their experiences in adjusting to the university's culture and academic settings.

Research Design

Life history interviews [24] were conducted with 16 students from the graduating classes of 2022 and 2023. Targeted sampling ensured a diverse range of demographics and student experiences. Of the 16 students, 12 are male and 4 are female; 6 are White or European, 4 are Black or African American, 4 are Asian or Asian American, and 2 are Hispanic or Latino. Additionally, 9 of the 16 students are domestic, 4 are international and 3 are of immigrant origin. The interviews were systematically analyzed by three members of the research team using consensus coding techniques [25] to identify the core components of the proposed personas.

Each persona contains three core components: Origins, Identities, and Trajectories. Origins focus on the variations in background and context students bring when entering the university, including demographic information and prior connections to the engineering profession before choosing an engineering degree. For Identities and Trajectories, an inductive coding approach was applied to capture students' lived experiences. Initial Identity codes included academic interests (e.g., math, physics, biology, economics, history), personal attributes (e.g., creativity, problem-solving), personal interests (e.g., video games, cars, cooking) and social relationships (e.g., family, Greek life, classmates, professors). Coders selected the top three identity codes for each student. Trajectories refer to the aspirations and goals students set for their future. A similar process was used to identify and prioritize the three most relevant trajectories for each student. Although interpretations and coding styles differed among coders, substantial agreement was reached, and no significant discrepancies required resolution.

The initial codes for identities and trajectories were compiled, noting which codes appeared in 25% or more of the interviews. Related codes and themes were grouped and refined through collaborative discussions among coders, resulting in the development of five relevant Origins, nine Identities and nine Trajectories, which are described in the following sections. The Origins, Identities and Trajectories are combined to create a matrix of characteristics where students can independently select each component without any predefined connections between categories. To further promote flexibility, multiple characteristics can be selected from each category to create a unique profile. These personas can be leveraged as educational tools to encourage faculty to recognize a broader range of engineering identities. Additionally, they empower students to see their paths in engineering as flexible and unique, demonstrating that diverse origins, identities and trajectories are all valid ways of being an engineer.

Results

We have summarized the proposed persona characteristics in Table 1, organized by Origins, Identities, and Trajectories. The framework highlights the diverse background, personal attributes and future aspirations of engineering students. We have provided a short description of each category and example(s) in the sections below.

Table 1: Matrix of Origins, Identities and Trajectories.

Origins	**Identities**	**Trajectories**
Gender Identity	Tinkerers & Builders	Security & Social Mobility
Race / Ethnic Identity	Math-Science Mavens	Enjoying Life
Social Class	Creative Engineers	Good Job with General Area of Focus
Citizenship	Social Engineers	Prestigious Job
Connections to Engineers	"Big Picture" Thinkers	Engineering Management & Leadership
	Well-Rounded Engineers	Entrepreneurship
	Inclusive Advocates	Engineering for Social Good
	Family-Oriented Engineers	Graduate Scholars
	Engineering Athletes	Engineers Beyond Boundaries

Origins

Gender Identity

Traditional engineering identities are presumed to be masculine by default. As such, women may find it difficult to be perceived in "technical" identities due to associations between femininity and "social" knowledge. From an early age girls are also socialized differently than boys, and so the origin stories for most of the female engineers in this study tended to not include activities like taking apart the computer to see how it works (for example). Rather, women were more likely to be drawn to engineering through their mathematical abilities and interest in science. "I found out that I really liked calculus and biology, and eventually physics," Riley reflected. "I had no engineering background at all, like no comp sci classes, no engineering…I kind of just picked that because I was like, you know, I've never done it before. And it sounded cool. So I was like, I'm willing to take a chance." Rather than being inspired by an initial passion, her interests in technology grew as she explored the field in college.

Racial / Ethnic Identity

Engineering identities, in a U.S. context, are also white by default. Racial and ethnic identities impact engineering identity performances in different ways. Underrepresented minorities (URM), including Black, Hispanic/Latinx, and Native American engineers, tend to be perceived through a lens of deficits and have to do additional work to prove they are "smart", "disciplined", and "rational". URM students in this study were likely to have origin stories that included tinkering. One African American student, Carson, reflected, "I could visit like the one engineering teacher who was at my high school,

mainly because his room was really cool…I would go through with my friends and pretty much we'll just work on random things, like tinkering stuff…We were working on a gear shifting car."

In contrast, Asian engineers typically experience high expectations that they *should* be good at math and science. In addition to engineering, the Asian students we spoke to were often weighing competing pressures to pursue medical fields. A Vietnamese student, Lee, said although his parents wanted him to go to med school, he became discouraged after talking to his cousin, "[He said] sometimes it's just like too much studying and like too much pressure, especially from his parents." He liked computers so he decided to pursue engineering instead.

Social Class Background

Students experienced different kinds of opportunities to pursue engineering as a result of socioeconomic stratification. Students from upper- and middle-class backgrounds attended high schools that offered a wide variety of AP classes and support for college preparation. Students whose parents were doctors, lawyers, or professors had an additional advantage due to their familiarity with the higher education landscape. Riley explained, "My whole family is pretty much involved in the medical field. And so I would learn everything during school, and then I would come home and talk about it with my dad." Her dad was pivotal in helping her make big decisions about her choice of college and her career.

Some students from middle-class backgrounds had access to vocational high schools that helped them build engineering skills before entering college. First-generation students and/or students from lower-resourced schools often discovered engineering through outreach and/or after-school programs. Rowan described his experience in Project Lead the Way, which was a four-year high school program to build technical and design skills. "We were trying to see if there's a way to melt down these water bottles, and use them in filament [for 3D printers]," he said. "We did different tests of just melting stuff on our own with heat guns and running it through kind of a mold…It was a really cool experience."

Citizenship

U.S. citizenship and immigration status also had some impact on engineering origin stories. There were two subtypes in this category: students who were international students studying in the U.S., and students who were the children of immigrants. International students at this university tended to come from middle- to upper-class backgrounds whose families were more able to afford the high cost of undergraduate tuition in the U.S. They often attended private schools with connections to U.S. higher education institutions that offered counseling support for students who wished to attend college abroad. When choosing a college, international students were looking for schools where they had personal or family connections and/or strong international and ethnic student communities. Kai says, "I connected with a Vietnamese alum who's working in [a nearby city], he told me about the school. So I visited the university and I saw the community surrounding that. And I was like, this feels right."

Students whose parents were immigrants chose engineering due to their expectations that this was a job that offered financial security. These students differed from other low-SES or first-gen students in that their families were much closer to precarity due to uncertainty around citizenship, and this intensified their desire to get a "good job" after college. "[I was] born here, but my parents weren't," Angel says. "They're from Mexico. [Engineering is], like, one of the big bucks majors. One of the occupations that brings in the money. So I just kind of stuck with it. I never really considered switching my major. I still haven't." Students in both of these categories seem to "stick" with engineering due to its promise of future stability.

Connections to Engineers

Some students wanted to become engineers due to personal connections they had with family members or friends who were engineers. In some cases, one or both of their parents were engineers and they saw their path as simply following in their parents' footsteps. "My dad was a rocket engineer, and my uncle was also an electrical engineer. So that's why it's like, maybe engineering just runs in the family. So that's why engineering kind of fell into place," Kai reflected.

In other cases, their parents worked with engineers and passed along messaging that engineering was a "good job". Rowan says, "That's, I would also say, part of the reason why I kind of got interested in the utility side stuff. [My dad's] subcontracting out, like, an electrical company and their engineers, and he just kind of oversees the job…But they were just kind of pushing me, like, just go to college, go try. You can get a degree, make more money off of it."

Identities

Tinkerers & Builders

Students who identify with a "Tinkerer" or "Builder" identity are drawn to engineering for its "hands-on" opportunities. These students enjoyed playing with Legos or taking apart their toys or small appliances as children. Some were drawn to coding, construction projects or automotive hobbies. These students enjoyed classes with "hands-on" applications and may spend time working on independent projects at home or in makerspaces.

Angel described himself as a classic tinkerer: "[I would take apart] the microwave, clocks, things that didn't work anymore. Stuff like that. And then I just was interested in how they worked. And basically, how everything ticked." Whether deconstructing clocks, fixing computers, or programming their own video games, tinkerers were driven by a sense of curiosity and a willingness to spend hours making something work.

Math-Science Mavens

While most engineers were good at math and science subjects in high school, "Math-Science Mavens" continue to enjoy the intellectual challenge of advanced mathematics, physics, computer science, and other science-based classes in college. These students appreciate the "applied" or "real world" problems of engineering, but may also seek out double majors or minors in their favorite subject(s). Some students identify as both "Tinkerers" and "Math-Science Mavens", but Math-Science Mavens are generally more interested in analytical problem-solving than hands-on application.

Sam, for example, really enjoyed her advanced math and computer science classes: "It's kind of like solving a puzzle. I just felt like I had a sense of accomplishment because I was pretty good at it." What she really wanted from her engineering degree program was intellectual rigor. "I was kind of like, just give me something *real*." The sense of pride that was achieved by mastering a difficult subject was shared by many students in this category.

Creative Engineers

"Creative Engineers" value creativity and have talents in art, music, cooking, dance, or other hobbies. Some of the students we spoke with pursued their hobbies independently, as a form of relaxation and a break from engineering. However, some students saw these creative talents as deeply connected to

their engineering identities. The arts, in this sense, were another form of "tinkering", but the medium changed depending on the task, from noodling on a guitar, to modifying ingredients in a recipe, to 3D printing.

Kelly was more interested in the arts in high school than in math or science. He tinkered with various technologies, such as 3D printers, due to his interest in animation. Engineering, from his perspective, helped him to articulate his artistic vision. "[The throughline is] the idea that you can think of something and just will it into existence. Whether that's just an art sculpture project or some engineering-related project."

Social Engineers

"Social Engineers" are students who intentionally build relationships and networks. Social relationships are an important aspect of the educational experience and a recent survey indicates campus social life as an increasingly important factor for students choosing a university [26]. For 'Social Engineers', developing meaningful connections is a central focus. Many students seek friendships with peers who share similarities such as international status, common majors and schedules, or similar religious views. These relationships are often formed through special orientation groups, student organizations or Greek life. Students with the strongest social networks tended to navigate the challenges of COVID more easily, as they had established support systems in place.

Riley, who started in a different engineering major, switched in part because she wasn't connecting with her classmates and faculty in that department. After changing majors, she went through a brief "trial period" where her new classmates liked her, but they needed time to get to truly know her and form closer bonds. Riley ended up with several social groups that she values, including her athletic team and housemates, but she says "I'm happy with most of my human interaction being through my classmates, because I really ended up loving all of them."

"Big Picture" Thinker

"Big Picture Thinkers" view engineering as a means to help people, achieve social good and benefit communities. They approach problems by focusing on the broader system, potential impacts and overarching goals, aiming to avoid getting bogged down in the smaller details. This approach can make it difficult for them to identify with the stereotypical image of an engineer, one who works in isolation on technical tasks.

Jordan chose to study engineering with the goal of addressing the power grid issues she faced in her youth. Throughout her college years, she pursued an interest in sustainable energy and took elective courses to deepen her understanding of infrastructure. For Jordan, being a "good engineer" goes beyond technical knowledge; it also requires empathy and a focus on community. She explains, "Being a good engineer also requires attention to the community that you're working with. In addition to being knowledgeable, you should be able to empathize with them, and really, like, understand what they want, and how you could potentially help."

Well-Rounded Engineers

"Well-Rounded Engineers" enjoy pursuing a wide range of disciplinary subjects as a part of their liberal arts experience. These students would not necessarily describe themselves as "big picture thinkers" or "creative engineers", but they nonetheless appreciate having a broad education. Some of these students

enjoy subjects like economics, finance, and management. Others are excited about the ideas they learned in anthropology, languages, political science, and history.

"I've loved economics just as much if not more than computer engineering," Morgan says. "And so I ended up taking more economics classes since that first one. And so I've taken three classes like the introductory class, micro and macro…And I've loved that…Taking the economics classes has made me want to pursue graduate studies."

Inclusive Advocate

Students driven by the belief that mutual success benefits everyone strive to create a supportive and inclusive community. Our "Inclusive Advocates" go out of their way to support classmates facing academic challenges and advocate for diversity, valuing inclusion across gender, race, religion, and academic backgrounds. Many of these students recognize the positive impact of support they received early in their academic journeys and are eager to pay it forward by helping others in similar situations. Mentorship and peer support are central to the Inclusive Advocate identity.

Alex recalls how the upperclassmen in the student organizations he was part of gave him "a kickstart into college". Throughout his four years, he participated in an engineering student program designed to support underrepresented minorities, first-generation college students or those with educational or socioeconomic disadvantages. Reflecting on his experience, Alex shares, "They're like a mentorship group. And that has been the best thing I've ever been a part of."

Grateful for the mentorship he received, Alex embraced the opportunity to give back after his freshman year. "Once you're done your freshman year, then it's your turn to start giving back. I've tried stopping by that room as much as possible. And just like, hang out and talk with freshmen, and then outside of the school part helped them with the social stuff." Alex also values diversity and inclusive collaboration within groups. He recalls his experience leading a project, "Everyone needs to have an opinion on things because if one person just talked this entire time, we're going to get nowhere. There's not going to be a good idea."

Family-Oriented Engineers

"Family-Oriented Engineers" describe their family as being a source of motivation and structure as they pursue engineering. Contrary to typical engineering identities that demand detachment and objectivity, these students value community connection. Their families shape their ideas of what an engineer should do and be in the world. Lee described how his family was a primary influence in being successful in school, "I guess a lot of those factors that helped me kind of get work done on time and studying was rooted from growing up. My parents were always pushing education and studying ahead of time, getting your work done on time."

Similarly, Remy cited support from his family as critical to the ups and downs of college life. During COVID, when he was struggling academically, he said, "my parents have told me that they support me 100%, which, you know, I'm glad for that. It is a bit surreal, when things like this are happening, but like, you have a support system that doesn't fold on you." Engineering is a difficult degree program, and for these students, their families are important sources of support and encouragement throughout their education.

Engineering Athletes

"Engineering Athletes" are students who describe past and/or ongoing involvement in sports and athletics. Some students explained how the discipline developed in sports is important to their success in learning. Alex describes how playing lacrosse positively impacts his learning. "Academics comes first, sports come second. Everything else is third, social life third, and all that stuff. My best academic days are always when we had like 6am practice on Fridays."

Other students do not necessarily describe being an athlete as being directly related to engineering. Rather, it is part of who they are. For example, Nico describes the role that soccer places in his life, "I'm gonna be honest, [soccer is] probably in the DNA. My grandpa loved to play soccer when he was younger. And since I was little, he would take me to practice or we'd just play soccer with my friends, either on the street or we would go to an actual field and play soccer. It was never a bad day to play soccer."

Trajectories

A "Good Job"

When we asked senior engineering students what they hoped to do with their engineering degrees, many were unsure about the future and held relatively flexible goals to get a "good job". However, what a "good job" means depends on the student: for some it means financial security, for others it means getting a prestigious high-tech job. In our attempt to decipher what students meant by this phrase, we identified four possible interpretations: 1) Security & Social Mobility, 2) Enjoying Life, 3) General Area of Focus, and 4) Prestigious Jobs. We then highlight five additional trajectories for engineering students.

Security & Social Mobility

For some students, engineering is a pathway to financial security and social mobility. Getting a "good job" means finding a job that pays well and helps them to support their families. As Nico put it, "[My dad] always told me, 'if you become a mechanical engineer, you will always have a job, you will always have good pay.'"

Students from low-income and/or immigrant backgrounds may face additional expectations to support their parents, grandparents or extended families. Angel says, "It's just like, they've raised me, they've been through hell, they've put aside their lives. The least I can do is help them out in their old age while I have all this money." For students who are on visas, getting a job in the U.S. offers the security of being able to stay in the country to work. In these cases, the exact company or industry is of less importance - any engineering job will do, and that very security is the point of getting the degree.

Some students in this category expressed a sense of pride in becoming an engineer, a profession that makes their families proud. This pride may persist into their careers, as it did for Rowan's dad, who worked in construction: "We drive around and he's like, way back when, it was one of his first jobs. Or, I'll meet somebody brand new. He's like, 'Oh, yeah, that person, I built their house.'" It was important for Rowan to have the same sense of pride in his community.

Enjoying Life

To other students, a "good job" is one that offers opportunities to pursue their passions, or at minimum, offers enough flexibility to pursue their interests outside of work. For some students, like Lee, being passionate about the work they're doing at their companies is important. "I'm really trying to focus

on seeking passion. Engineering sometimes, like, all the difficulty makes you not like it so much. But fortunately, [the company I'll be working for] has a lot of cool government funded projects. So hopefully, this next year will really help me find passion and solidify that this is what I wanted to do all along." Students with the desire to be passionate about their work are also excited about opportunities for continuous learning through their companies.

For others, it is about finding a job with enough flexibility to enjoy their lives outside of work. River reflects, "So the other thing is, I'm more than just what I do for my career. So I'm probably not going to be an artist for a living, I'm probably not going to be a musician for a living. But like, I am going to be doing all of these other things while I'm also working as an engineer. So I think that's really going to depend on where I work." Flexible work hours, remote work, the ability to travel, and/or proximity to family are important for these engineers.

General Area of Focus

A handful of students have narrowed their prospects to a general area of focus in which they were seeking jobs. They are less specific about their goals than the "prestigious job" seekers, but have clearer areas of interest than students in the previous two categories. Ramsey explained the conventional wisdom in the department, "So, being an electrical [and computer] engineer, either you work in software or you work in power engineering, where you're working in power plants." These were, indeed, the two most frequent categories into which students would sort themselves: power or software. However, as Ramsey eventually recognized, there is more variety than is generally acknowledged, "Funnily enough, I'm not going into power engineering or software at all. I'm going into research and development of antennas." Several students ended up with similar jobs related to "signals", which was another prominent track in the department.

These broad areas of interest are seen as places to begin career exploration, which students anticipate refining after they have worked for a few years. Kai explained, "I know as a new grad, I just need a place to start. So once I start in my new software engineering job, I'll start to learn what it means to be a software engineer. And then I can start questioning myself at that point to see okay, is this what I want? Or do I want to switch around a little bit?"

Prestigious Jobs

A few students are interested in specific fields or companies that align with a personal interest or goal. In some cases, they really want to work on "cutting edge" technologies, and other engineering jobs are less desirable. For example, River would like to work for companies that align with his self-concept of being a "tech nerd." He brainstormed a few different places where he might be able to live this role: "The pipe dream is to work for a company like SpaceX, right? I'm just a huge nerd when it comes to all the stuff that they've been doing. Even working for a whole bunch of companies that I don't even know exactly what they do behind the scenes, but it would be cool to work for them. Like AMD, or Nvidia, Intel, you know, I am a huge computer nerd…it'd be really cool to be part of that as well."

Engineering & Project Management

Many engineering students express an interest in becoming a manager later in their careers. Morgan elaborates, "I would like to be a project manager, kind of like my role on the senior design team. I enjoyed being a project manager. I'm not getting as much technical work, but it's definitely good to see what a management role would entail."

Other students interested in being a manager express interest in continuing their education through their employers. Blake spoke about acquiring a master's degree to become a manager. "I definitely want to become a manager one day or kind of work my way up in a company. So that's kind of why I also plan to get my Master's at some point. I'm not sure what I would want that in yet."

Entrepreneurship

Other students view engineering as a pathway to entrepreneurship. These students are generally more interested in taking risks, pursuing opportunities that align with their values, and having autonomy. When we asked Lee about what he was interested in pursuing, he admitted, "I don't see myself working as an engineer forever. I want to maybe open a business, and become an entrepreneur. Whether that be like opening a coffee shop or something like that. I think I enjoy talking to people and helping others rather than just grinding the salary job."

Kelly's motivation for entrepreneurship combines his creativity, engineering skills, and social media. He is pursuing being a YouTube influencer. "I was always very inspired by a lot of YouTubers, Mark Rober was a very big one that got me into engineering. And a few years ago, I was actually featured in two of his videos. So that was pretty huge for me..." Students like Lee and Kelly may view their engineering degree as a way to secure financial stability, enabling them to pursue other career paths on the side or prepare for entrepreneurial ventures later in their careers.

Engineering for Social Good

Some students are motivated by the desire to do something meaningful that will help others and create a positive impact on the world. For some, this motivation takes the shape of a specific vision, such as pursuing careers related to environmental sustainability, where they can work on projects that allow more people reliable access to electricity or reduce environmental harm. Angel dreams of starting his own Makerspace, which is rooted in his own childhood experience, "Because when I wanted to build things as a kid, I didn't have the tools. So I guess that kind of space is better for people that are kinda like me, I feel like it would help out a lot." This effort could also serve as an on-ramp for underrepresented groups to learn about and enter the field of engineering, thereby contributing to greater inclusivity and diversity in the profession.

However, not all students have a specific, focused vision for how they hope to make an impact. Instead, they are driven by the overall goal of using their skills and knowledge to serve the greater good. These students are often systemic thinkers that want to solve complex sociotechnical issues. They may also pursue work in interdisciplinary fields that blend engineering with areas such as public policy, healthcare, or community development. Students motivated by engineering for social good are guided by a sense of purpose that extends beyond personal success, seeking out ways to use engineering as a tool to achieve this goal.

Graduate Scholars

The students who aspire to pursue advanced degrees and further develop disciplinary expertise and skills are on the Graduate Scholar trajectory. Their paths may lead to academia, research institutions or higher-level roles in industry. Ramsey, for example, chose to pursue graduate school to gain access to the industry positions that require high-level innovation and critical thinking. He explains, "This opportunity sounded like the perfect way to set myself up for a career, you know, not just at the bottom rungs of the ladder, but, somewhere in the middle, as, like, a Senior Project Manager at a big tech firm. So

for me, going through the [graduate] program, building up the knowledge and intuition that you have to have to be able to perform well in that job. It just felt like the natural transition for me."

Others were less clear about their goals, but felt graduate school was the next step. Sam admitted, "Yeah, maybe that's why I'm sticking to education, because I don't really know what I want to do yet." Regardless of individual motivations, the Graduate Scholar path is often shaped by the pursuit of intellectual challenge and continuous learning.

Engineers Beyond Boundaries

An engineering degree can lead to a wide range of career opportunities. The skills acquired through an engineering education, such as critical thinking, data analysis and problem-solving, are highly transferable to various fields including finance, law and other disciplines. For instance, Kelly secured a position at a tech company created uniquely for his skillset, combining engineering and the arts. Speaking of the job offer, he noted, "It's technically under marketing, which at first didn't sound very great, just because I wanted to do more engineering stuff." Kelly was worried that this would be seen as "wasting his degree". But after talking to a mentor, he came away with another interpretation. "He was just like, 'Who cares?' I was like, 'Yeah, you're right!' You're at a point where you have a degree, you're enjoying what you're learning, you're enjoying what your job is. Which still, doesn't pay as much as it could, but it's still more than enough to support yourself. That's also just a path that you're going down, not necessarily the destination. So it was like who cares? Just enjoy what you're doing." Although it can be challenging to define what qualifies as a career "outside traditional engineering," many students in this study expressed a desire to begin their careers in engineering roles while remaining open to exploring more diverse roles in the future.

Constructing Personas

These personas are intended to be flexible, since we understand individual identities to be complex and multi-faceted. When we invited students to create their own personas, we left the Origins categories open-ended, allowing students to define their own origins using terminology that felt most authentic for them. Under the Identities and Trajectories categories, students were allowed to select as many identities as they wished. Our expectation was that students would resonate with 3-4 identities per category. An example of a persona card is shown in Figure 1.

Students resonated with these identities, although we were sometimes surprised at the categories they chose for themselves. In particular, students strongly desired to be perceived as either "tinkerers" or "math-science mavens"; nearly every student selected one of these two personas. This may be partially due to the initial sorting that happens when students choose engineering as a major - they have already identified themselves as being math- or technology-focused. But it may also reveal the strength of the technical-social dualism in engineering; students may feel subtle pressure to present themselves as strongly math- or technology-focused despite having broader interests.

Students also offered useful suggestions for how to improve the personas. For example, the separation of personas into origins, identities and trajectories was due to student confusion that some personas seemed to be identity-based while others were trajectory-based. These represent some initial findings. We intend to analyze student feedback more thoroughly in future work.

In order to use these persona cards amongst educators, we plan to curate several fixed personas to use as examples. These personas will be carefully constructed to avoid harmful stereotypes. The intent of

these personas is to push back against presumptions that "math-science mavens" will necessarily be white or male, or that "big picture thinkers" will largely be women or people of color. We wish to emphasize that students from any Origin category may see themselves in any Identity or Trajectory category. For example, despite having initially pursued engineering due to an interest in math, there was at least one woman who mentioned that she appreciated "hands-on" activities in her classes. Reflecting on one of her favorite classes, Sam remarked, "We built a computer from start to finish. I thought that was pretty cool." Despite lack of early exposure to these kinds of projects, she might come to resonate with a "tinkerer" identity through additional opportunities.

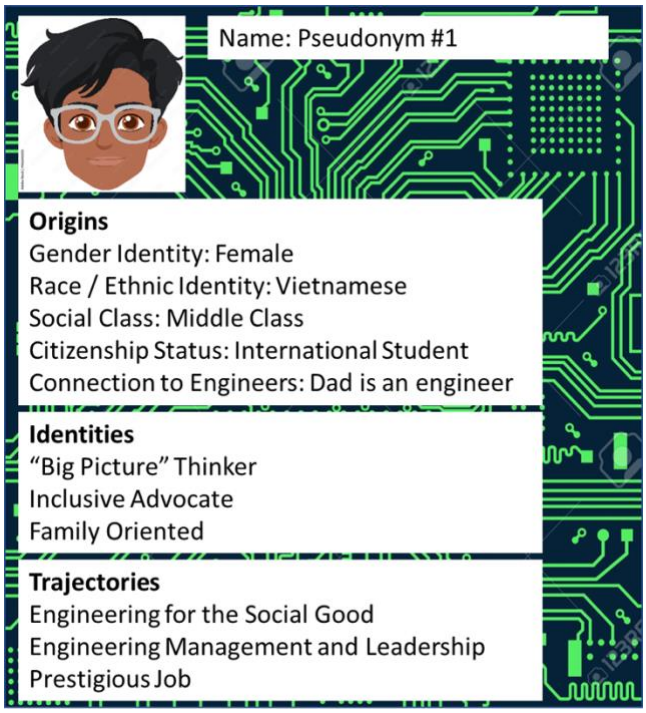

Figure 1: Example Persona Card.

In our early analysis, and perhaps due to our small sample size, we have found no evidence of clear correlations between Origins and either Identities or Trajectories. On the contrary, in this first pass, we found a mix of gender, racial, and social backgrounds within most of these categories. In future work, we will continue to explore these correlations and that data will inform the creation of cards for use with faculty.

Conclusion

In this paper, we have developed a set of personas for use amongst engineering educators and students in engineering departments. These personas are intended to counteract what have traditionally been a very narrow set of recognized engineering identities and pathways. The categories were generated from interviews with senior engineering students, which were analyzed by three members of our research team using inductive and consensus coding approaches.

Each persona is separated into three components - Origins, Identities and Trajectories - from which students can select multiple elements in each category to construct a persona that represents their

own experience in engineering. The Origins category included origin stories that varied by Gender Identity, Racial /Ethnic Identity, Social Class, Citizenship, and Connections to Engineers. The Identities category included the following engineering identities: Tinkerers, Math-Science Mavens, Creative Engineers, Social Engineers, Big Picture Thinkers, Well-Rounded Engineers, Inclusive Advocates, Family-Oriented Engineers, and Engineering Athletes. The Trajectories category included four possible definitions for a "good job" (Security & Social Mobility, Enjoying Life, Good Job with General Area of Focus, and Prestigious Job), along with occupational tracks for Engineering Management & Leadership, Entrepreneurship, Engineering for Social Good, Graduate Scholars, and Engineers Beyond Boundaries. These personas reflect the real identities of engineering students and expand our conceptions of who engineers are and what they do beyond a simple "technology" focus.

We intend to use these personas on our research team amongst faculty to help the department envision changes in the program that would benefit students who resonate with "alternative" identities and pathways. We also plan to use these personas in conversations with students as examples of engineering identity that are broader than typical "tinkerer" or "geek" stereotypes. By asking students to participate in building personas that resonate with them, we hope they will be more likely to bring their whole selves to engineering and see themselves as "real engineers".

In our future research, we plan to continue to refine the personas in focus groups and interviews with students. We will also look for correlations between Identities, Trajectories, and demographics such as gender and race. However, given our liberal arts context, this research would benefit from similar studies at other institutions to understand how university context impacts engineering identities. Similarly, we are limited by small sample sizes and significant cohort variation, so larger institutions may be better able to speak to broader trends relating to engineering identities and trajectories. Finally, more research is needed to determine what effect these personas have, if any, on our original goal: moving the needle toward recognizing a wider range of engineering identities and pathways, both within this department and more broadly across the profession.

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