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Abstract

As part of a longitudinal study of engineering students on four campuses spanning four years, students were asked questions each year about their images of the work of engineers. Such questions included: what do you expect to do on a day-to-day basis, how did you become interested in engineering, what are the characteristics that make a good engineer, and others. In responses to such questions students described how they imagined engineering workplaces and the work of engineering. We found that students in their first year of preparation to become engineers knew little about what kind of work they would be doing in the future as engineers. That is, they developed hopeful images of engineering. In some cases these images were altered or augmented in later years to become more mundane. For some students images from the first year remained virtually unchanged into their fourth year. Our discussion reflects how students' identities are affected both by common, widely circulating images of engineering and the absence of real workplace experiences in the undergraduate engineering education.

Introduction

This study reports on findings from four years of ethnographic interviews with engineering students at four schools. Specifically we are analyzing the images of engineering that students construct over the course of their undergraduate engineering educations. Early on we noticed that students in their first year of study to become an engineer knew very little about the work they would be doing as an engineer. This may not be surprising but we found that even after four years studying engineering, participating in coops and internships, working as undergraduate researchers, and being involved in engineering organizations students' images of their lives as engineers remained indistinct and vague. For some students images from the first year remained virtually unchanged into their fourth year. That is students constructed hopeful images of engineering, images with high expectations and high status. We also have an interesting asymmetry in our data; many students had vague images of the day-to-day work of engineering, but they had more vivid and extended imagery about what their lifestyles would be when they were employed as professional engineers [1].

Another asymmetry that emerged was that students identified with a particular image of engineering work, the designer, whom they recognized as an engineer whose status and distinction was regarded as higher than that of a draftsperson. In this paper we discuss how students' images of engineering work and engineers changed over the four years of their immersion in the engineering curriculum. We provide an analysis of the origins of students' images of engineering and what causes them to change and suggest some ways in which this imagery affects the engineering education experience. We also discuss dominant images across the four schools, showing how some images of engineering are so dominant that students who do not fit within those images must perform what we refer to as reconciling work in order to repair threats to their engineering identity.

An important part of our study has been how do students develop an identity as engineers. Our approach to identity has been shaped by both anthropological and sociological research traditions

that examine identity. We take identity to reflect two aspects of the self: outward representations of the self and the multiple ways that an individual is positioned in the social world by both other individuals and institutions [2, 3]. For the present study we are focusing on the sense of self side of identity, and in particular the sense of future self that an engineering student constructs in several ways: an imagined self in relation to an image of engineering, as a profession, as an engineer, and as a professional role. An aspect of identity development isf the emergent images of engineering that our students developed over time. In some cases these images are developed within specific disciplines of engineering whereas in other cases such images we found to be specific to the particular College of Engineering at a particular university.

The Academic Pathways Study (APS) is a multi-year, longitudinal study of learning and development among undergraduate engineering students at four engineering institutions that represent an institutional type. These are a Large Public University, an Elite Private University, an Historically Black University, and an Engineering Technical College. Subsequently these institutions will be referred to as the following: Large Public University (LPUB), Suburban Private University (SPRI), Urban Private University (UPRI), and Technical Public Institution (TPUB). The present discussion focuses upon semi-structured ethnographic interviews that occurred over four years among 16 students at each of the four engineering institutions. The analysis presented here is based on the entire 64 students responses across all four years of their participation. Our semi-structured ethnographic interviews were conducted in such a way that students could reflect upon their life experiences in order to investigate integral components of their life-world. We asked students the same questions over four years allowing us to observe changes and alterations to the narratives they develop about their engineering educational experiences. The majority of the data presented below was drawn from response to questions such as: what do you think it takes to be a good engineer? What do you expect to do on a day-to-day basis as an engineer? How would you compare yourself to other engineering students? How would you compare yourself to non-engineering students?

Many students responded to our questions during ethnographic interviews through the use of narrative [4]. Such narratives are often representations of past events or students develop a narrative that enables them to position their identity in relation to aspects of engineering culture. The latter type of narrative work involves what Wortham describes as interactional positioning [5]. While our semi-structured interviews are not interactional events, they do offer many opportunities for students to position themselves in relation to others – e.g. other engineering students, as well as students who are not studying engineering. Schiffrin [6] argues that a narrator's self-identity is situated both locally (the immediate situation) and globally (the cultural aspects of our identity) and that through narrative we are offered lens, or portrait, into how they perceive themselves in the social world. In a sense, the narrative work that engineering students do (representations of the past and positioning) grants us access to snapshots of how they view themselves in relation to the dominant images of engineering culture developed within their respective Colleges of Engineering. Schauf [7] found that narrators will often construct repositioned narratives when their identities are threatened. Such work he referred to as narrative repair. As we will discuss below sometimes the dominant images of engineering are so strong that students must reposition and repair their identities so that they fit within these dominant culture.

Images that change over time

In our analysis of student-constructed images of engineering we have noticed two general types: those that refer to theories, fundamentals, processes, and mathematics; and those that refer to conditions of work such as group work, communication skills, and writing. The former we refer to as images of engineering as a science and the latter we refer to as images of engineering as an occupation. Images of engineering changed over time among students within our study. Such shifting images included: the image of a good engineer, images of engineering work, and images of the engineering workplace. For example, students' images of what a good engineer is changed over their educations to include such things as good interpersonal skills as opposed to only technical engineering skills. In what follows we juxtapose earlier interview responses (years 1 and 2) with later interview responses (years 3 and 4) to highlight how the characterization of these images has changed over time.

The image of a good engineer

Many students' understanding of what it takes to be a good engineer changed over the course of the four years of this study. In the first few years of engineering education many students do not take courses in engineering, rather they take prerequisite courses in mathematics and science. Changes that emerged in our study began to surface as students enrolled in more and more courses in their respective disciplines and in some cases completed internships or co-ops. Students often entered college with an image of what it took to be a good engineer based on experiences from high school. For example, Nate in his freshman year interview, when asked what his image of a good engineer is, stated that he believed being a good engineer involved "working smarter not harder," an image he developed in high school.

> Working smarter not harder…Pretty much same image I had before I came here, yeah. But that was i-, that was, cause, the thing I noticed in that, in high school, even the people that worked really hard and like got good grades and whatnot, they, they generally ended up suffering in like other areas (Nate, SPRI, Year 1).

Nate's image of a good engineer being someone who "worked smarter, not harder," changed by his junior year interview where he discussed a good engineer as being someone who cannot only apply mathematics and science to problems in the world, but someone who is able to describe those problems through objects.

> How would I define "engineering?" Um, application of mathematics and science…Um, describe it in, I mean, we more describe it through objects that they work with on a daily basis or see on a daily basis. I mean, just like a vehicle, a car, that's an innovation in engineering. Cell phones, innovation in engineering. (Nate, SPRI, Year 3)

Specifically Nate shifted his notion of what a good engineer is from something vague, "working smarter not harder" to something tied more into the narrative of engineering as a science – how the application of math and science leads to innovation. Darrell's quote from his freshman year interview revealed some similar ideas about what it takes to be a good engineer that included qualities like thinking abstractly and not thinking within a set of rules and presumptions.

> I think a good mechanical engineer needs to um be able to collaborate well with other people, that's a very, very key aspect. Um, because, I learned a lot this quarter that great ideas don't always come from one person… I think that's one thing that a mechanical engineer really needs to be able to do well is work on a team. Another thing is you have to be able to think abstractly. You can't always think along the lines of-, of, here is a set of rules or preconceptions and you have to stick to them. You have to be able to design and develop and improve on technology that has already been designed and developed and improved on by previous people… Once you get out of the design and, you know, creative thinking and brainstorming aspects, you get to the implementation. A mechanical engineer has to be able to know how to implement, you know, designs, you know, math and physics is gonna come in real handy there. (Darrell, SPRI, Year 1).

In a later interview Darrell shifted his notion of what it took to be a successful engineer based partially upon his work experience. As comes across in the next interview segment, his shifting image of a good engineer involved things that did not always get emphasized in class – working well with others and communication skills.

> Um, I'm much more the practicing engineer side. Um, I think I-I also know what that's like because I've worked, um, for a sum total of about half-a-year now, if you add all the time together at [Name of Company]. And, um, I think that I really understand, you know, that that is what they say about the industry is true, and there are a lot of qualities that are not necessarily, um, not necessarily emphasized in engineering curriculum that I think are becoming more emphasized as you see curriculums changing, which are your, you know, your non-engineering type of things. You know, not your problem-solving but your presentation. You know, not your mathematical ability but your ability to work as part of a team. Um, I see those qualities as being even more important, and I constantly rate those as the highest on the surveys that you guys send out, too, um, because that's what it is. I mean, the most successful people, they're in the industry, and the ones who will, um, be noticed for their work and who will advance in their careers the fastest are not necessarily the ones who, um, are-are the best, um, fundamental engineers. (Darrell, SPRI, Year 3).

Darrell noted that the engineers who were successful were not necessarily those who had the most excellent mathematical abilities, but rather those who possessed skills such as working with others, communication, and the ability to present one's work. That is, it is not primarily an understanding of science that enables one to be successful in engineering, but also, and more centrally, abilities that have to do with conditions of working with others, such as communication and teamwork.

In a similar manner to what Darrell mentioned above as being a part of a team, we noticed how William's perception of what a good engineer is shifted from one who mastered technical aspects of the field to one who also has an ability to communicate.

> I think um being an good engineer is something that evolves as—once you get into um the workplace Um, I think I know for [name of company], um, that you're not uh a full-fledged um you don't get to be a full fledged uh type of engineer where if there's a

> problem, they just come and ask you to solve it by yourself for uh, for years, so I think there's definitely still a learning process involved even after um, you kind of graduate and that and have supposedly mastered all of the technical aspects of of your field of engineering, so I think that it's a continued learning process um I think also, to be a good engineer um, which is kind of strange, (William, UPRI, Year 2)

> Um, you need all the things that, um, I just said but you also need, um--cuz a lot of people talk about engineers as people who aren't really good communicators. Or people who don't have a person-to-person skills. Um, I think that's also very important. And if you have those you're going to be a lot more marketable. Or a lot more likely to be promoted to the positions. Where you had to lead the meeting or you have to do stuff like that. If you can, you know, effectively communicate, and people can understand you. (William, UPRI, Year 3).

William's year 3 quote draws our attention to qualities of an engineer that are not related to engineering technical knowledge. Rather he feels that the qualities of a good engineer that will make him "…a lot more marketable" are those related to communication skills. In his year 2 response William focused on technical knowledge and skills that will develop over time. In year 3 he has introduced other skills that are relevant to being a good engineer that go beyond technical engineering skills.

The shift in Deborah's understanding of what it takes to be a good engineer was based on what she felt was a tenacious spirit that engineering students must maintain into to complete their programs.

> Someone who can see the final goal um very tenacious-, they gotta be like tenacious because if not, you won't get through it. Cause they even tell you it's a weeding out process, you know. The person you're sittin' to-, you know you hear that all the time, but they actually said, you know like "Okay, many people drop it every year." And you know, if you make it past your junior year they say, you know, you're cool, so. It's just basically being determined and being a hard worker. (Deborah, UPRI, Year 2).

In contrast to the previous excerpts we see how Deborah's shift in what it takes to be a good engineer is based on her image of what engineering is as a science, having a good understanding of theory.

> I think they think what it means to be a good engineer is basically all this theoretical stuff, cause they push the book on you so much. I think they think if you have all the theory you should do well. (Deborah, UPRI, Year 3).

In general we can characterize the images that students had of what it takes to be a good engineer as shifting from vague to more specific images over time. We suggest that these changes were the result of more exposure to engineering coursework. Here we note that in a few cases images of engineering as a science surface initially in how students perceive success in engineering. That is, they believe that comprehending the fundamentals of engineering (physics, mathematics, etc), will enable them to have success and be a good engineer. In many cases what shifts in these

images of what it takes to be a good engineer are features and conditions that do not have anything to do with the fundamentals of engineering, such as good communication skills and working in teams. Students become aware that they need to acquire a skill set that goes beyond engineering as a science.

Images of engineering work and the engineering workplace

Students' visions of their future engineering workplaces changed over time. These changes are again related to their exposure to more coursework in their respective majors, as well as their participation in internships. One shift we saw was that students' workplace images changed from being hopeful expectations in early interviews and later years' responses becoming more mundane/less high status. In some cases this shift did not occur until year four, whereas others gradually developed a more detailed understanding of their future workplace over all four years of interviews.

Erica developed a more mundane less high status, yet detailed, image of her future over the four years that she was interviewed in our study. As a chemical engineering major, Erica initially perceived herself working at a company as someone who is responsible for equipment purchases as well as developing catalysts and processes for a plant.

> I, I could definitely see myself kind of working with a company and saying what, like looking at equipment and saying, "Oh this is good, and you should get this," or whatever, like that kind of thing. Um, I could also see myself working in a lab trying to, you know, invent the best catalyst for whatever. So I, like at this point I think it's too early for me to know like which side of, of the engineering I want to go towards. (Erica, LPUB, Year 2).

The emphasis on inventing something new, "the best catalyst…" illustrates the role that innovation and creativity played in the images that students developed initially as engineers. This image is of an engineer who invents something or creates an engineering innovation. Notice how Erica's idea of what she would actually be doing changed in her junior and senior year interviews. Ultimately Erica realized that she will be working on some process, not designing it.

> I mean, like Dream Job would be working at like AmGen or a biotech company as a practicing engineer, you know working in some process. (Erica, LPUB, Year 3)

> So, just how it works different, like, trouble shooting. How you would, if something happens how you would fix it. There's things that we make take one week to make from start to finish so if something goes wrong in the process, you know, four days down the road you're out four days worth of work so it's really important to be able to get this stuff up and running quickly if something goes wrong, and kind of just learn the different tricks to, to get it back running. (Erica, LPUB, Year 4).

By senior year, her image of the chemical engineering workplace had become more detailed and involved a very shifted image of her role. Where in her sophomore year she saw herself designing a process, by junior year she imagined working in the process, and finally in her senior year Erica is trouble-shooting the process. We noticed a similar shift with another Large Public

University student, Colin, who noted early on in his interviews with us that he wanted to be a designer not a drafter, as a design job was more prestigious.

> Drafting? Or to like check up on other engineers, like make sure that they, um, did all the calculations correctly and then, the part will actually work. That's like a lot-that's pretty boring to me. I'd rather be an innovative person like making it up and stuff. (Colin, LPUB, Year 1).

Colin's preference for being a designer was developed, in part, outside of the classroom. Colin's father is an engineer who designed a part of a bomber.

> Like, cause if I design a part then I go, "Yeah, that's my part." Like my dad designed the bomb bay doors in the [name of bomber] so, like he can go, "That's my part." And like every bomb that drops [mumbles] takes a lot of pride in that. Like if you're the drafter, all's you really get is like calculus and stuff, so. Even though there's a high demand for those people because it's the [inaudible] side of the job. (Colin, LPUB, Year 1).

In the quote above we can observe how the prestige factor plays a significant role in developing Colin's images of the engineering workplace. Drafters who sit behind a desk working out calculations on other engineers' designs are not awarded the lifestyle prestige of their designer counterparts. Colin wanted to be an "innovative" person, as opposed to a draftsperson who is afforded the opportunity to be creative. Another important consideration was the role that family members, or friends of family, who were engineers had upon students entering the field of engineering, as well as the images of the field that these people depicted or represented which were sometimes adopted by the students. In the case of Colin, his father, someone he referred to frequently as his "best friend," and his father's role in the engineering workplace is valued by Colin, and in some ways Colin's knowledge about this role cemented an image in Colin's own mind of what he aspired to do himself. The image of engineering work he glimpsed through his father became the standard by which he judged his future work. Notice however that his image of a designer changed already by sophomore year, here Colin noted that he would not necessarily be designing new things, but instead updating older designs. This more mundane image is similar to Erica's, a student at the same school (LPUB).

> Um, hopefully, probably like designing some faster like computer thingy [laughs]. Or I mean like probably like, more than likely that's not gonna happen, I'm probably gonna be like updating and like making current stuff faster. Which I don't really want to do but like that's where most of the money's gonna be at so. (Colin, LPUB, Year 2).

Colin's image of his future engineering workplace shifted from being a very hopeful expectations (being a designer and an innovative person) to one that was more mundane, "I'm probably gonna be like updating and like making current stuff faster." He still wanted to be doing design work, but he had become resolved to the fact that this is a less likely possibility for him in the image he has of his future engineering workplace.

In other students we noticed a more gradual development of this understanding of the differences between drafting and designing. For instance, with Steve this shift develops from research, to

design, then to the actual practicality of what he anticipates his workplace to look like. In his freshman year interview Steve emphasized the research aspect of his anticipated engineering workplace.

> Well, the mechanical engineering class that I took would lead me to believe that I'm doing research all day. Which, I'm sure would be true if I went into the academic setting, but um, but I may end up working for some sort of firm, um, if I got say a biochemical engineering degree. I could go and work for a company that makes say replacement knees or things like that. (Steve, SPRI, Year 1)

Steve's sophomore year interview focused upon a dominant image of engineering that we have noticed previously in both Erica's and Colin's excerpts above, being a design engineer.

> As an engineer? Hmm, I imagine it depends on what, like, phase of the project I'm in. Like if I'm in the initial design phase, coming up with lots of random ideas, you know, my brain to meet whatever fantasy the client might have. And the client is, like, the same, or another department in the same company, or, you know, like same designing piece that needs to fit into something larger, you know. And then, once the design is settled upon, you know, refining it, making it work, like coming up with unexpected difficulties, which I'm sure will come up. And then, cross my fingers, actually seeing it work and get into production. As a civil engineer, like that would involve being on the job site and consulting with the construction company, stuff like that. (Steve, SPRI, Year 2)

By junior year Steve had changed his expectation of his future engineering workplace to include drafting and busy work in much the same manner that both Erica and Colin also changed their descriptions of their future work as engineers. In other words, the image of engineering work each held had less and less to do with an image of pure design work as they progressed through their engineering majors.

> At first, probably, you know, some drafting, some busy work. Hopefully as time goes on, more designing and more decision-making, um, kind of overall planning stuff, because that's what I really like doing, the planning and problem-solving rather than the actual, you know, implementation. (Steve, SPRI, Year 3)

Whereas Erica and Colin had a gradual development of their perceptions of their future work, some students did not develop an adequate sense of an engineering workplace until much later, after they had a job offer. In contrast to the gradual development of more detailed understandings of the future engineering workplace that we observed in the previous three students, with Max we noticed an abrupt shift, which is apparent in the excerpts below from his freshman, junior and senior year interviews.

> I really don't know…Hmm-mm. Get up, go to work, come home I don't-, I have, I have no idea…I see myself working in the petroleum field. But that's about all I see. (Max, TPUB, Year 1).

> I hope a lot of it'll be in the field…Doing paper work, planning wells. (Max, TPUB, Year 3)

> Drilling and Completions, and he does the completions work the stimulations and stuff, and they needed an engineer to help do the drilling engineering and optimize the program, and then to help the VP do some of his engineering so he could do more of the manager stuff. And, that's gonna' be me, so I'm gonna' get to drill these wells, complete the wells, and bring 'em online. Which is like huge experience. And, it's exactly what I need. So, I'm so stoked. And, all my rigs'll be, it's a big program, they have seven rigs runnin' right now. (Max, TPUB, Year 4).

In his freshman year interview, his notion of work life as an engineer was incredibly vague. He knew he would have to get up and go to work, and that he wanted to work in the "petroleum field," but had trouble "seeing" anything beyond that. By junior year, Max talks about a potential location for his work "the field," and talks only briefly about what work he might be doing—"paper work" and "planning wells." There is no description of what designing a well might entail or what the paper work might be. In contrast, in his senior year, Max presented a distinct detailed understanding of what his future workplace would look like as a petroleum engineer. Max described the actual job he accepted and was going to be doing once he graduated, working as a petroleum engineer. What Max's excerpts suggest is that the engineering educational experience does not include progressive familiarization with future workplaces.

Within our data set we noticed that hopeful images are often augmented by mundane less high status images of engineering work and the engineering workplace over time. In the excerpts below we notice such a shift with Chris who, as a freshman, described how he would like to do research on new materials.

> Well, hopefully where-, if I get a job in the field that I want to get in, I'll, I'll be hopefully working on some sort of research team, in working for…materials, and basically well obviously that would be a lot of theoretical work, you know, a lot of math and stuff in there, but then also, you know, hopefully decent amount of lab work trying to create these new materials, and also a lot of testing and everything. (Chris, TPUB, Year 1).

Chris' use of hedging, "hopefully," indicates that the job he was describing was not a certainty in his eyes, and therefore represents an image of engineering work that is more hopeful. Furthermore, Chris expressed the possibility that what his work would look like would depend on the field in which he worked. Although he wanted to do research on new materials (his hopeful image), he had an awareness that there were other possibilities. Then, like Colin, we see someone who as a freshman had an idea of different rolls and responsibilities he might have, but who had a preference, namely that he would be working to "create…new materials" as Colin had hoped he would be designing components.

In his senior year we see that his expectations shifted to a more mundane view of work. There was no more talk of what he hoped to be doing in his senior year interview, but instead there is talk of what he expected to be doing. Again, Chris spoke about one's work being driven in part

by what he described as specific industries. Different industries demanded different contributions from engineers who worked within them. Another dominant image of the engineering workplace that we have observed in our data emerged in Chris' senior year interview–working for large engineering firms.

> Ah well, it kind of depends on the specific industry. Like probably if I was for example to go into Lockheed Martin, I'd end up as a junior engineer and probably end up working on ah, well problem solving for projects. Ah, maybe a little bit of design work but I think more of the design aspect will probably come later in my career. Just speaking realistically I mean I'd like to just go in and start just doing all these advanced material designs and everything but that's not how the world works…Oh like maybe say I'm working in space systems, having someone come up to me, hey we're building this tank. It's going to hold 3000 PSI or whatever and you, we need it to be made of one of these four materials. Figure out which one of these we should use and how thick the tank needs to be like. And do this with the minimal weight or whatever. I mean something fairly basic. We've done plenty of that but ah, just I envision relatively short term tasks and projects like that. (Chris, TPUB, Year 4).

In the quote from Chris' senior year interview we notice his shift from an image that was hopeful of the workplace to one that became more mundane. As mentioned above in our discussion of the quotes from Colin, there were agents who influenced the students' images of the engineering workplace.

In many cases these agents are relatives who work in engineering. Raymund, a student at Technical Public Institution, describes what he believes what he will do on a daily basis based upon what he knew his father did.

> I see my dad-, I mean my dad he's an engineer. He sits in his cubicle, at his computer all day, typing up code and doing stuff. I don't know I don't really want to be doing that but that's engineering for you. I mean, I really don't know what-, I mean it's, I haven't really thought about "Well, after school, what am I gonna be doing?" I think it's sit in a cubicle all day and I might be doing this, might be doing that, and I really don't know. And that, I guess, I guess that's gonna come with hopefully getting internships I mean if I get summer internships I get a good grasp of "Alright, that's what that person does, that's his title, that's what he does. Okay, that's what that person does." And I mean, everyone's got their different roles. What do I want to be? I don't know, maybe I want to be that or that. I don't know. I really don't know right now. (Raymund, TPUB, Year 1).

As we mentioned earlier, the image that he had constructed in part because of his understanding of what his father, an engineer, did at work, was one that was prevalent in the students' images of engineering work—working in a cubicle at a computer. As we have seen with other students, this is not an ideal work condition for Raymund, but he shrugged it off as if it was a condition that he believed was just the way engineering was, and something he'd have to accept.

Although Raymund seemingly had a concrete image of the conditions of his fathers work ("sits in his cubicle", "writes code"), Raymund mentioned that he believed he would have a better idea

after he completed a few internships, which indicated that he may have felt this image was a bit sketchy. When he was interviewed in his senior year, he had completed two different internships at two companies, but still had little idea of what he would be doing on a daily basis as a practicing engineer, even saying he had "no clue."

> I have no clue. Like I, it's hard to answer that because like we talk, we talk about engineering and engineers, like we, we use those terms a lot when we talk about the school, and what happens with the school, 'cause that's what this school's about. But, it's such a broad term. Umm, I know some people sit in front of the computer and program all day. I know other people who test hardware. And, they work in hardware. There's software, there's hardware, umm, I know that a lot of people, I mean, I guess there's, there's a design component of engineering where they're thinkin' about how components, what components to use; how they fit; where they go; what their purpose is, and given that purpose, how to spec the; and, how to design them. But on a day-to-day basis, I really don't know still. I mean, I'm trying to draw from my internships, [name of company 1] really wasn't an engineering internship. [name of company 2] I think a lot of the stuff was, kinda' trying to think of they, I look at [name of company 2] and it's very similar to machine design. But it was frustrating because I would try to apply, it was, Frito-Lay I guess the big project I had was the combination of machine design and fluids. Umm, dealing with pumps and pipes, and all that stuff. And, what I would, knowing what I know, at that point in time, it's figure out all the specs, and draw that out, and calculate how big that, that pump needs to be. How big the pipes need to be. What, what this is, what happens the blockage. How much pressure's in there? And it's, and I would try to do that, but I couldn't. I didn't have any specs on the pumps. Like I'd go down and try to figure out what pump that was. I don't know what pump it is. (Raymund, TPUB, Year 4).

Raymund's excerpt does, however demonstrate familiarity with some of the categories of work that he might be doing (e.g., testing, programming, designing components) but he does not seem to be able to construct an image of what he will be doing. He relies on his work at one of the internships to describe his future work. His internship at one company he described as not being engineering work, whereas in his other internship he tried to apply some of his engineering knowledge. Yet he was frustrated by not having the correct "specs" in order to apply his engineering skills. This excerpt reveals how despite having exposure to actual engineering workplaces, students may still leave a program without any understanding of he the actual engineering work that they will perform when they are employed as engineers.

We have shown in this section how students' images of their future engineering workplace changed over time, focusing upon how there is a shift between hopeful images to ones that more closely resemble what students will expect to find when they are working engineers. There were, however some students for whom these hopeful images were never replaced with more mundane less high status images. One such example is Adam, who despite having had many internships at which he worked both as a designer and a draftsperson, maintained an imagined hopeful sense of what engineers do over his four years of interviews with us. During his freshman year ethnographic interview Adam responded to the question, "what do you expect to do on a daily basis?" in this way,

> I've just like pictured myself like looking over like design sketches on this backlit, you know, white piece of paper. (Adam, LPUB, Year 1).

Note that by the time of Adam's year 1 interview he had already completed an internship where he did work drafting and designing for a skateboard company. In the Fall term of his senior year he obtained another internship with a local engineering firm where he essentially performed the role of draftsperson as described by Colin above. In the excerpt below Adam, during his senior year interview after he had completed the internship, described what he anticipated doing on a daily basis after graduation.

> Adam: Ahh, I go into work and I have a couple of meetings and stuff. And I take out my engineering drawings and I'm like okay, "I still need to change this and this and this and this on the drawings." … Ya, and it's on the lighted board. With the see-through paper. And you got the grids everywhere …
> Interviewer 2: Did any of that match up when you had your internship when you worked at?
> Adam: No. No, my internship was boring. (Adam, LPUB, Year 4).

The interviewer's follow-up to Adam's response highlights how despite having had actual workplace experience some students left an engineering program with no idea of what the actual workplace would be like for them. Adam's non-changing hopeful image of the engineering workplace suggests that in some cases such images are so powerful that regardless of what students are exposed to in a real workplace they do not transform into more mundane images. While this did not force Adam out of engineering, it did enable him to maintain hopeful sense of what engineering is.

In this section we have detailed images of engineering that changed and shifted over time: images of a good engineer and images of engineering work and the workplace. What we observed in images of engineering work is that over time these images shift from hopeful images to images that are more mundane. This was exemplified in how the designer image shifted among students from doing work that was new and innovative in early interviews to work that was making improvements to existing designs. We also observed how students may leave an engineering program with images of the engineering workplace where they may have no idea of what the kind work they will do on a daily basis despite having completed internships or co-ops. Such was the case of both Raymund and Adam.

Images from colleges of engineering at four universities

In this section we highlight the dominant images of engineering that were specific to each of the four schools in our study. Our findings illustrate how some images of the field of engineering were developed at a larger cultural level at these schools. In some cases these images were so dominant that students at a school forced themselves to do reconciling work in order to identify the aspects of their engineering identities that did not fit within these images. At Suburban Private University the dominant image of engineering fostered a culture of great expectations. Technical Public Institution students found themselves working in strong teams of engineering

students and developing a strong sense of ethics. Students at Urban Private University sought to develop a sense of engineering that fostered social good. At Large Public University students developed an image of engineering as superior to other disciplines and were exposed to a design process that involved creativity and the goals of efficiency and cost effectiveness.

We recognize that virtually all engineering programs want their students to develop high expectations, to be able to work in teams, develop a sense of ethnics, be devoted to social good, and to strive to promote creativity in the design process. However, what we are examining in this section are the dominant images of engineering that emerged from the semi-structured ethnographic interviews of students at each campus. That is, students perceived their schools to have these characteristics, and believed that their schools emphasized these areas more than other schools. In essence we are discussing the perceptions of students, rather than whether, for example, Technical Public Institution undergraduates actually have more classes that emphasize teamwork than other engineering schools.

Suburban Private University

At Suburban Private University students expressed the belief that the campus culture encouraged high achievement, entrepreneurship, and getting to the top. This culture, in turn can be viewed as impacting students' images of engineering. Students were encouraged to be creative and to have great expectations about their futures. Faculty members frequently talked about famous Suburban Private University engineering students who went on to become fabulously successful entrepreneurs, like founders of dot.com corporations who had changed the world with their innovations. Engineering students were encouraged to take entrepreneurial risks, strive for high achievement, and if possible to create and found their own companies. Thus for students at Suburban Private University, the image that engineers were entrepreneurs and risk-takers who would make millions of dollars and change the world with their innovations was prevalent, and in some cases empowering. For example, Rudy, co-founded an IT firm while still an undergraduate computer science student and became so busy with the business venture he dropped out of Suburban Private University his junior year. During the second year of operation the business had grown to 24 employees. Although not a college graduate, Rudy was confident that he already had the skills to help keep his complex business enterprise running, and the ability to direct co-workers with college degrees.

> I guess that also is because I'm confident that I can figure out how to fix it later, which helps. Um, I mean, I was just, um, my, was kind of, well, it's pretty complicated and involved, and, uh, I mean, I guess, uh, most junior dropouts might not have been able to do it. So, it helped to not feel like, "Oh, I can't do this," whatever, or I wouldn't have tried…Well, so for one reason or another, most junior dropouts can't do this or they would; right? So, I mean, either they can't do it because they can't convince themselves that, uh, it'll actually work out or because, uh, it's a risk that I'm willing to take, or, uh, whatever the reason, like, other people don't tend to do this. And I didn't really care, like, "Oh, I can make it work." Like, their reasons for not doing it must be different from-from mine. So. (Rudy, SPRI, Year 4)

Rudy discusses further how many of the people he has hired at his company do have engineering degrees.

> Uh, they're still there. Almost everyone we've hired …does have a degree. Um, if only those are the people that are looking for jobs most of the time. Uh, we certainly would not turn someone away that was really good because they didn't have a degree; that would be a stupid decision. Um, yeah, so far, it tends to be, uh, people with degrees. Most are fresh out of school because it's easy to find people from SPRI looking for jobs. But that's not, obviously, required either. There's a broad range of people. (Rudy, SPRI, Year 4)

During his fourth year interview, Randal talked about how he had entered Suburban Private University thinking that after graduation he was going to start a company, make a fortune, and then do philanthropy. By his fourth year he still had the entrepreneurial spirit, and was certain that he was soon going to start a consulting firm. Randall talks about his future as a long list of possibilities, and seemed to relish the opportunity to incorporate his entrepreneurship into work. This seems to be evidence of his buy-in to the image of engineer as entrepreneur.

> You iterate once, you see new opportunities, new problems, new solutions, etc. Every sin-, I, I'm, I guess I'm creating more prototype cycles for myself and not think five years-, but if I were to think five years, at this point, given all that probably involved in a start-up, at the time. Because I, I feel like I need something hands-on um I'm, I'm gonna be doing a consulting firm this summer but it, it acts like a start-up, actually, interestingly enough but. Um either to-, either doing that consulting because it's a really cool environment um, it, it's a lot of-, I feel like I'm able to do a lot of my entrepreneurial stuff in that environment, such as "Oh let's get a new client and work on this and prototype this." Like "Let's create a, let's get $100,000 grant to do this newsletter thing." Which isn't unheard of. I don't know how to get that but. It's like, and "We can use NT and do all this really cool stuff. Or hey, let's think of a, an arts-, let's create a art blog in which uh people post their works and say, 'Hey, would you like to rent this work?'" Um, and companies rent their work and put on their office space and you can actually shuffle it around. And um like it's somewhere I can have ideas and just implement them. (Randal, SPRI, Year 4)

Suburban Private University's culture of great expectations seemed to affect the goals of many engineering students, and over time to raise them. For instance, Emma during her freshman year felt that she didn't ever need to be the leader of the company she worked for. Rather, it was important for her to be in a position where she could help people.

> Um so-so, average. I don't see um, see myself as like top maybe like oh, CEO of Hewlett Packard or something like that but um. Just there working, I don't-, I feel like it's important to-, for me to like be a top notch person but it's not that important as long as I'm doing what I'm like, like doing what I enjoy doing like um, so like-, as long as I'm helping people somewhere, I'll get in, so, yeah. (Emma, SPRI, Year 1)

By her fourth year at Suburban Private University, Emma's expectations had been raised. She felt that in the future she wouldn't simply be an engineer working on construction projects, but rather the owner and moving force behind real estate developments. In the quote below the interviewer has asked Emma what she expects to be doing ten years from now.

> Um, ten years from now? Far. Um, probably still in the same general field, like something related to construction, but, um, but I probably won't be doing construction projects. Um, I might move to, um, a construction project, I guess what I mean is construction problems from a builder's perspective, like general contractors or something. I might move to the owner's side or to real estate developer, and then do something related but not actually on a construction project, like the development part. Um, yeah. (Emma, SPRI, Year 4).

So, Emma in her senior year, also seemed to express having an image of her future work evolving from "doing construction projects" to "being a real estate developer." She will be shifting her role from doing work for others, to leading and creating this kind of work for others, so like with Randal and Rudy, we see Emma's image of her future work buying into the engineer as entrepreneur or "mover and shaker" image so prevalent among Suburban Private University students.

In getting to the top, Suburban Private University engineering students were encouraged to have a world perspective, and many students talked about how their professors worked on engineering projects around the world, and they expected to do the same. They also discuss how it was important to be politically sophisticated and to master the subtleties of social relationships in engineering ventures. Here Emma discussed how, in one of her freshman engineering courses, the instructor discussed how politics play an important role in engineering.

> So, um, I think at least for him, you not only have to know engineering, but also how the politics works? To be like a good, to know what's going on and-, so he also taught us a lot of behind the scenes politics. Like how-, why um the drill tanks are um drilled in um Utah I think and then shipped over to Florida, versus just made there. It's because some senator was there and he was the one who supported it, that's why all the way across the country, so. (Emma, SPRI, Year 1).

What we have highlighted here are aspects of Suburban Private University's engineering culture that fostered a culture of great expectations where students were encouraged to be adventurous in exploring a variety of unfamiliar subjects in their undergraduate coursework, and to take risks in constructing their careers. This culture, in turn, shaped the dominant image of engineering on campus, that of the engineer as entrepreneur, risk-taker, captain of industry and world-shaping innovator.

Technical Public Institution

Because Technical Public Institution is a small school that focused upon the sciences and engineering, students who studied engineering at Technical Public Institution were exposed to a lot of engineering courses beginning in their freshman year. The work they did in these courses

and the emphasis that they saw placed on certain skills during their time at Technical Public Institution shaped the students' images of engineering and engineers. In particular, group work for students at Technical Public Institution was common from an early point in their undergraduate engineering curriculum. Consequently a common feature among TPUB students' images of engineers was that they could thrive in an environment in which group work was the norm. This also impacted their views about what their engineering work would look like as well in the same manner. Related to the image of engineers as good team workers, was the image of engineer as effective communicator, which was also a common at TPUB. Other common themes among the images TPUB students had of engineers and engineering also seemed to be related to curricular features of the engineering program at TPUB. Students took classes in ethics as engineering majors, and many TPUB students incorporated "being ethical" or "ethics" into their description of the traits a good engineer would possess.

In her first year interview Gabrielle discussed the social aspect of engineering that she felt was emphasized at Technical Public Institution in response to the question, "what do you think makes a good engineer?" For Gabrielle, working in groups and effectively communicating one's ideas to others were important parts of her early image of an engineer.

> Mmm, um I'd say working in groups would be a big one. And um being a people person, not only somebody who can crank out numbers, but also being able to talk and explain how you got this um and I think that would be a big key to it, uh what they would want. Cause I'm even trying to think about what the-, how like, who the professors are and what kind of people they are, and those are kinds of people I see as engineers and it's-, I think they want us to be like them. (Gabrielle, TPUB, Year 1)

Leslie in her third year interview discussed themes similar to Gabrielle, namely that engineers needed to be good communicators.

> Um, communicating very well. Communication's huge. Um, 'cause you can know what you wanna' do, but you, if you can't tell other people then forget it. Cooperating with people too, 'cause you're always gonna' be working in a team no matter what. There's no way you can't, very rarely do you work by yourself. (Leslie, TPUB, Year 3).

Like, Gabrielle, then we see that Leslie's image of an engineer incorporates skills, not coincidentally, that were points of curricular emphasis at Technical Public Institution. Leslie also mentions the ability to cooperate and work with others as an important skill as did both Gabrielle and Marilyn during their third year interviews.

> I can see a lot, a lot of teamwork in anything engineering. I mean, anything that I want to do basically. I guess, um, if I was gonna' be one of those people in ah, um, like just sitting at their desk you know, doing just their work, and nothing else. Then, I don't, I don't see a lot of teamwork. But, I'm sure you would have to have meetings. All those people would get together. They'd have to communicate and put in their input, I mean. So, I think teamwork's huge, and I didn't think it was a big thing at all. Like, freshman year I thought teamwork was so stupid, and why do teachers put us in teams and you

> know. But, it does, it does help you a lot…I think I'm a lot better. A lot better. (Gabrielle, TPUB, Year 3).

> Well most of them really are like, to be a good engineer you have to be uhmm like, they always stress the group work at Technical Public Institution a lot which is like totally different from here. We don't do a lot of group work here. But, at Technical Public Institution, like "Yeah, we stress group work, and being able to work in teams." (Marilyn, TPUB, Year 3)

While ethics is an important aspect of any engineering curriculum, we found that when we asked Technical Public Institution students what it takes to be a good engineer more often than not they referred to ethics in their responses, and the number of research participants at Technical Public Institution who stressed ethics was much higher than the three other campuses. Christina discussed how some classes outside of engineering, such as Nature and Human Values (NHV), also stressed ethics, and she came to believe that a good engineer is a well-rounded, "good person."

> Um I guess, I don't know. Um, I think there's more to being good engineer than just knowing how to problem solve. I think um, you know, like in NHV they stress the ethics I never really thought of that. But I thought everybody had ethics. But apparently I was wrong. So, ah, you know, um, I don't know, just That-I mean like the problem solving that's just from my engineering classes. Ah, from the language arts classes you know they kind of stress you know the ethics. And being a well-rounded person I mean, to be a good engineer I think you would also have to be a good person. (Christina, TPUB, Year 2).

Christina discussed this further when she described the role that engineers played in constructing and designing things to which the general public was exposed. As such she believes that engineering involves a sense of compassion and an understanding of the needs of the public at large.

> I mean, like engineers are going to be doing things for people, for the general public. And, um if all you can think about is how to solve the problems, just solving it period, and not taking into consideration, you know, people's welfare, people's health, and um stuff like that, there's no point. You're not a good engineer if you can't think of the people you're doing this for So, I think you would have to be a good person, You would have to be kind of a little bit compassionate, Towards, you know, the human race…like when they were king about in NHV, They talked about the atomic bomb, I know that's such a-a used scenario. But it's so true, I mean, like, you don't want to be making these things that, you know, have the potential to harm people (Christina, TPUB, Year 2).

Max in his first year interview with us discussed how ethics and scientific ethics are stressed in a series of courses that they are required to take as engineers. He notes that there is a commonsense aspect to ethics and engineering that if you are a bad person, you are going to be a bad engineer.

> Not really, I mean, they pretty much teach you what you need to know I guess, I don't know, NHV they put so much into engineering ethics and scientific ethics and stuff that it seems like it's commonsense too like if you're a bad person, you're gonna be a bad engineer no matter what. If you're a good person, you're gonna be a good engineer, (Max, TPUB, Year 1)

What Christina stressed earlier about taking the interest of the general public into account in engineering is emphasized here again by Gabrielle who reiterates that engineering design should not be motivated by money.

> Having ethics is probably a big part of it. Having to understand that you can't build a bridge there just because you're going to earn a lot of money, you know. What if it's not safe or something. I mean, definitely have to think about that. Uh. And then understanding what you're building, you know? I mean, like, some construction workers can just double up houses, they just know to put three beams here instead of one there. And I'd rather be like, well why use that? You know, look around. Like I was looking at the ceiling, this [inaudible] ceiling, and it's pretty cool though. (Gabrielle, TPUB, Year 2).

Technical Public Institution students are exposed to a culture of engineering that stresses the importance of communication skills, working in groups, and ethics. One of the reasons that these images are dominant at Technical Public Institution was through the emphasis by the TPUB curriculum on these elements in a series of core engineering courses in general engineering that all students were required to take in their first few years. As such many of the quotes in which students discussed these images at Technical Public Institution also referred to these courses. In a sense these courses are a form of enculturation into the engineering norms and mores at Technical Public Institution.

Urban Private University

Nearly the entire interview sample of Urban Private University engineering students talked about their involvement in engineering organizations that served the community. For instance, Louise, an extremely busy third year EE student at Urban Private University, talked about her involvement in four engineering organizations, and the role of engineers helping the community. She also discussed the possibility of returning to Urban Private University in the future and donating her time to teaching, in an effort to help upgrade the level of teaching at the university.

> So I'm active with Tau Beta Phi, Society of engineers I was president. NSBE I was programs chair, so I had to plan programs so members there's just a lot going on between activities and school…Well, that's more than I'm probably more but I can't do more than four. I can't go to that many meetings a week…Um, I'm part of Society of Women Engineers. I'm president of that's an organization that tries to help women come into engineering and encourage them to stay in engineering. It provides a network for professional women. But then at Urban Private University we have so few women and um, the chapter was almost nonexistent last year so it was really hard this year to try people to join so we had to work like doubly hard. To get people to join, like, whole

bunch of things. Even so cuz we're so small people didn't really notice us cuz it was so tiny…The other thing I did this year is I started a program for the middle school kids over there. At the Urban Private University middle school. We have, we left enough money to have enough of them. We had like 25 of them but this year November they are gonna try to expand it. It was in November and they go exposure to computer networking and like before the, it was funny because we they paid attention and answer questions and we would give them gifts. Like, game and stuff It was [good] cuz they all answered questions…But it was really good cuz they really learned a lot from it that's something that we did. (Louise, UPRI, Year 3).

Louise's discussion highlights the importance that Urban Private University students applied to community involvement. This sense of engineering for the social good is present throughout the Urban Private University data and as we will see in the excerpts below, many students anticipated using their engineering degrees to serve the community. Amadi discussed how she would like to develop a company that would hire other engineers to get women involved in engineering and employ chemical engineers in different working environments. Notice that the interviewer has asked Amadi to describe what it takes to be a good chemical engineer and Amadi's response focuses upon community involvement, not the actual practices of a chemical engineer.

Amadi: Planning and organizing events and scheduling, just getting people--like I would like to employ other engineers, so just getting people employment different places, um looking into how a chemical engineer can be used in some odd work areas, some new arenas, getting women and black women particularly, engineering women into fields that's underrepresented. Um, getting children involved in engineering. Just doing a lot for the community regularly, every day.
Interview 1: *OK. What would say it takes to be a good chemical--the next step.*
Amadi: Oh. After my degree?
Interviewer 1: *Yah.*
Amadi: Uhhh. I would do a lot of community involvement and use my--the power of my degree to get more people to where I am. I think it just takes, um, teamwork, like I don't want to do it alone, (Amadi, Year 3, UPRI)

In a similar fashion to how Amadi described being a good chemical engineer involved community involvement, Shermont also discusses how being a good engineer involved reaching outward from the field of engineering to help other people in the community.

When growing up I never had the opportunity for anyone to teaching me or encourage me and like [inaudible], you know what I mean? Being a good engineer isn't just about being this smart, rocket scientist. It's about like, helping other people. That's definitely-that's one of my biggest goals and post graduation like, really get involved, like. I'm suppose to start Big Brother, Big Sister, ah, next semester. Well, I turned in my application to the Boys and Girls club since, like, beginning of this semester. (Shermont, UPRI, Year 3).

Urban Private University exposed students to a number of ways in which they could serve the community, through various organizations on campus and other opportunities. Students participated in groups where community service is important and also groups that serve specific interests in the engineering community. The sense of the need for engineers to perform service to the community seemed more powerful than at the other three campuses in comparison.

Large Public University

At Large Public University the dominant images of engineering include an exaggerated sense of superiority compared to other majors and efficiency and creativity in the design process. At Large Public University the application process in order to get into an engineering major creates a competitive atmosphere that has the effect of developing a sense of superiority of engineering in relation to other majors and disciplines. Faculty members at Large Public University promote this attitude, as the narrative by Colin below suggests. The people up North are what engineers at Large Public University refer to the liberal arts and business majors who are located in the North campus.

> And in my engineering classes always make fun of the business school. … Like one example was, ah, in one of my classes we had to design an adder so you put in your number and another number and it would add them together. So (sigh) we designed it and everything. And then he's like, well now maybe the business school or the people up North want a subtracter instead. So you would, you would tell them is that it would take you 6 weeks to design it. Although all you have to do is like, switch one little thing. And then they want like, an adder and subtracter together. And every time, we had this long story about how it took you 6 weeks to do it although it only takes you 10 minutes and by the end of it we got a trip to Hawaii. (Colin, LPUB, Year 3).

The narrative above illustrates how the engineering faculty at Large Public University fosters an image where engineers are superior in ways to other professions. Other majors or disciplines were not as clever as engineers, or perhaps the engineers' work was so revered by others who expected it to be terribly difficult, and as a result these others could be duped into paying an engineer more money for a little work. Here we noted that Large Public University students discussed their coursework as being more intense than their non-engineering fellow students, which seemed to foster this notion of engineer as superior to others. The two excerpts below illustrate how Large Public University engineering students compared themselves to students in other majors through the intensity of their work and their perception that they think differently than others.

> It seems like engineering students always have more intense homework. It seems like they're always [in] labs. Um, and don't have as much free time. Like, I see my sorority sister who's in engineering and she, she always has labs and tests that are really important, um, and I think that's more with some of the science majors, but as far as the liberal arts majors it's like, it's really different. (Bryn, LPUB, Year 4).

> Um, I know when I think about things I always think about steps in order to get there. I'm a very visual person. I learn things very visually. And I think I noticed my

> engineering friends being the same way. Sometimes, like, if were explaining stuff to, um, let's say a [inaudible] major it's difficult to kinda understand peoples' thought processes… I'm just thinking like, maybe rules to a game or something. Like, my buddy, one might be at the house, a [inaudible] major he always hangs out with us engineers. He could tell the different mindsets. I think engineers think in the same way. At least once they make it through the senior year. (Simon, LPUB, Year 4).

Such examples where Large Public University students created comparisons to the work of students in other majors created a narrative that intensifies the difference between the disciplines. As we observed above with Colin's quote, sometimes such narratives of engineering dominance are constructed in the classroom.

For students at Large Public University a dominant image seems to be efficiency and creativity in the design process. Compared to other schools in our data set where students talk about design, they usually talk about how they aspire to be a designer. Whereas, at Large Public University the students may aspire to be a designer, but they also talk about design as a process.

Renee's coursework has also instilled in her a belief that engineers must be able to define problems and come up with solutions that are "practical." In addition to coming up with practical solutions Renee also discussed how engineering work involved a design process, which she explained was stressed in an introductory engineering class.

> Probably um that you can define problem well and come up with good practical solutions, and hopefully more than one practical solution, where you can list the pros and cons of each one, and then look at which one, because of it's pro and cons, would be best to actually go and apply. Um, and that's pretty much true in general. I think the eng-, it's hard because the engineering school is so diverse. Because it covers so many aspects of science but I think that's kind of the general theme in every single one of em is that you have to define the problem, and you have to come up with solutions. And then there's, you have to have a design process. That, we went over that in Engineering 100, there, this is the method for the design process, and it's kind of this back and forth thing where you improve as you go along, and just kind of being very systematic about it, um. There's a big emphasis on that. (Renee, LPUB, Year1).

The big emphasis that Renee mentioned indicated that the curriculum of one introductory engineering course has influenced her view of what engineering work will look like.

In addition to students' images of engineering and engineers being influenced by the curriculum, students at Large Public University were often heavily influenced by their instructors. In the quote below Erica is discussing interaction from one of her classes and how engineers have to take efficiency into account in thinking about their designs.

> Um, in my chemical engineering class this quarter, my teacher always asks us like, "What do you want in your refrigerator?" What do-, not like 'what do you want to eat' [laughter] but you know what I mean. Um, and so he like always said, like when somebody says "cost efficient" and all that kind of stuff, he's like, "Oh future engineer!"

> so, I think you have to, um, be able to think like an engineer and kind of take in more than just like, "Will it work?" but like you know, "How's it gonna affect people? How, you know, can you afford it? Can you mass-produce it? Can you," all that kind of stuff. So I think you have to have like I guess the common sense, well that's not necessarily common, but you have to have kind of a sense of, of all different things that go into, into each process, as well as like just an understanding of what's going on. (Erica, LPUB, Year 2).

Erica also acknowledged that this kind of thinking was an important part of being a good engineer, and thus possessing a special type of thinking was a feature of her image of engineering, as it was, we found, for many engineering students at Large Public University. Erica marked this kind of thinking as special through her use of the phrase, "well, that's not necessarily common" when referring to the kind of thinking an engineer would need to be able to do. Of course, Erica would probably say that this is common sense among engineers, who were expected, in her image to be striving to make things more efficient. Below Colin expands upon this image of engineer as improver of efficiency by noting that creativity is equally important to being a good engineer.

> Um, probably to be creative and then have a strong set of fundamentals that I was talking about earlier... Um, well like, well every problem, usually, I think, I mean the physics [inaudible] probably has more than one solution to it, so like the creative thought, the more like you can see different ways to fix things, you know… And then that'll help you find the most efficient or cost effective one [mumbles]….Uh, like, um, strong in math and science and, like if you need to fix a bridge, you have to know like about the stresses on the bridge and probably like calculations for it and everything (Colin, LPUB, Year1).

While Colin notes that an engineer needed to have good fundamentals, in this case physics, he also suggested that engineers needed to have a sense of creativity and efficiency. This image of an engineer as being creative was picked up by other students at Large Public University. In the quote below Johnny was discussing how engineers needed to have strong creativity and think "outside of the box."

> …a hard-working person's always better than like a not hard-working person. And um, maybe into-, like creat-, creative and like have like a creative side, and think outside of the box. And um, just have a good personality, to be able to work with like other people I think that's it." (Johnny, LPUB, Year 2).

Both Colin's and Johnny's references to creativity are good examples of how design at LPUB is presented in such a way that it is considered a process.

At Large Public University students became exposed to an image of engineering that created a sense of engineers as superior in relation to other majors and also an image of engineering work that focuses upon creativity and efficiency in design. Where students at other schools in our data set discussed their aspirations to be a designer, engineering students at Large Public University discussed design as not only something they aspired to do but they also discussed it as a process, a process where the goal was efficiency in making design decisions.

Reconciling Work

In some cases images of engineering either at a school or of an occupation are so dominant that some students have difficulty in terms of how they perceive themselves within such images. As a result of this conflict students perform what we refer to as *reconciling work.* Reconciling work refers to how students who were not able to meet either the dominant image of engineering at a school, or what they perceived to be the dominant image of a field of engineering, augmented aspects of their identity through narrative in order to fit within a dominant image. Here we focus upon a few cases where students performed such reconciling work in order to fit in with images of engineering.

One such case of a student performing reconciling work was Adam who had expectations of engineering being all mathematics. We noted in the previous section that at Large Public University a dominant image of engineering that emerges has to do with design creativity and efficiency in the design process. We consider the quote below from Adam's year 4 interview as an instance of reconciling work.

> We're gonna challenge you and give you this and [your gonna] design something. And so I've gotten more. I've taken like, math in a different direction. I like designing things and I like math. But they've been kind of separate. And now it's kind of like, I'm gonna take this math, well this engineering and take math stuff and push it into design. So it's gonna be both. And that's kind of, it's been interesting. (Adam, LPUB, Year 4).

For Adam, the image of engineering that drew him to the field of engineering, that it was all mathematics, conflicted in part with the design that he was learning in school and enjoyed. This and presented him with two images of what an engineer would do that were incompatible. He thought that engineering would entail more math, and was disappointed to find it did not, so he found a way to incorporate mathematics into the design work that was such a prevalent part of the engineering work image emphasized in his work at Large Public University. The reconciling work that he did involved him placing more mathematics in his own design process so that his anticipated image of engineering (having a lot of math) would fit with a dominant image at Large Public University – creativity in the design process.

For some students different fields of engineering created their own cultures. For example, when we asked students to describe themselves in relation to other engineering students often they responded by saying that they were fine with students in their particular major, but other types of engineering students were very different than they are. In terms of the latter, some students, such as Joe, found that they did not fit in with the way in which engineering was approached within a certain field. Joe was a direct admit to Large Public University in electrical engineering (meaning he was in EE as an entering freshman, which was a rarity on campus). However, he found that as he took classes within the EE major he found himself disappointed at the lack of "theory" in these classes. These class experiences projected an image of electrical engineers as mired in details whose only concern was with something working, and not with how something worked. Joe's image of engineer was someone for whom how something worked was crucially important.

Joe switched his major to computer science and engineering because it allowed him to work with more theory. In Joe's year four interview we asked him to hypothetically counsel a student who is more interested in computer theory as to which major to pursue.

> it seems to me that EE is more the details and CSE is more of a theory, which are you more interested in it?' I would ask him that. See what they say. I mean a lot of this stuff seems to be cultural like, you feel, I fit in with this culture more than this one, and that's what you choose and to me that's how I made my decision. (Joe, LPUB, Year 4).

While Joe did switch majors, the one thing that stands out about the quote above is Joe's reference to culture, and that he fit in more with the culture of one field of engineering than he did the other. For Joe the part of the culture that he did not fit in with in electrical engineering was the detail-oriented process. That is, his image of engineering as a science did not fit with what was going on in his electrical engineering coursework. Instead he found his niche in the theory-driven computer science. Joe's senior year interview quote reveals reconciliation work in the sense that he was then referring to the differences and difficulty he had with electrical engineering as cultural differences.

In contrast to Joe at Large Public University, Louise at Urban Private University favored the field of EE over computer science because she felt that a career in computer science would condemn her to sitting in front of a computer writing code all day. Early in her undergraduate career Louise found programming fun, but a summer internship convinced her that she would not be satisfied with a career in the field of computer science. Although by the end of her second year Louise was still not completely certain about completing a major in EE, she was positive that she would not major in computer science. One of the reasons that Louise did not perceive herself as a computer scientist was an image she had of someone sitting behind a computer writing code all day. In the excerpt below Louise is responding to the interviewer's question about the difference between electrical engineering and computer science.

> My original interest is in computer s-, uh, electrical engineering. But as, I took programming and it was really easy, like it was so much fun. I was like, "Ah, maybe I can do both."So I applied to that and since I was an underclassman,cause it was for underclassmen, I got into it so I just wanted to see how it was. And since I didn't really like it that much…but I'm gonna do more of electrical engineering this summer. And then I'll compare and know for sure and,but right now I'm thinking more of electrical engineers. … I just, I don't think I'm passionate about it enough to do it all my life, sit in front of a computer all day,*every* day, writing code. [laughs] I don't think so. And I think, um, because [name of company] is just all computers, you can't leave very-, like even if you changed your group, you'll still be sitting in front of a computer doing pretty much the same thing. Like if you, if you worked at a company that had more diverse job descriptions, yeah, I think that's the word, yeah, you, you pretty-, you can be an IT, you can be programming, or you can be in the field or som-yeah, you know, that kind of thing. That's why Microsoft's not the place for me (Lousie, Howard, Year 2)

One of the dominant images at Suburban Private University was that of students (and by association engineers) who would meet great expectations. Darrell, for example, was an

ambitious mechanical engineering student who had designed laser light shows for well-known rock groups while still a high school student, and wanted to direct one of the major light design companies in the United States after graduation. He had to reconcile his ambitions with the fact that he had not taken advance placement classes as a high school student, was working extremely hard in his introductory math and science classes at Suburban Private University, felt that these classes, especially physics, were poorly organized and taught, and was anxious about failing. In his second year interview below he discussed his lack of preparation and fear of flunking the first course in the physics sequence.

> But I guess course # X just really hit hard because everyone else was more prepared than I was. And there were a couple other students in my same situation, too, and I, we had all talked about it and really thought that we were working really, really hard and it was just very tough because the means were quite high and we feel that a lot of that was because they'd had a lot more prior preparation. And I guess it added on to stress, because myself and others included who hadn't had the previous experience kind of really felt the pressure of, "What if we fail this course?" Like, we're working so hard that there's no reason why we should fail, but when everything's added up, we're just one, or we're just a number in a class of 400. It's like how, you know, we had no idea how many people, if anyone, ever fails the physics classes, but we definitely felt it should not be us, by the measure of work we were doing. We were…but there was still that kind of underlying uncertainty, because you never know how a class is going to be curved. There's really no other indication, other than, like, how you're doing representative to everyone else in the class. Other than that, there's no indication of if you're at risk or anything. And I think it just added undue stress. It's like we were working really, really hard; I think we shouldn't have had to worry about that but we did. And I also don't think the classes in general, I mean, there's a lot of stigma against the physics sequence here. People, if they can, will take it elsewhere. Engineers will often take physics over the summer and then take the summer class sequence if they have a community college near their house that offers it, just so that they won't have to take it here. (Darrell, SPRI, Year 2)

Darrell did take some of his required introductory physics classes at a much less prestigious state college where he felt the teaching was better than at Suburban Private University. By the fourth year of his undergraduate studies at Suburban Private University, Darrell had already worked on a laser research project for two years at a major defense laboratory, and believed that he was on a career track that would eventually land him a job as a director of a major lighting design company.

At Technical Public Institution Gabrielle believed that she had been exposed to numerous opportunities to do engineering work in teams, but felt she dominated her classmates, and took the initiative too much when working in teams, rather than being a collegial team member. She worked at not being so dominant, but when she attended a regional women's engineering conference Gabrielle found that she was not the only one who liked to take the initiative in team projects. Below Gabrielle is responding to the interviewer's inquiry as to how she is at working in teams.

> I think I'm a lot better. A lot better. But, I'm still the person who kinda' takes charge, you

know. Um, and I'm not sure if it's, if I'm like that at this school because so many people are just so shy and they don't wanna' start speaking out. Because, you know, I went to a SWE conference, the regional conference in, over in Kansas a few weeks ago. And, it was all engineers of course, and it was cool because all of us girls were, we were fun, and, and people would just start taking initiative right away. And, I was so surprised 'cause that usually doesn't happen. Um, but I don't know. It's - teamwork is just everywhere. And, I think I have grown a lot. (Gabrielle, TPUB, Year 3)

Gabrielle's reference to how she has "…grown a lot," identifies how she had to adjust and perform reconciliation work in order fit within a dominant image of engineering at Technical Public Institution – that engineering is teamwork. The image that conflicted with this dominant image, that she was too dominant, conflicted with the image of engineer as good teammate. Perhaps one reading of her story is that at the conference she began to see that "taking charge" aspect of her performance in teams as a making her a stronger teammate, after being around many people who had that attitude. She had come to see assertiveness and teamwork as compatible rather than disparate.

Conclusion

We have discussed how students' constructed images of engineering change over time from images that are hopeful and romantic to images that are more mundane and more realistic. While we do not know the direct relevance of this shift, we think one of reasons is that over time students receive more direct exposure to imagery and experiences in their specific fields of engineering through coursework and internships. At the same time we also discussed a few cases where romantic expectations of an engineering workplace were maintained throughout the entire four years of students' undergraduate educations and cases where an image of the workplace was not developed until students already had a job. These instances suggest that some students do not get exposed to actual engineering workplace scenarios during their undergraduate education. We have also drawn attention to dominant images of engineering at specific schools in our study suggesting that such images are developed at a larger cultural level within the College's of Engineering at these schools. These images are so dominant that in some cases they force students to perform what we called reconciling work so that their identities can be seen to reflect, or at least refract, these dominant images. We suggest that these dominant images can both help and in some cases hinder the identity development of undergraduate engineering students. They help in the sense that they offer students something to aspire to be and hinder to the degree that they force students to consider how their own identity matches the dominant images of engineering that they are exposed to.

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