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Women's Experiences in the Transition from Capstone Design Courses to Engineering Workplaces

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Susannah Howe, Ph.D. is the Design Clinic Director in the Picker Engineering Program at Smith College, where she coordinates and teaches the capstone engineering design course. Her current research focuses on innovations in engineering design education, particularly at the capstone level. She is invested in building the capstone design community; she is a leader in the biannual Capstone Design Conferences and the Capstone Design Hub initiative. She is also involved with efforts to foster design learning in middle school students and to support entrepreneurship at primarily undergraduate institutions. Her background is in civil engineering with a focus on structural materials. She holds a B.S.E. degree from Princeton, and M.Eng. and Ph.D. degrees from Cornell.

Prof. Robin Ott, Virginia Tech

In 1995 Robin received a Bachelor's degree in Mechanical Engineering at Virginia Tech and has since gained 20 years industry experience. Early job experience included working as a design engineer for a Naval Sea Systems Command contractor where she designed a Countermeasure Washdown System for the MHC-51 Coastal Minehunter ships. She also spent time as an Application Engineer at Parametric Technology Corporation, the creators of 3D CAD software PRO-Engineer. In 1999 she joined Kollmorgen, a motion control company based in Radford, where she held multiple roles of increasing responsibility during her nine years there. While at Kollmorgen Robin worked with Shingijutsu Global Consulting experts from Japan and earned black belts in the DBS kaizen areas of Standard Work and 5S and traveled globally to qualify suppliers in Asia and Europe. Most recently Robin worked as Senior Director of Project Management for a small bio-tech company, Intrexon, located in the VT Corporate Research Center and had the opportunity to introduce manufacturing principles into a highly specialized DNA production facility. Since joining the faculty at her Alma Mater in 2015, Robin has been coordinating and teaching the Capstone Senior Design program in Mechanical Engineering while pursuing graduate work in Engineering Education.

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Marie C. Paretti is a Professor of Engineering Education at Virginia Tech, where she directs the Virginia Tech Engineering Communications Center (VTECC). Her research focuses on communication in engineering design, interdisciplinary communication and collaboration, design education, and gender in engineering. She was awarded a CAREER grant from the National Science Foundation to study expert teaching in capstone design courses, and is co-PI on numerous NSF grants exploring communication, design, and identity in engineering. Drawing on theories of situated learning and identity development, her work includes studies on the teaching and learning of communication, effective teaching practices in design education, the effects of differing design pedagogies on retention and motivation, the dynamics of cross-disciplinary collaboration in both academic and industry design environments, and gender and identity in engineering.

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A Narrative Analysis of Women's Experiences Transitioning from Capstone Design to Industry

Abstract

Substantial research over the past few decades has documented the challenges women experience both as students in engineering programs and as professionals in engineering workplaces. Few studies, however, have followed women from one context to the other to explore the ways in which school experiences, and particularly capstone experiences designed to facilitate this transition, do and do not prepare women for their work as practicing engineers. To address this gap, we draw on data from a larger multi-institution study to address the question, "How do women experience the transition from engineering school to engineering work?"

Participants for this study are drawn from a larger study across four universities (three mechanical engineering programs and one engineering science program). All participants identified as "female" on a screening questionnaire that included options for transgender and gender-nonconforming, as well as an option to skip the question. The full data set includes interviews with the participants conducted at the end of their capstone design course, responses to open-ended questions sent each week during their first 12 weeks of work, and interviews conducted after three, six, and 12 months of work.

To answer the research question, we used purposeful sampling to identify four women whose interviews represented different trajectories across this school-to-work transition; we then used constructed narrative analysis to present their individual stories and identify salient points of similarity and difference for discussion. We also present implications for engineering educators, including that life-long learning should be expected, communication and collaboration are as essential workplace skills as technical competencies, and that gender is not necessarily a homogenizing force. Above all, we emphasize the power of the individual voice in better understanding the experiences of our students.

Introduction and Background

Concerns about women's experiences in both engineering classrooms and engineering workplaces have been prominent in the literature in recent decades, particularly because the proportion of women entering and persisting in the field plateaued in the 1990s at approximately 20%, well below women's representation in the population at large [1]. At the undergraduate level, research has shown that female students often report lower levels of self-efficacy than male students despite equal levels of competency, that female students can experience stereotype threat, and that, despite some cultural shifts, micro-aggressions and gender biases persist from both faculty and male students [e.g., 2, 3-7]. Landmark studies such as Seymour and Hewitt [8] and Tonso [9] brought such challenges to light more than two decades ago, and recent work by [4, 10-12] suggests that all too little has changed in the intervening years. Such challenges also carry over in the workplace, where studies have shown that women may often struggle to be seen as "real engineers," particularly if they excel in management or professional skills [13-15] and they continue to experience embedded cultural biases as well as overt discrimination, particularly when we consider the intersection of gender with other dimensions of identity such as race or class [16, 17].

Yet research also shows that such impacts are not uniform; generalizations about women's experiences of engineering may erase the voices of individual women as they move through school and into professional careers, and trends may not manifest equally in every context. For example, work by Jones et al. in 2010 showed that for first-year engineering students at one large state university, women actually reported higher perceived ability than men, and in a study by Winters [19], men were equally or more likely than women to make career decisions based on family concerns. Studies that provide patterns across women's experiences remain valuable because they allow us to look at barriers and challenges at a system-level. However, they may also perpetuate a deficit model that reinforces perceptions and beliefs about how women engage in engineering work and pursue engineering careers. As a number of recent studies make clear [16, 17, 20], studies with small numbers often allow us to gain deeper and richer insights into the experiences of individuals that can also illuminate larger structures. In a recent narrative analysis of one female student's experiences, for example, Secules et al. [17] explore the ways in which both systemic bias and individual agency interact in dynamic ways to shape the student's experiences of her engineering program.

In this paper, we take up the challenge of exploring individual experiences in greater depth through narrative analysis of four women's experiences transitioning from engineering school to engineering work. In doing so, we also fill a critical gap between studies that explore women's experiences in school and studies that explore their experiences at work. Our longitudinal data captures our participants' experiences at key points across the transition: 1) immediately prior to graduation, 2) after three months of work, 3) after six months of work, and 4) after one year of work. This transitional data allows us to trace our participants' perceptions of themselves as engineers and their evolving understanding of engineering work as they move from student to professional and address the question, "How do women experience the transition from engineering school to engineering work?"

Methodology

Data for this paper are drawn from a large multi-institutional study of students' transitions from their capstone (senior) design experiences into engineering work [21-24]. The sections below describe the sites, participants, data collection, and data analysis.

Site Descriptions

The research study involves four different universities: two large public comprehensive universities (one in the mountain west and one in the mid-Atlantic), one small public technical university in the southeast, and one small private college in the northeast. Three have a year-long capstone design program and one has a four-semester design sequence that spans the junior and senior years. All focus heavily on industry-sponsored projects; three also include faculty-sponsored and national-competition projects. All emphasize professional workplace practices, and teams typically have individual industry and/or faculty mentors in addition to the course coordinator. Full site details are available in [21].

Participants

Data for this paper draw on the first cohort of participants in the overall study. In the spring of 2017, we interviewed 62 graduating seniors (29 women and 33 men) from four different universities and invited them to participate in a year-long data collection process that included twice-weekly surveys for 12 weeks as well as interviews at three, six, and 12 months of work. Of the original 29 women, 22 completed the three-month interview, 20 completed the six-month interview, and 15 completed the 12-month interview. (A second cohort was recruited from the May 2018 graduating class, with data collection still in process).

Data Collection

As noted above, the full data set for each participant includes four interviews as well as 12 weeks of survey data. In this study we focus on the four interviews, which capture participants' experiences from just prior to graduation through their first year of work. Note that the time periods for the workplace interviews are nominal; we contacted participants at these specified time intervals, but given the work, travel, and personal schedules of participants, the interviews themselves may occurred at various time points after the initial request.

The semi-structured interview protocols probed participants' experiences in their engineering environment (school or work), including their responsibilities, challenges and accomplishments, definitions of engineering, and perceptions of themselves as engineers. The interviews prior to graduation were conducted by five different researchers (given that all institutions concluded their semesters at approximately the same time), while all subsequent data collection was managed by three researchers (co-author Gewirtz as well as two additional members of the research team, Alvarez and Arunkumar). The initial interview used a common protocol for all participants. All subsequent interviews used a common base protocol, but then tailored prompts to follow up on previous data collection; for example, the three-month interviews explored experiences reported in the weekly surveys, the six-month interviews followed up on comments from the three-month interviews, and so forth. This approach allowed us to maintain a general set of questions across participants for comparative analysis, while also exploring individual experiences in depth. It also allowed the interviewers to build a rapport with participants over time; in most cases, the same researcher collected all of the workplace data (surveys and interviews) from a given participant; however, during the period when many of the three-month interviews were occurring, Arunkumar completed his graduate degree and was replaced by Alvarez. This rapport was particularly important because all three interviewers identify as male, and we were particularly sensitive to rebuilding rapport during the shift from Arunkumar to Alvarez. The interviews did not explicitly probe for experiences related to gender; at the same time, the transcripts indicate that participants were able to discuss a wide range of experiences, feelings, and personal vulnerabilities or insecurities, and gender issues emerged in some (but not all) cases.

All interviews were transcribed verbatim and cleaned to remove identifying data.

Participant Selection

To select participants for this analysis, we reviewed all the interview files for the women participants who had completed at least the 3-month interview, looking specifically at three main

items: (1) perceived preparedness, (2) extent of engineering identity, and (3) mention of gender issues. The first two items were included as direct questions in the interview protocol. In each interview, after being asked to describe their current job responsibilities, participants were asked to rate how prepared they felt for these responsibilities, and follow-up questions were used to explore these ratings. In addition, each interview asked participants to "describe what it means to be an engineer and what engineers do" based on their experiences, and then asked, "To what extent do you see yourself as an engineer at this time?" with follow-up prompts to explore the answer in depth.

To reduce bias, we reviewed the transcript set for each participant in rotating pairs, such that each participant's file was read by two researchers but the researcher pair differed for every file. For every interview (3, 6, and 12 months) for each participant, we mapped the participant's perceived level of preparedness, ranging from "not at all prepared" to "very prepared". We also interpreted the participant's engineering identity, using a "weak", "average", and "strong" scale. And we noted whether the participant mentioned that they had experienced gender bias or discrimination ("yes") or not ("no") (although no interview question directly probed gender-based experiences).

Figure 1 shows a visual representation of the trajectories of all 22 participants with respect to perceived preparedness, engineering identity, and gendered experiences:

- Time is on the y-axis; early work experiences are at the top, moving down through six months to one year at the bottom of the figure.
- The x-axis depicts perceived preparedness, with lower perceived preparedness to the left and higher perceived preparedness to the right. (Note that while we also have perceived preparedness data from participants' pre-graduation interviews and their weekly surveys, we used only the workplace interview data to select participants for this paper; subsequent larger studies will use the full data set.)
- The size of the circle reflects extent of engineering identity; the larger the circle, the more the participant identified as an engineer.
- The shading represents mention of gender bias/discrimination (shaded = yes, unshaded = no).

As is clear from Figure 1, there is no single women's experience in the transition into work; each participant follows her own unique journey, informed by many different factors and experiences.

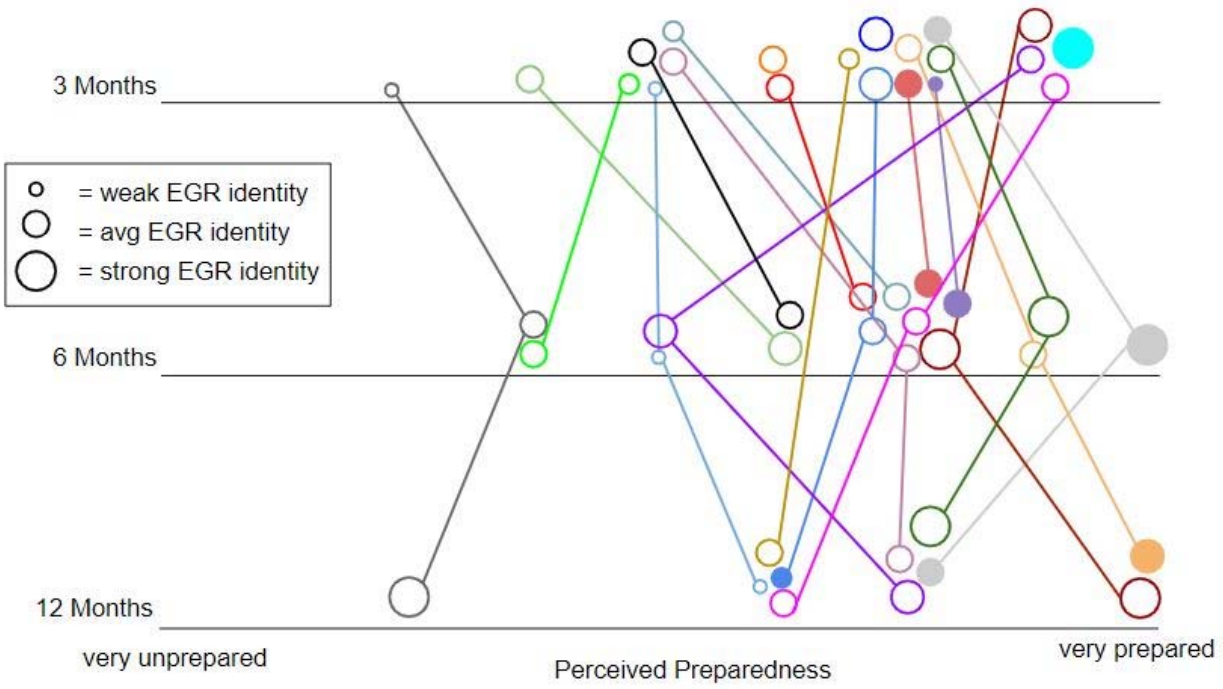

Figure 1 - Perceived preparedness and extent of engineering identity of women participants over time. Shaded circles indicates that participants mentioned experiencing gender bias or discrimination.

Guided by a maximum variation sampling approach, we then re-read the full files for participants who had a complete set of 3, 6, and 12-month interviews and selected four that reflected variation across the trajectories represented in Figure 1 as well as variations in experiences and career trajectories as reported in the interviews and variation across study sites. Figure 2 shows the four selected participants with respect to perceived preparedness, engineering identity, and mention of gender bias. These four participants are drawn from three of the research sites; to safeguard participants' identities, we do not include information on which participants are from which sites. Importantly, while we selected these four to showcase a diversity of women's experiences, we also note that no small selection set could ever fully represent the breadth of women's experiences.

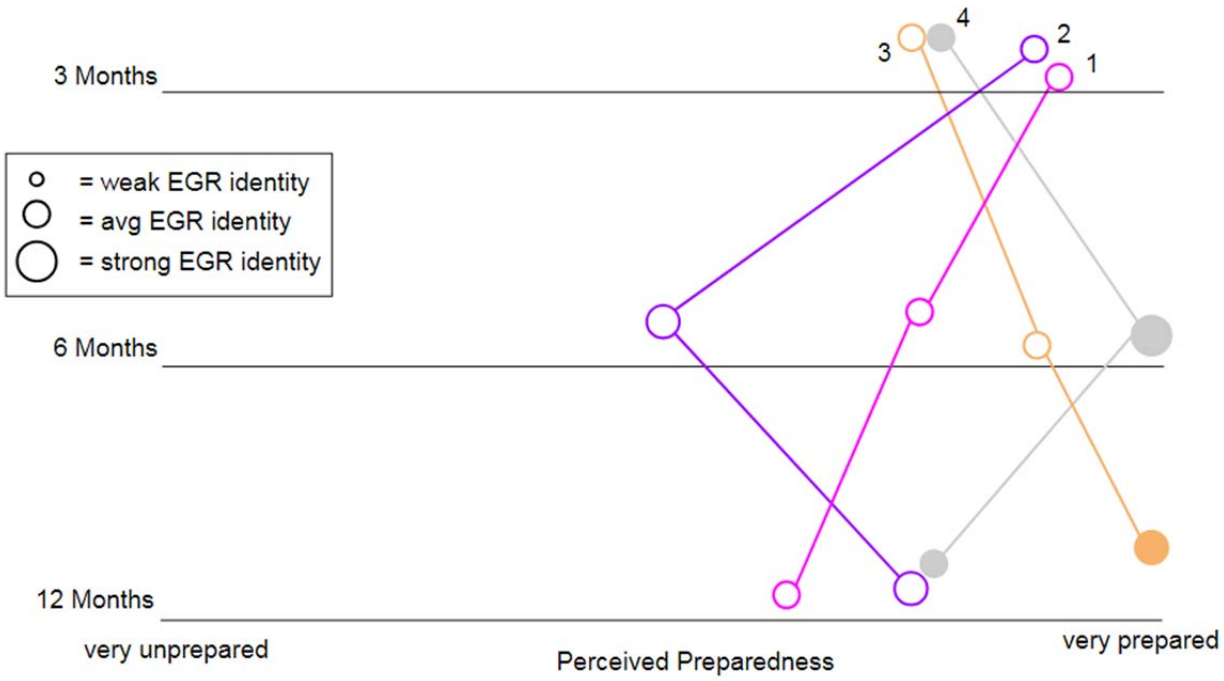

Figure 2 - Selected four participants for narrative analysis. (As in Figure 1 above, the shading indicates whether the participant mentioned experiencing gender bias/discrimination.)

As noted earlier, interviews were conducted nominally at three, six, and 12 months of work; Table 1 shows the exact timing for each participant and notes company size and sector.

Table 1 - Participant Employment and Interview Timing

Selected Participant	Employment	Anticipatory Interview Timing	3-Month Interview Timing	6-Month Interview Timing	12-Month Interview Timing
1	Medium-size company in land development; Large infrastructure development company	1-2 weeks before graduation	12 weeks	26 weeks	54 weeks
2	Large national research organization	1 week before graduation	15 weeks	45 weeks	69 weeks
3	Large manufacturing company	1 week before graduation	15 weeks	31 weeks	57 Weeks
4	Large electronics company	1 week before graduation	13 weeks	32 weeks	58 Weeks

*Medium = 100-1000 employees; Large = >1000 employees

Data Analysis

Narrative analysis is based on the premise that narratives are a natural way that people construct meaning [25]. During semi-structured interviews, interviewer and interviewee co-construct narratives together. Interviewees share experiences as part of an authentic connection with the interviewer, characterized by interviewer curiosity and interviewee reflection on their own "venting," in a way that provides communicative validity [26]. Co-construction also gives the narrative liberatory power, the potential to address topics and raise issues that defy expectation and status quo [17]. In the past, narrative analysis has been used in engineering education to understand the how students and faculty define engineering [17, 27], how institutional structures marginalize and support engineering students [20], and how students perform the engineering design process [28].

In particular, for this paper the researchers performed what Kellam et al. [29] call "Constructed Narrative Analysis," so called because the researchers reconstructed participant narratives with direct quotes from the interviews. For each participant, two researchers read through all transcripts and selected quotes from 60-80 pages of interview data to construct a condensed narrative from the participant's own words. According to Kellam et al, this method preserves the social reality of data collection and increases narrator reliability, as it only sparingly uses the voice of the researcher, which is separated from the moments of the interviews, to construct the narrative. While this process still involves researcher bias in that it is the researcher who selects the salient quotations, we intentionally used two researchers per participant to help mitigate that bias. It is our hope that these narratives come across as authentic to readers, highlighting the women's experiences in their own voices, and providing an opportunity for reflection on readers' expectations of workplace experiences.

The full author team then reviewed all the constructed narratives (with references back to the transcripts and dialogue across teams as needed) in multiple research meetings to identify salient points of comparison across participants.

4 Narratives

The following sections present the constructed narratives of each of the selected participants. Text in square brackets indicates additions or clarifications added by the authors to create a smooth narrative and provide any necessary background information; all other text is directly quoted from participants' transcribed interviews.

Participant 1

[In my junior year,] there was an advisor from aerospace who was like, "There's this [Collegiate] Competition. It's very cool. I think we should get a team together." He [got the leadership started] and then from there he was like, "All right. It's yours. Manage this." [I was] the project lead, me and one other person [of the 40-person team]. We over[saw] all the different sub-teams and manage[d] all that. We did a quick small scale [design] because we had like two months; we picked our members, then we tested, so it was all in two months. It was kind of just like a crash course of can we do this.

Then I kind of just continued on with that [project] for senior design. [It was] a new design team, kind of like one of those big car teams. They were like, "Let's try and build a [full-size design], see where our limits are, like how far we can push this."

I [was] the facilitator. … Every team ha[d] to pick a facilitator, so it was kind of just assumed, since I [was] the project lead [previously], I would just get that too. Senior design [was] seven of us, but kind of the same thing just with a smaller group of people. [The biggest challenge was] working with people and just getting everyone organized, and dividing up the parts. There was so many components to it that there's no way you could just do it all, so you'd have to divide up small detailed designs of each individual sections, and someone would work on each. [Also,] it's a lot of work when [the design is] on that large of a scale. You can't just go and pick up this small thing yourself. We would get our purchase through, but then it would [be] like a 24 foot section of steel, so we're like, "Okay. Now we have to organize a time that six people can meet and carry this over to our storage room." Just trying to organize people and getting everyone together was probably the hardest part.

[My major was] mechanical engineering, and I have a minor in green engineering. I kind of realize[d] halfway through college I like this environmental stuff more. Going into my junior year, I went to [developing country] working with a nonprofit company on clean water and energy projects then and that kind of sparked my interest [so I] picked up that green engineering minor and took more classes in that. The more classes I took, I was like, "I should have done environmental engineering, but I'm in too deep. I'm not going to change now. Mechanical engineering is pretty broad. I could still do that stuff. It's fine, so I'll just finish this out."

Then I actually got a job at [a] water company, and my title's actually civil engineer, doing land development stuff. My mom actually asked me, "Are you qualified? Do you know how to do this job? Because it's not what you got your major in." I was like, "Honestly, I don't think I'm qualified to do any job, ... because you go to college, and you don't really learn how to do a job. You learn the problem solving skills and the general ideas of it. … No matter what I do, I'm not going to be fully prepared for it going in. I'm going to have to figure things out." I mean, why not this one?

[The work in the land development job involves reviewing proposed construction plans to make sure they meet standards.] It's not really mechanical engineering and it's kind of more project management type of pace, but I kind of like that stuff. When new plan submissions come in they'll go to [my manager] and he kind of spreads them out and assigns them to us. Whatever assignments I have, I just work at my own pace to get my stuff done. Before I approve anything usually I just go check with another engineer quick, have them skim through it.

[The process of learning what to do was] more training by doing. For the most part, I wouldn't get any of the first submissions, I would get other people's resubmissions with the revised plans and the comment letter, so I knew exactly like this list to look for what's being changed. And that kind of got me introduced to what to look for.. So I would go through other people's resubmission plans and then sit down with them and go over why they put some comments and why it's better to do things a certain way.

[Capstone] really translates to my job a lot since it's a lot of dealing with the projects and keeping it organized, reviewing the plans and then once it's going to construction, tracking that they have all their paperwork and they have their permits issued and they do all their required meetings, pay all their fees. So, there's a lot of project management that's involved in it. [But the job isn't collaborative like capstone.] The people [in my job] were all very friendly and helpful whenever you had a question, [but] the cubicles were very closed in and you didn't really see anyone from your desk. For the most part, you were by yourself and just reviewing your own plans and going through them - not really collaborating so much unless something really unique came up that you had some questions on.

[By six months into the job,] I finally have gotten to the point where I get a lot of my own first submission plans. I can go through it myself and I have the hang of it. If there's something weird with that project or something that's kind of different, I'll ask for some other opinions but for the most part, I can do it all on my own. [But by 10 months in,] I felt I just wasn't being challenged enough and it was kind of like a dead-end type of position. It kind of just got very redundant, unless something unique popped up, which wasn't very often at all. I just felt like I was going through the motions doing the same thing on every project. It wasn't really anything too involved because then even if they did have an issue, I wouldn't be fixing it myself. I would just send the engineer who designed it, back a comment and have them fix it. I wasn't really getting a lot of experience in CAD programs and modeling programs and stuff like that. If I ever wanted to change jobs, I wasn't getting that experience that would help me change jobs down the road.

[My most significant accomplishment was being] the main contact for the fire flow system. Basically, if anyone wanted tests done for any fire flow pressure results in our system, they'd have to contact me and I'd go through the results and send them to them if they needed new tests done I'd process that and get those new results together and all for them. Within my last month, we started to transfer it over to someone else [and] I had the ability and the knowledge to be able to train this other person and answer his questions. When I started off, I had all the questions in the world and didn't really know much about anything, [but] within less than a year I was able to train someone else on it.

I wasn't really looking too intensely for a job because I was okay where I was. Then I saw this job posting and it kind of just all worked out real quick and it was a great opportunity and sounded like everything I was looking for, so I just kind of went with it. [The new job,] it's all water and wastewater. I'm on the design side of it so I'm actually coming up with a design, doing all of the CAD doing the modeling. It's more involved and more challenging in that aspect, which was something I was more interested in. [And the work environment is] a little more open and it's a little more collaborative type of atmosphere where something will come up and a couple of people might be working on the same project together so it becomes more of a discussion type of topic.

I feel like there's definitely some aspects that are a little bit of a learning curve, like the modeling programs and the CAD programs because I wasn't doing that in my last job. A lot of the details, like standard details about designs I kind of was very comfortable with from my last job so I already had the knowledge of that. … I actually have started using the modeling program a lot already and already am pretty comfortable with that. I was surprised how quickly I was able to pick it up. I was expecting it to be a lot harder of a program than it was.

Being on the design side, I feel like every site is different and you kind of got to figure out what would work best for this site specifically since you're the one actually designing it and not just checking that everything works out. You actually have to find a creative way of getting everything to work out and meet the standards. You kind of have to be able to design it and check yourself. … so I feel like this definitely involves a lot more problem solving and analytical thought process. Being involved in the design and all of that work, I feel more valuable as an engineer. I like my experience better in this [new] job.

Participant 2

[In my capstone course] there were challenges, but I've overcome those challenges. Like I said, a lot of our stuff was hands-on, so learning how to use some of the tools, but you just learn it and you move on. [...] I would say that just in general, [capstone] has really helped me become more confident in my abilities to perform any soft of task, really. Pre-[capstone], I didn't really know what it meant. How do you make something? Where do you even begin? I think [capstone] has really helped in that area and like I said, how to look up the specifications for parts. That's a really big part of it, that's a lot of what you learn in [capstone]. How to work as team effectively. We're all forced to do it in classes, but I think [capstone] really helps solidify your abilities there.

[When I think about my new job] I'm not 100% sure [what I'll be doing], but it is a hands-on position. It's a technologist position, which is why I applied for it. I'm nervous that I'm hoping that I didn't make myself sound like I knew too much. I'm nervous that they're gonna be like, man, she doesn't know anything. But otherwise, no, [I'm not nervous]. I think just because it's hands-on, I feel prepared for it, you know, like as far as my technical writing skills and my team work skills and my people skills and that kind of stuff.

[Now that I've been at work for 3 months] Mostly my responsibilities are just doing whatever anybody tells me to do, so that can range anywhere from working on [specific software package], which is something that I actually know how to do personally … or working on a report or attaching wires or testing some sort of a component. I'm not having to learn a whole lot yet, but for the stuff that I'm doing, I feel completely prepared for it. [...] I read up on different things. [...] Most of the components that I researched we generally have some sort of a user guide or user manual that comes with the component. A lot of the stuff in our program is off the shelf, so there's usually something to read about. Otherwise, if it's just a really basic concept that I need to familiarize myself with, I generally just google it, I mean you know like normal people.

I would say that in my experience in an actual job position is a lot more involved. I have to be really, really involved [in] the project. I have to know the in and out of a lot of the parts, whereas with the Capstone project, I don't really have to know a whole lot about the parts, I can just know my particular project or my particular piece and then hand it off to somebody else who is working on another part. Maybe it's just because those [capstone] projects are really small and this project that I'm working on here is very, very large, but the project size kind of correlates to how involved and how much of an understanding of the project I actually have. Even though I'm assigned to [my] group, I have to attend the meetings and still understand what's happening with all the other groups. Definitely one of the bigger challenges is [...] I'm trying to wrap my mind around the new project, get all the pieces separated and understood in my mind, so I'm [working on] sensors, that's fine but I also need to understand different parts, which requires a lot

background research. Like I can't just ask somebody in a meeting to explain this to me. I have to write down what I didn't understand and then go back and research it on my own, which is a little bit different, that's not something that we normally do in school, obviously, because you're taught everything. Here, if I don't understand something at work, I don't understand the whole entire topic. I have to go and do my research about not just a component or not just a theory. I have to go and research the whole entire topic. I talk to a lot of people. If I don't understand, there's definitely somebody who I can talk to.

[One] thing that helped me transition [to work is] just having a schedule laid out, just knowing what is expected of you is really what's the most important thing, knowing what ... Having good communication with my supervisors, knowing what I should be doing, what needs to be done. [...] Managing a schedule is always kind of hard. It's always a work in progress. The one thing that's kind of different about work versus school is at work, we go on travel, so I just recently made the mistake of trying to juggle the travel arrangements with my personal arrangements, it never clicked to me that I'm not going to be at home for a whole week.

[If I could give advice to the next class] I would tell them to be expect to be confused.

[After 6 months of work] we're still doing a lot of design work, which involves, obviously, report writing still. We call it redlines, but it's just updating drawing packages to fit our design and our needs. And then I've been doing a lot of traveling, and whenever I'm on travel, it's a lot more hands-on. I'll do maybe some software program ... Or I'll set up sensors, or cameras, or something similar. Sometimes it's more physical labor, it's just setting up fences and setting up infrastructure. My position is maybe a little bit unique because I'm the civil for these projects, which doesn't make a whole lot of sense 'cause I'm a mechanical engineer, but it just ended up that way. I was interested, and I expressed that I was interested in running some civil things, and then a lot of change of people, and I ended up being one of the only civil people in the projects.

I wouldn't say that I'm doing a whole lot of engineering. A lot of my time is just spent putting together reports and presentations, which is just from the design that is pretty standard for us, so it's not ... I think most of the engineering has already been done in my group, so anytime we do a site that's standard, it's pretty easy to just take from the designs that we have built up, so that makes it easy. There is some engineering. There's definitely some times where I'll have to make adjustments to something to fit the site, and that requires some calculations and some talking to people. I think there's a lot of hands-on stuff that is still really new to me. A lot of basic understanding of things that I don't quite understand. So I understand how to use the tools, but I don't always know what I'm supposed to use the tools on, if that makes sense.

There's a lot of challenge with just trying to understand what's going on. Trying to get a good picture sometimes. There's a lot of stuff about my job that I … the process of going from a 30% design all the way to a 90% design, and really understanding what's involved in each of those pieces, can be a little bit challenging. Sometimes it seems like I don't know … I don't even know what needs to be in the 90% design as compared to the 30% design. I don't even know I'm missing [something] sometimes until I found out that I'm missing it. I think what's different is, in school, after you take that test, you've learned that item. You're done with it. But that's not the way it is here. You maybe do the 30% design, and then three months later, everything about

the design has changed because the scope has changed and you don't like the way it was or whatever the case is. You've learned new things.

I have a to-do list, and I have lots of sticky notes. That's how I cope with this. I think keeping a to-do list is really the best way for me. 'Cause if someone mentions something in a meeting and I think, "Oh, I should really take a look at that," or "Oh, I should really learn about that," I'll write it down.

[At the 12-month interview] I don't know that anything has really changed since the last couple of months. I have been traveling a little bit. Been doing a little bit more site surveys, actually. That's pretty typical at this point in time. I think [these site surveys will] get, it'll become more comfortable. Just like , just the first site survey I went on, I mean, I had an idea of what I wanted to look at, but then I got back and I was like, man, there's a lot of stuff that I should have looked at while I was out there. And then in talking to some of the more advanced people, they just, with time, you begin to understand the things that you need to look for.

I think for me it's just, I mean, I don't, just trying to figure out what I don't know has been the most challenging thing. I mean, we're at a 60% design right now, and I know for a fact this is not a 60% design, but I don't know what's missing. [So you] just do your best. I just keep a running list of things that I think need to be looked at and just kind of start at the beginning, and if there's anything that I think might be missing, I go and talk to somebody with some experience, and see if they think what I have is good enough, and maybe we don't know so we talk about it a little bit. Just, you gotta, you have to hold yourself to some kind of standard. I can't expect anybody above me to catch my mistakes, 'cause it's just, there's just so much going on. People don't have the time or the resources to really find [mistakes in] what I've done, so you, as an individual, we have to kind of find [errors] in things ourselves.

I think one thing that's different between school and work is in school, it kind of seems like you can put in a three quarter project, and somebody will read through it, and really thoroughly. They'll tell you what they think is missing, and they'll really thoroughly go through it. And at work that's not the situation. You can't expect someone to grade your stuff. The first go-around I was like, I don't really know what I'm doing, so here. I made this. And then I would expect some kind of feedback. And then almost every single time, we wouldn't really get a whole lot of feedback. And then eventually I realized, okay, nobody's gonna give the feedback that I'm looking for. I have to search for it, basically. I have to take this to my, to somebody above me and say, "I need you to look at these pieces, and really look at them."

I think I'm really close to feeling like an engineer...I think for me it's an understanding of how this system works, and being able to, if there's a problem, or the customer has a concern, I'm able to go through and explain, explain what I think, and how I think we can fix the solution, and if that doesn't work maybe we can come up with an alternative design that's still meets the requirements. And I think, for me, just going from, going from zero to a hundred percent design is really just, is what it's gonna take to be at least an engineer in my field. Maybe just in general.

Participant 3

The project I was working on for my Capstone was designing the exterior parts for a high pressure application. I think one of the biggest challenges for us as a [capstone] team to begin was that I was the primary person who had had finite element analysis experience prior to this project, so catching the team up to speed on that and then, one of my teammates had had probably more [CAD software] experience than I had had previously, but the other two had never touched it before.

I think once we stepped back and reassessed the scope of the project, it turned out quite well. I think we were really excited with the final design that we came up with. I think it addressed some of the major issues with the existing compressor design, because we started with a model that operates at a much lower pressure and we tried to modify that design such that it could withstand the higher pressures.

I think the most valuable thing I learned [in capstone] is that you can work successfully with a team on an engineering project and get some really great results out of it. I'm glad that I learned that now before going into the workforce and saying oh, I hate group projects. They can go well.

[Now that I've been on the job for three months] I get the feeling that my boss is testing the waters a little bit, like, throwing projects at me to see how I handle something really open-ended or handling, especially research into either materials or parts. I don't see it as a negative thing. I see it as just getting a feel for what I'll be capable of doing even though I'm really new, if I have the capacity to learn these skills and support everything that both she and I are doing currently. I'm the newest person but also the other engineer has to leave the country in February or March of next year, so I'll be the only engineer. So, I get the feeling that he wants to get a sense of, does he need to hire someone else to have two of us on R and D while she's out of the country for the next year, or how's that going to be with me being the sole supporting engineer for that time.

[One challenge I had was] meeting in-person with the pump salesman, that wasn't something I would've thought of myself. Like, I hadn't yet seen the benefit of having an in-person meeting with someone who's clearly an expert in his field 'cause he's been working at that company for 20 some odd years. And then, I felt a little bit like I was being tested by my boss there where he asked me on the fly, and I think that was a challenge for me because I wasn't yet expecting that sort of question from him. Like, that was the first time where he sort of popped out with, "Hey, what do you think of this? Like, here on the spot." And sometimes, pulling words together into a coherent sentence to explain where I'm thinking so far, like, it takes me a while to get to the point sometimes. So, I think the biggest challenge was trying to say what I was thinking coherently at that time and say, "Oh, well, I feel like we should go with this pump because of what he said so far." So, putting it all together was probably my biggest challenge at that stage

Well, I think, now that I know that [my boss] tends to ask those sorts of questions on projects, like, he wants to have input from both myself and the other engineer on things 'cause he's not the R and D team by himself. I found myself starting to ask similar questions while I'm working on things to try to say, "Okay, I know my boss is going to ask this. What do I think about it?" Or write down summary sentences when I go into meetings saying, "This is what I've been working

on and here's what I've concluded so far" so that I'm ready or prepared to address those sorts of questions.

[My biggest challenge in the first three months has been] getting up to speed on how the company runs and how our specific product line works. We have about 12 different machines that have anywhere from 50 to 150 parts each in them, and everybody has the part numbers memorized. The most overarching [challenge] is catching up with the specific terminology and how everyone refers to the machines and the parts onsite because everyone has so much more experience with them than I do

[Having dinners with my boss while on a business trip] was an interesting experience for me because on one hand, I'm trying to ... overall, I want to maintain a really professional relationship because I'm aware of the fact that I'm young and I want to be taken seriously. And so, I try to maintain some level of seriousness even in an outside of work situation. But on the other hand, I can tell from eating a few dinners with my boss while we were on this trip, that he generally likes to talk a bit more than I do and just ask, "Oh, how's life going? How's this?" He's just generally chattier than I am, versus I've never been that way regardless if I'm trying to be professional or not. Like, I will gladly eat meals in silence and I don't find it weird and I'm coming to realize other people find it weird. So, that was a bit of an experience, just getting used to, "Okay. No. He's just making small talk because that's how he built up business relationships over the years, and working with different people and that's how he comes to know them." So, that took a little bit of getting used to.

[My description of what it means to be an engineer], based on my experiences so far, I would say engineering work is troubleshooting. Troubleshooting the machines that we're testing, troubleshooting the parts or the tools that we're trying to help out the machine shop with making metalize easier, troubleshooting why some pump on a cart isn't running properly. I would say it's troubleshooting so far.

[My experience with teamwork] continues to grow in a positive way, it's really helpful to have the other engineer with a little bit more experience on her end and being able to check in with her on, "Oh, how would you approach designing this tool?" Or, "Do you think this drawing looks okay?" It's not so much direct collaboration. It's more oversight.

I'm curious to see if [the other engineer leaving] gives me any further autonomy once we have more projects to work on. Like fewer check ins or fewer scheduled check ins and maybe I can take a project and run with it a little bit more, which I think would be kind of fun

I think it's hard to gauge [how much autonomy I currently have] just because there's sort of this lack of work. A lot of the projects, especially with like the data processing that I'm doing right now, I took part of it on because my boss was looking at it himself, but he was looking at it from a database point of view and I was looking at it being able to sort it using [Software 1] and [Software 2] and I thought, "Oh, it might be fun to take a look at it from a different perspective. Do you mind if I try it this way?" He said, "Yeah, sure. Go for it." I guess there's less autonomy in this particular project just because we're working on the same project from different angles, so checking in to see where he thinks I could go with it has been a little more rigorous than maybe some other projects might be just because of the nature of it.

[At the six month mark] I think generally things are going well. Work has been a little bit slow as of late. Two manager levels up from me, so I have my manager, but then my boss's manager who sits in [Country], we've had some difficulty keeping someone in that position consistently and so I think ... Actually, as of this morning we finally got notification they hired someone for the position, but it's sort of produced a stalemate at work in terms of getting new projects to work on because we've been waiting for direction from the other offices.

I would say [I feel] less tested at this stage. I think I've at least been able to prove a willingness to perform research and solve problems really analytically and I think my boss looks to me now for that extra opinion on things, like with the data sorting.

I've proven myself able to do the kind of research it takes to find out either vendors or materials or parts and I think that's given me the chance to maybe go beyond that once we do get further projects, I'm hoping. I don't get the sense that I've disproven any ability to get things done that are asked of me.

[Capstone overlapped with my work experience] in the [Software] experience that I had from Capstone, getting comfortable with working with assemblies, different types of 3D files, making appropriate mates and deciding how assemblies should work together and having the chance to practice that beforehand so that I actually sort of know what I'm doing when I'm working with the [Software] files now.

[Living in a new town] took a little bit of getting used to just after being ... I mean, I grew up in the same town and I went to all of my pre college years were just spent with the same probably 100, 125 kids from preschool up through 12th grade. I have made conscious efforts to get out and join with local organizations. I started volunteering at a local animal shelter on the weekends, because I thought, "Oh, that would be a good way to, one, get myself out of the apartment for something other than work or grocery shopping," but two, it actually gave me an en route where two Tuesdays ago I actually adopted a cat, so things like that.

[I've been here a year but] it's been pretty slow in the past month or two. We're still waiting to see if this new machine that we've been working on, or that's being worked on since way before I even joined the company will get launched. And there's not a lot of directive coming from above in terms of new projects we should be working on otherwise. So, my boss even turned to me today and said, "Hey, do you have anything you're working on?" "No." "If you have something I'd love to hear it."

Because a lot of times when we do get projects to work on [my boss will] either say, "Okay, I have time to work on this. I'll do this myself." Or, "Hey, can you take this on and work on it?" So, I have my running list of projects that I've been chipping away at and I've whittled it down to pretty much nothing at this point. So, I think he was asking me, "Hey, is there anything left on your list that I could take back so I have something to work on too?" "No. I wrapped up my last major testing project this morning and things were good. So, I'm done too."

[Because work is so slow] it's a decent time for some self-reflection or maybe spending more time when problems do arise on tasks that you might having ... I might not have had time to focus on some of the problems that I'm sure will come up in the days to come. So, maybe it will

be helpful, but in the meantime it can be frustrating to not have anything to even chip away at slowly.

I guess what I find most challenging is sometimes I get called into meetings with vendors, the people that we source the parts from for these machines. And there's always some apprehension going into these meetings of being taken at face value and whether or not they're going to treat me like an adult who's going to be part of this meeting.

[An example of a challenging situation includes] I've occasionally had interactions where people who see me say, "Oh, you look like you're 12," pat on the head, cute little engineer, and get dismissed. So, I think I wasn't super prepared for dealing with that. I guess in name I thought it might happen here or there, but actually having people do that was different. So, I'm coming to terms with how do you deal with somebody like that?

So, by having a fact-based argument and just being prepared, and I have already told my boss, "Hey, this is what I've found with this. I don't see any reason to change, and when we go into this meeting this is how we're going to present it." I think that's the best that I can do, is to come across as seriously as I can and say, "Here it is," and let the facts speak for themselves.

Participant 4

[During capstone] it was so much more apparent that [one team member] didn't do as much work as the rest of us, and that really held us back a bit. That's why I ended up jumping and doing like the [work], was because those were supposed to be her tasks, but they just weren't getting done.

If I were ever in a project manager real role, I wouldn't have to worry about the technical portion. I think I would have ... I would have been able to put a lot more effort into [this team member] having the ... I don't know. I wouldn't have wanted [this team member] in the project, like on a project with me in the future, but I don't know what it's like in a career, how much room there is to rearrange groups or how often you're going to get stuck with people who don't want to work.

[One of the most important things I learned was that] I'm able to use the resources given to me [...] I'm able to reach out to people. [...] after four years of being at [college], I think you learn that everyone's pretty willing to answer whatever questions you have.

[I'm nervous about] just having to ask questions to a different gender, which I feel like shouldn't be a problem, but …It could be a problem. I don't know. I don't know how well received all of my questions will be. [...] I don't know. I think they'll be very open to me. I'm not sure how ... I have no idea.

[At 3 months of work, my coworker] was put into the position to delegate, she didn't really know what she was doing, and I guess that's what was frustrating.[...] I guess my biggest problem with this situation is I need to still be able to work with her on a professional level even if I don't get along with her, and even if I don't agree with her method of working through a tool, I still need to be able to work with her...I wish I had known more just so that I was able to actually be able to pinpoint the problems better.

[Another coworker] was flirting with me, and it was really awkward, and my other female coworkers warned me about him very early on [...], so that was something that I had to look out for when I first started working just until I was grounded. There's another worker who's very I guess condescending almost dismissive of women, so there was that also that I had to work with. I mean now it's fine, just because I know everyone.

There's a group of probably like 10 of us who I've gotten to know really well, and we actually have where we go out and have bonfires and everything on the weekends, and so I mean I have gotten close to a crew. There's also individuals who are older who are I've also gotten really close to on a professional level, [...] the majority of our department is absolutely fantastic.

[Now that I've been at work for 6 months, I'm on a work trip in Europe.] They usually send the women [engineers] to [Europe] just because it's a smoother transition into the whole working overtime, working long hours, not getting that much time off for yourself. [...] My coworker told me that one guy worked himself so hard that he got a stroke and now he can't move out of his space, because he was overworking. It's just that thing where it's much more relaxed in Europe than in Asia.

[With respect to the gender they send abroad] It's mostly just a sexist thing.

So the local guys here have had a lot of experience with other [engineering] women and they don't have very many positive things to say about them. It's just a pattern that I want to break [...] it involves me just doing a larger percentage of all of the physical stuff. Never complaining about anything. Health-wise or if something hurts or anything. Trying to lift things that are heavier. Just trying to physically prove my strength but also asking a ton of questions and taking the initiative and doing things. Knowing what to do before someone asks me...

[One local engineer] asked, why aren't you your usual laughing self. What's wrong? Are you okay? At lunch, he was making a joke about how if you drink too much beer, you'll become unintelligible like a woman...

[In school] they babied us and then Capstone was the first experience we had. It was getting rid of that illusion and trying to get us prepared for the real world, and then we get into the real world, and then we weren't prepared for this necessarily. [Our professor] could have been a little bit harsher...

[One of the pieces of advice I would give to students is] just don't be shocked with all the sexism that you find, once you leave [college], I don't know. I don't really know how to word the sexism thing better without making it sound bad. "Get used to it."

[At 12 months at this company] we've recently hired more women so it's been interesting to see how that dynamic's changing. [One newly hired woman,] I didn't know how to talk to her, how to get her to open up. But, at the same time I got frustrated because she didn't seem to want to engage in what we were doing.[...] I wanted to, like, be intimidating but not really intimidating, but I wasn't making, … I don't know, it was interesting. I was very mixed. I wanted to seem like I knew what I was doing so that she knew that, like, oh there are successful women at this job but, at the same time… I don't know…

I mean you're constantly surrounded by people and especially on trips, you're surrounded by just one person usually and you have to … You get to know them really, really well and you have to deal with that, like everything, the good and the bad and there's no options. If you don't like it, you have to deal with it because that's it, that's the only person that you're going to see talk to until you're back. I mean all the problems that you have, you have to figure out a way to either deal with it or to solve it or to tolerate it or something because not liking it is not an option.

[On a recent work trip], I tried to fix [the tool] and I took the whole thing apart and put it back together and, when the field service guy saw that, he freaked out and he took the [tool] from me and he started fixing it himself and then he turned to me and started explaining magnetism to me[...]after a couple of days, he was fine with the fact that I was there and I was a woman. That one worked out well....It was interesting because the things he saw me do, they were tiny tasks, like putting the super tiny screw back into this really tight spot. That was more … that was almost sexist too just because it's easier for me to put tiny screws in because my hands are smaller.

I feel like just like the way that I still freeze up when it comes to certain issues, sometimes I know I get stuck for a while and someone else is able to pick it up for me like [...] not being able to pick things up as fast as I would like to.

[...] I mean I do know about impostor syndrome, but I mean you just have to like wonder like is everyone else … Do they know as much as I know and they are just faking it a lot better, or does everyone actually know a lot more than I know, and I'm just not catching on to it as quickly?

… I mean ‘cause my supervisor at one point [on a trip] said that [the job] is all about pretending you know what you don't know, until you actually do know what you don't know.

[At a performance review, my supervisor,] he said, oh, you’re a really good worker. Everyone has been saying that you're the first woman who actually likes working, like the hands-on stuff that most of them shy away from. He was like, it's really good. He said I was learning really well. I mean it was pretty positive.

Discussion

Diverse Trajectories

As the narratives suggest, each of these women experienced their transition to work in different ways. All had positive capstone experiences and carried learning gains from those experiences into their jobs, but in very different ways. These narratives of transition thus help highlight the sheer diversity of engineering work - design, troubleshooting, problem-solving, reviewing, field work, office work, and more. Each of our participants describe engineering in different terms, and each went into positions that took them well beyond the technical knowledge they had amassed in school.

Participant 1 found a job that did not align with her major (mechanical engineering), but did align with her interests and her minor and elective courses (civil engineering and sustainable development). Working for a medium-sized company, she was relatively confident in her skills especially related to project management and quickly mastered the work. She primarily worked

independently but got along well with her coworkers and supervisors. While she initially liked the work, near the end of her first year, she grew bored of the routine tasks and changed jobs. Her new job was in the same broad field, but offered more opportunities to do design work and problem solving in a more collaborative environment.

Participant 2 also left school with confidence in her ability to learn as well as to communicate and collaborate effectively. She also went into a job that aligned more with civil engineering than with her mechanical engineering degree, but she expressed less confidence about her ability to make the shift (perhaps because, unlike Participant 1, she had not taken relevant elective courses). Notably, while she enjoyed her job and her colleagues, comments about not knowing enough persisted throughout her first year, and as her narrative indicates, she had multiple strategies for both identifying what she needed to learn and for gaining that knowledge. Site visits became an increasing component of her job, and she moved back and forth between hands-on installation of products and office design/review work, noting the differences in time scale and scope between school and work projects. At the end of the year, though happy and successful in her job, she still didn't fully consider herself as an engineer because she had yet fully understand the complete design cycle.

Participant 3 experienced a somewhat different work environment in a research and development (R&D) setting more closely matching her mechanical engineering degree. Like Participant 2, she found herself challenged by the process of coming up to speed on the full scope of work in her company, but she also felt herself tested by her supervisor in the first few months. She is on a much smaller team than Participants 1 and 2 (with only one other engineer - a woman - and her supervisor in R&D), and that results in more interaction with her supervisor and coworker around the project work itself. The sense of being tested and having to provide herself persisted throughout her first year of work in that even after feeling that she had gained her supervisor's confidence and trust, she notes that vendors or others outside her work group perceive her as young and inexperienced. Like Participant 1, Participant 3 also finds herself growing bored at work - not from the repetitive nature of the job, but from a lack of work resulting from shifts in the larger company.

Finally, *Participant 4's* transition to work was characterized by more reported challenges with coworkers, including both not getting along with one individual and experiencing overt sexism from several others. She works with a number of other female engineers, and described developing positive relationships with her colleagues that extend outside of work, but also describes a culture within her local office that is at best distrustful of female engineers, and in some instances more openly dismissive or hostile. Participant 4 also grapples with issues of confidence, raising the issue of impostor syndrome and questioning her own knowledge, but she also gets positive (if sexist) support from her supervisor for her ability to tackle the hands-on dimensions of her work.

Emergent Themes

At the same time, while each participant experienced a different trajectory in their transition to work, some common issues emerged across the narratives—though again often in different ways.

Lifelong Learning. Perhaps most notably, and consistent with the diversity of engineering work, all four discussed the challenges associated with needing to learn new things - both about technical concepts and about the culture and goals and products of their company. Participants 1 and 2 went into fields that differed sharply from their undergraduate preparation, but even for Participants 3 and 4, who were working in areas closer to their "school knowledge," learning curves were steep. Capstone typically served as critical preparation here, providing them with the both confidence in their ability to learn and strategies for building that knowledge - a pattern that is consistent with findings from our larger data set [21, 22].

Confidence. Confidence also emerges as a theme across these narratives; in part, this emergence results from the interview protocol itself, which asked participants each time how prepared they feel for their jobs. Beyond the direct question, however, participants often returned to the issue at various points in their interviews as they talked about what they needed to learn and how they learned it. In some ways, these questions of confidence are consistent with studies highlighting the role of self-efficacy in female engineering students' major and career intentions [5, 6], but it is important to note here that both the level of confidence and the focus of that confidence shifted across participants. Participant 1 routinely found herself confident in her work, even as she described needed to learn new skills and knowledge. For Participant 2 and to some extent, Participant 4, confidence centered on what they needed to know for their jobs, with Participant 2 highly attuned to her need to continually expand her understanding of the technical work at hand and Participant 4 talking explicitly about impostor syndrome.

But Participants 3 and 4 also grappled with confidence in ways explicitly linked to their identities as women; both experienced, to varying degrees, situations in which they perceived others doubting their work and their credibility because they are female. The experiences of these two participants, reflect the kinds of gender dynamics commonly identified in studies of working engineers [13, 15]. Those dynamics did not emerge in interviews with Participants 1 and 2, though we note that absence from the interviews does not necessarily mean absence from their experiences.

Interpersonal Relationships. Also common across the narratives—and commonly linked to capstone design learning—is the critical role of interpersonal relationships at work, as demonstrated in multiple other workplace studies [30-32]. For each of these women, asking questions of coworkers and supervisors proved essential in both developing their knowledge and gaining confidence and a sense of belonging at work. Their work was typically highly collaborative, though a notable lack of collaborative work was one element in Participant 1's decision to change jobs, and both the scope of the projects and the need to get up to speed led to ongoing discussions and collaborations. Importantly, though, as Participant 2 noted explicitly, these interactions demanded initiatives on the part of the new engineers themselves; their workplace colleagues did not seek them out to provide information or review their work to provide feedback unless prompted by the new engineer herself.

While these emergent themes resonate with previous studies of women's experiences in some ways, additional research is need across all participants (women and men) in this study to better understand the extent to which these issues reflect common experiences of students as they move from school to work.

Implications for Engineering Educators

While the study presented here is limited by our choice to examine only four narratives from a much larger set, the richness of the experiences they reflect has several distinct implications for engineering educators both within and beyond the capstone course.

- While engineering curricula provide students with baseline technical knowledge, they cannot provide students with all of the technical knowledge needed for the diverse array of possible engineering careers. Lifelong learning, despite its removal from the most recent list of student outcomes from ABET [33], remains a critical skills for engineering professionals. Capstone design courses play a key role in facilitating students' ability to tackle the unfamiliar and learn through multiple channels (books, the internet, product documentation, colleagues), but the consistent need for this skill in the workplace suggests that it should perhaps be more pervasive across the curriculum, and that engineering faculty should perhaps be less concerned with "covering the content" than with helping students develop the capacity to manage their own learning.
- As many previous studies have noted [34-36], collaboration and communication (formal and informal) remain essential workplace skills, and for these participants as well as others in our study [21, 22] and other studies of capstone courses [37], these skills are a paramount learning outcome from capstone courses. Engineering work is fundamentally socio-technical, and over-reliance on solely technical learning outcomes can inhibit students' ability to successfully transition to the workplace. Faculty thus need to consistently explore opportunities to embed professional skills development into engineering classes and curricula.
- Gender, while it remains a salient identity for many women in engineering, is not a homogenizing force. Individual women's experiences in both engineering school and engineering work are shaped by a variety of personal, organizational, and cultural factors, and both educators and researchers need to be attuned not only to systemic patterns, but to individual voices. Cultural changes remain imperative to ensure that no female engineer has to experience the kind of biases faced by Participant 4, but educators need to continue to see their students as individuals, not categories.

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