Expanding the Engineering Workforce: An Exploratory Study of a Mid-Career Transition from a Non-Engineering Background

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Introduction

The United States has vocalized a desperate need for an increase of engineers in the workforce to maintain the country's position as the forerunning performer and collaborator of science and technology activities worldwide [1], [2], [3], [4]. As published by the National Science Foundation, the United States' science and engineering enterprise has relied on a large STEM labor force that has been traditionally developed through the K-12 to higher education pipeline [5]. It is becoming increasingly clear that this formula is insufficient at meeting the nation's engineering workforce needs due to issues in accessibility and achievement gaps for individuals with varying sociodemographic and economic backgrounds. To meet the country's engineering workforce needs more efficiently, it would be helpful to establish alternative pathways to creating well-educated, capable engineers that are accessible to people of varying backgrounds.

One means of identifying alternative pathways is by observing the transitions to an engineering profession by mid-career individuals with a non-engineering background. Approximately 200,000 engineering jobs are created per year, yet traditional educational pathways for engineers are awarding only about 142,000 engineering degrees per year [6], [7]. By focusing in on individuals with a non-engineering background, a larger pool of untapped engineering workforce potential that can assist in fulfilling the need for engineers is created.

Beyond this, focusing on mid-career individuals means identifying streamlined means of molding engineers. In this study, mid-career refers to individuals with 10 to 20 years of experience; this stage is where many professionals master and maintain skills, begin taking on leadership roles, and reevaluate career goals [8]. Understanding how mid-career individuals transition to engineering is particularly valuable as many of them face constraints that prevent full-time academic retraining, often due to personal and financial responsibilities. Additionally, their transitions are frequently challenging as traditional career structures tend to privilege those with a four-year degree while individuals who pursue alternative credentials, such as certificate, may be perceived as less qualified [9]. This urgency to transition effectively into a new career underscores the need for innovative, alternative pathways that facilitate mid-career entry into engineering.

By beginning to examine transitions such as these, we can begin to understand what alternative pathways to an engineering career are not only available but also already have a presence in industry (even if it is limited). Having an awareness of both accessibility and presence of an alternative pathway will be useful in establishing it as a viable pathway as they both circumvent the issues apparent in the traditional route of higher education and begin to address the question of whether alternative forms of engineering education are able to prepare the engineering workforce at least as well as a four-year degree does. While there have been many studies on engineering practitioners [10], [11], [12], [13], there have been limited studies on individuals who became engineers through non-traditional pathways. Therefore, using Schlossberg's [14] Transition Theory, this study aims to explore the following research question:

RQ: What constitutes the transitional experience of a mid-career individual with a non-engineering background when they begin an engineering career through a non-traditional pathway?

Literature Review

Historically, engineers have been developed through hands-on experience either through apprenticeships, in-house training, or trade certification which offered professional mobility [9]. Early engineering careers did not always require a deep understanding of the theoretical underpinnings such as calculus or physics. Rather, individuals were trained for the jobs they would be performing specifically; this changed with the industrial revolution which craved an increasingly innovative workforce [15]. This route of training became less popular with the introduction of the French education system which emphasized how engineers' knowledge must reach beyond the applicable [16]. Despite these developments, recent publications have suggested that both graduates of engineering programs and industry professional express concerns about the lack of practical knowledge and skills emphasized in higher education [17], [18]. This raises questions about whether the theory-heavy approach to engineering education sufficiently prepares graduates for a career in industry.

Recent work regarding the engineering workforce demographics note that most engineering professions regard a bachelor's degree as the minimum education requirement for an entry-level engineer [19]. While in 1995, approximately 25 percent of working engineers did not hold an engineering degree [20], as of 2022 "nearly everyone working in an engineering occupation held an engineering degree as their terminal degree" [21]. This establishes higher education as the dominant path, but the presence of engineers without this educational background demonstrates alternative pathways as possible. With this information, we can consider a few alternative avenues of engineering education such as certification programs, trade programs, and associate degrees.

Programs which offer certifications of engineering skills and knowledge have begun emerging [22]. These programs are often regarded as another means of professional development similar to earning a master's in order to better-qualify for promotions or competitive job openings; the main difference is on the specification of the award [23]. These certifications are often earned by individuals who are seeking career advancements rather than by those who have career transitions in mind. For example, it is reported that only about 26% of individuals who earned technology certifications did so with a new career in mind while about 73% desired to upskill [24].

A group that can potentially be making up this population of non-bachelor's-holding engineers are those with trade and associate degrees. These degree formats are much more accessible in terms of time and financial commitment [25], [26]. Additionally, these degrees provide the necessary hands-on training and development of practical skills that industry is looking for in the workforce. Community colleges that implement retooling efforts are particularly adept at meeting workforce needs, though there is some debate over whether they are comparable to a liberal arts education [27]. While some can find positions as engineers, those

with trade and associate degrees are often relegated to roles of "technician" or "mechanic" due to their programs' emphasis on the practical rather than the theoretical [28].

One area that remains relatively unobserved is of those who have a bachelor's degree in a non-engineering discipline but a career in engineering. Generally, the career transitions have been studied in mid-career individuals but lack focus on transitions to engineering careers [29]. Specific to drastically different career transitions, past research has compared the trends of recent college graduates of STEM and non-STEM programs remaining in their professions [30]. Despite this, there is limited work assessing the transitions of mid-career individual with a non-engineering background's into engineering careers. This is particularly true of ones that focus on their means of identifying and pursuing the necessary knowledge to achieve that career transition.

Theoretical Framework

Schlossberg's [14] Transition Theory was the guiding conceptual framework for this study. Transition Theory defines a transition as any event or non-event that changes the relationships, routines, assumptions, and/or roles of an individual. These transitions can be categorized as 1) elected (transitions that are predictable), 2) surprise (transitions that are unpredictable), and 3) non-events (transitions that were supposed to happen but did not). Non-events can be divided further: personal (due to an individual's aspirations), ripple (due to another's nonevent), resultant (due to an event), or delayed (due to a setback but may still happen). Schlossberg's model aims to understand the ways in which people cope with these transitions by identifying the resources they have. The resources people typically have access to can be divided into four categories (the 4S's) including (1) situation, (2) self, (3) support, and (4) strategy.

Coping through situation includes identifying the characteristics of the transitions one is experiencing. When one copes through self, they are urged to identify their sense of purpose and make meaning of the transition. Emphasizing support when coping looks like reaching out to family and friends, partners, professional networks, institutions, and larger communities for support. Finally, coping through strategy is essentially creating a gameplan for reframing and redefining the transition.

Application of the theory to the area of mid-career transitions to engineering is valuable as it accounts for the various reasons an individual may pursue this transition and offers four categories of tools that individuals may apply to sourcing alternative pathways to an engineering career as a way of coping with the career transition. For these individuals, the overarching transition is one from their former non-engineering career to an engineering career, but their more immediate transition is one to student of engineering. Overall, the career transition is comprised of moving into the new career, moving through the transition, and moving out of the transition once the goal is achieved. With this particular transition identified, utilization of this theory will assist in defining their means of coping with the transition. If an individual's transition is expected or not will affect their means of coping which may in turn alter their chosen educational pathways to an engineering career.

Methods

Narrative analysis was the methodology followed in this research; following a pragmatist framework, the aim was to identify the factors involved in one participant's experienced career transition [31]. A narrative analysis is particularly useful for presenting the human experiences embedded within situated action [31], [32]. Given the topic of interest, the why and how of the participant's career transition, a narrative analysis provided an opportunity to explore his actions and the impact of various situations on those actions.

This methodology also aligns with the theoretical framework employed which assists in framing transitions chronologically; similarly, narrative analysis "employs a thematic thread to lay out happenings as parts of an unfolding movement that culminates in an outcome" [31], [32, p. 5]. This connection is further forged by the theoretical framework's use of categories to understand the various ways individuals move through a transition; narrative analysis understands that individuals are not consciously living life event-by-event, rather they reflect back and pull events from the larger structure that is their life [33]. For this study specifically, the narrative of mid-career transition to engineering is the focus of Mac's story. Mac provided an oral history; he reflected on the events that make up his transition to engineering, their causes, and their effects [31].

Study Participant

While the defining population of interest for this work is mid-career individuals who transitioned to an engineering career using an alternative pathway, following a single participant is permitted in narrative analysis [31]. This pilot study follows Mac who specifically transitioned from his career as a fifth-grade teacher to a career as a software engineer; he was known personally by the author, so this aided in the contextual understanding of the stories shared around his experiences. An IRB-approved recruitment email was sent to the individual to invite them to participate.

Data Collection

Despite being a narrative analysis, two one-on-one interviews were conducted with Mac as an adaption of the three-interview series structure used in phenomenological studies [34]. This was done to allow for additional opportunities for Mac to control his narrative and to assist in identifying any need to alter the pilot study's interview protocol for future work. In the first interview, the participant discussed their history and experiences as related to the context of this study, and in the second they clarified past statements and reflected on what they shared. It is this focus on experiences and reflection that mirrored the goals of narrative analysis and therefore encouraged the use of Seidman's work in the structure of the interviews.

The first interview was semi-structured in nature. This format allows for narrative data to be collected while allowing conceptual frameworks to be applied which can assist in maintaining a relevance to the topics of interest [35]. For this study, that means semi-structured interviews assisted with framing Mac's story within Schlossberg's Transition Theory [14] constructs which assisted in theme development and "restorying" in a way that addresses the research question posed [31]. The interview protocol was separated into designated constructs of the conceptual

framework. The questions did not need to be asked in a particular order nor did they all need to be asked [35]. Being a semi-structured interview, the goal was to ask open-ended questions that could be led in a variety of directions by the participant. For this reason, not every question was asked if the participant guided the interview in a way that naturally addressed another question.

As the second interview was conducted as an opportunity for the participant to reflect on the experiences they had shared previously, the interview was unstructured to offer full freedom to the participant. This follows a structure similar to the narrative interview style which initiates reflection by the participant by introducing a topic, withholding interruptions and providing non-verbal encouragement, and encouraging participants to expand on their statements [36]. The protocol for this interview was limited in that it only contains the introduction to the conversation. Both interviews were scheduled for a maximum of one hour. While many narrative analyses can spend extended periods of time with participants and collect various narrative data sources, due to the time available with this participant, data collection was limited to these two interviews [31], [33].

Data Analysis

The procedure for narrative data analysis offered by Creswell & Poth [31] was followed. This began with managing and organizing the data collected by transcribing audio recording and transferring them to Word documents in which they were later coded. A priori codes of "situation," "self," "support," and "strategy" were established as these are the categories provided by the conceptual framework employed, but in vivo codes were welcome to emerge. The texts were read through twice with general notes emerging in the margins which identified the emergent codes "prior" and "after." The third through of the interviews initiated the coding process in which the a priori and emergent codes were used to pull out each quote which represented them best. The codes and their quotes were organized in a codebook for further reference.

Once pools of quotes were made and refined for each code based on the observed patterns, they were put in a "coherent developmental account" [32, p. 15]. This author ultimately decided to imitate the chronological order of transitions offered by Schlossberg's Theory [14]: "moving in to," "moving through," and "moving out of" the transition. This is a very high-level chronological order which allows for a story structure to emerge while maintaining the categorizations offered by the conceptual framework.

With the plot of Mac's story established, the next phase of analysis was the assessment of interpretations. This is where themes were interpreted which represent the major tenets Mac holds about his career transition within each code. Some of these themes were further divided into subthemes. The final phase of analysis is the overall representation of the data which will be offered in the findings. This "restory" is a retelling of what Mac shared which highlights the factors that shaped his experience as a mid-career individual with a non-engineering background who transitioned to an engineering career following an alternative pathway. Along with this comes the context of his lived experience as one cannot avoid the influence of "human purpose and choice as well as chance happenings, dispositions, and environmental presses" [32, p. 16].

Findings

The findings of this study were ordered chronologically; the order is high-level in nature, dividing the phases of Mac's career transition into three: "moving in to," "moving through," and "moving out of" the transition. This aligns with the framing of Schlossberg's Transition Theory [14]. Observing his story in a "before, during, and after" format provides a general chronological structure without require each individual event to be unwound from another happening at the same time and potentially for the same reason.

Moving In

When first interviewing Mac, he quickly began describing the context around *why* he made his career transition. He noted two reasons that impacted his interest in a career shift: dissatisfaction with the field of teaching and interest in technology. Regarding this, he said:

> It was probably a combination of having to deal with being told what to teach and [having it] handed down from the district level. Really kind of taking all the control away from the teachers. We really were just, I don't know if anybody else thinks about it like this, but sort of like a puppet of just saying what you're supposed to say […] that kind of takes away from teaching. I feel like, you know, um, so that was part of it, but also, I was always interested in tech. I learned over the years how much people in tech make. So, you know, you have a teacher salary, then you have somebody in tech making three times that.

Mac's dissatisfaction in his career stemmed from his pay and having to deal with the bureaucracy of the education system. Around this same time, Mac recalled participating in an ultra-marathon which really shifted his perspective on whether he should take the leap of transitioning careers. Mac shared:

> I did an ultra-marathon when I was living in Texas [and it] pushed me to the limits, I guess you could say, of like what's possible, what's not possible. I survived it the first year and then we did it again and we beat our time by like two hours. So, after that, I was like, man, it sounds cheesy, but I can really do anything. And it was after that, I kind of went home and signed up for an online bootcamp.

The shift in Mac's perspective of what's possible, that he "can set goals and, and make them happen now," is what he referred to as "mental confidence." This is something that set the standard for his mindset throughout his career transition.

Moving Through

Situation

Control emerged as a theme from Mac's interviews as an element of his transition that he had say-so over. Being an anticipated transition, Mac had the opportunity to take time understand what it was he wanted to do and how he should go about accomplishing it. He spent "a month

just thinking about where [he] was going […] a month of hard focus, studying, [and] looking" at job listings and educational programs that could help him establish his pathway to a tech career.

The path that he determined would help him reach his goal to join tech as a software engineer required him to put his nose to the grindstone and invest monetarily. Mac landed on a coding bootcamp that was eight months long and $8,000 up front. Regarding why he chose this route, he said:

I definitely looked at master's stuff. I think it might've just been […] price and my overall goals and how they lined up [that influenced] why I ended up at a boot camp instead of higher education […] I think it's less about [a degree] and really more about your portfolio and the work that you're building […] If you can talk about it and show and explain what you did, that's going to be super valuable.

Mac identified a coding bootcamp as the best option for him in terms of accessibility, both in cost and time. He preferred this course as "it was go at your own pace and [he] was still teaching at the time. So [he] would teach and then come home and do that at night." This was important because he need to "still pay bills and keep [the] needle moving forwards." The self-paced course allowed him to pursue his goal in a comparatively inexpensive manner and uphold other time-consuming commitments he had in his life.

Strategy

Once education was identified as his main strategy for achieving his career transition, Mac needed to identify what type of course would benefit him best. He landed on a "a front end and back end, full scale web development bootcamp." He first modified the understanding of what education was required for software engineering when he noticed "[companies] were starting to get less strict about needing that computer science or engineering degree." This shifted his perspective of what education he would need and provided him more readily accessible options to gain the necessary knowledge. Mac shared: "[When I] decided on software engineering, I signed up for [an online] boot camp software engineering full scale, which just means like, front end and back end."

He noted this as being a great option because one did not need programming knowledge to begin, rather a "programming mindset." Leaving this course, Mac felt he had "all the skills [he] really [needed]." Various skills were taught in different modules of the course with Mac noting that the one he held on to most was:

Don't repeat yourself. If I'm building stuff today, I'm trying not to repeat the same code over and over again, you know? Like you can find better ways to do that. Just like overall design, really being thoughtful about your approach [and] if-then statements.

Beyond the technical knowledge picked up, Mac said the other very important outcomes from the online bootcamp was "a portfolio [and] projects that you can point to and say, yes, I built this stuff" and the training he received on what comes after earning the certification. Mac shared:

A whole module [was] just on, like, the job search and […] advertising yourself as a software engineer […] They had us update our [professional profile websites], add connections, update your job title as an engineer […] not a junior software engineer, [but a full] software engineer.

Support

Mentors played a role in Mac's career transition. With his main navigation strategy being online education, he had access to various mentors throughout the bootcamp: "the live people you could talk to were really helpful because you could just, you know, shoot the breeze with them. Like you could just ask them, hey, what should I be looking at for careers after this?" While they offered some insight in their weekly 30-minute video calls, Mac noted that "they give you a different mentor [for each module] […] so that can be challenging. You lose all the context, all the stuff you just built up with this other guy." The bright side he noted was that it helped him learn "how to compartmentalize and solve problems and ask very, very specific questions."

Mac also noted that his bootcamp offered "a whole [coding chat site] [where students] could bounce ideas off other students." He noted that this was a great opportunity for other individuals in the module to navigate problems during the times they didn't have access to their mentors and collaborate on additional projects to build up their portfolios.

Self

Mac's outlook on his situation throughout the transition would oscillate between positive and negative. On the negative side, Mac felt immense levels of stress; on top of learning new material that was imperative to retain for his new career, he felt uncomfortable with how little he knew when he began the bootcamp. He said, "I've never felt dumber than when I was learning. Like honestly, it was so, so humbling." Mac deemed this "imposter syndrome" as those who ran the bootcamp had mentioned this might be a feeling they had.

One the positive side, Mac felt that he had control over his mindset to the point where he could overcome these negatives. His outlook: commitment and tenacity. Regarding the former, Mac said:

If you are dedicated and you're committed to doing the work and you don't play victim, which is very popular these days, [you can do it]. It would've been very easy for me too to say, "I am so stupid at coding, I should give up right now."

Hand-in-hand with that is tenacity which Mac expanded on what it meant to him. He noted tenacity encompassed "resourcefulness [and] just keeping after it [until you] eventually figure it out." He related this back to his experience training for his ultra-marathon and claimed that he encouraged himself and remained consistent by "holding onto some of those, I guess you could call them victories" as he did when he was training.

Moving Out

At the time of his interviews, Mac had completed his transition and has been working in the field of software engineering for several years. His position now, his second since joining the field, is that of senior integration consultant in where he is able to combine the best of his previous career and his new career. Mac believes he "had that education background, and when [he] started looking for jobs, that actually helped [him] out a little bit" as the jobs he enjoys combined "engineering knowledge plus being able to teach people." When asked whether he thought his bootcamp would have prepared him well for a career that was more tech-oriented and less people-oriented, Mac said:

I'm happy with being this liaison between tech and people, you know, talking to people. That's just the teaching plus tech background, it's kind of the sweet spot. But I think I do have enough. It's hard to say […] I know what I would look for if I was looking for a job. I probably wouldn't look for a full software engineering job, I would look for these [engineering] services jobs, like implementation, consultant, implementation engineer, those kinds of things […] I don't think my portfolio's big enough [but] I know a lot of people that did go into hardcore software engineering [straight from bootcamp].

Mac then reflected on his transitional education experience and noted that the only thing he would change would be working in an in-person environment. He thinks:

Going all in, like in person would be great. I think even just being in person with work and stuff, you just learn a lot more just by osmosis, just like hearing people. You can walk to somebody's desk and ask them a question. You can hear somebody say something and now you know it too. Remote work and doing it from the computer isn't necessarily like that. So, if I had to do it over again, I probably would stop, it would be hard, but with teaching, or at least have summer breaks or something, but I would go in person.

While he would have preferred and in-person course, Mac did not necessarily see a formal higher education degree as the answer to this. He commented "that [many large research institutions have] their coding bootcamp [where] but you get real college credits" and thought some of these may offer in-person options. Besides the opportunity to engage with other students in-person, a course like this, "would be an ideal scenario where [Mac] can have some real accredited paperwork [he] can point to." While Mac does not agree that this is always the case, he understands that there is "the assumption [that] a higher education, something from an accredited school is going to hold more weight than a certificate, like a PDF certificate that I printed out."

When asked what advice he would give to someone making a similar transition to him, Mac reiterated the importance of outlook. He said:

I've said tenacity like 20 times, so I feel like I have to say that again! But you really have to enjoy it too. Like if you're forcing yourself to do this and just nothing about it is enjoyable, don't do it. You have to have some kind of motivation to do it. But if you have that and you like it and it's still, it's hard from time to time, but just keep pushing through it because everyone has to deal with it.

Discussion

   This study aimed to understand one participant with a non-engineering background transition to an engineering career following an alternative career pathway. This includes what led to this transition, the personal and educational characteristics that affected his journey through the transition, and how this participant was received in the field as a representation of his exiting the transition. His journey from fifth-grade teacher to a leadership role as a software engineer demonstrates one alternative pathway that is readily available, accessible, and effective. Mac's journey offers insight into the other elements of a mid-career transition that may go unnoticed but that were instrumental to his success. For instance, when actively moving through his journey, Mac utilized Schlossberg's [14] concepts of self and strategy. Within the self, which Schlossberg's theory characterizes as finding a purpose and making meaning of one's transition, Mac emphasized commitment and consistency as the key factors in his success.

   Within strategy, which Schlossberg's theory characterizes as reframing and redefining one's transition, the online bootcamp was Mac's main and most effective tool. By reframing his career transition as a learning opportunity and defining the learning as a necessary step, Mac was able to take passionate and thought-out steps towards his new career. He credited this bootcamp with providing him all the necessary knowledge for his career in which he is now in a leadership position. The format of Mac's bootcamp aligns with a perception that having knowledgeable instructors is often more influential than the format in which the knowledge is delivered [37]. This builds on the work that discusses the certifications offered for professional skills and provides a different perspective of their use: a certification that establishes professions rather than only developing them [22], [23]. Mac's story also challenges the notion that a bachelor's degree in engineering is the baseline requirement for engineering fields [19].

Conclusion

   As a mid-career transition-er, Mac was well on his way to living his life; he had a stable career, a wife, newborn child, and bills to pay. Alternative pathways offer a way for individuals to circumvent barriers to careers. For instance, those in the mid-career phase of life often do not have the luxury of spending four years and thousands of dollars on their education. Mac was able to modify this requirement by identifying an alternative form of education, an online bootcamp, that would leave him with the necessary skills and portfolio for a software engineer.

   One limitation of this study is the effects of retelling one's story. Mac's recollection of his career transition is colored by hindsight from the position of someone who successfully transitioned careers. Additionally, it is the first author who is attempting to then "restory" Mac's recollections. Due to these factors, there may be a disjunction between what Mac experienced at the time, what he remembers now, and the way his story is represented here. Another potential limitation to this study's ability to address the issues presented in the introduction is the hyper-specificity of Mac's story. Being that it is *his,* there is no expectation of Mac to provide insight into other people's experiences. By using his story, it should be acknowledged that while he fulfills the criteria of an individual with a non-engineering background who made a mid-career transition to engineering following an alternative pathway, he is more specifically an individual

who transitioned from being a fifth-grade teacher to a software engineer after six years using an online bootcamp. His story is only one perspective of this topic but is nevertheless helpful in beginning to explore alternative pathways to engineering.

While Mac's journey reflects a unique combination of personal attributes such as his "mental confidence" shaped by ultra-marathon experiences, this specificity highlights the diverse factors influencing individual transitions. Not every mid-career professional will possess the same level of resilience or resources. However, this pilot study demonstrates how Schlossberg's Transition Theory and narrative analysis can frame such distinct experiences, offering a structured lens through which future research can capture a broader spectrum of transitional stories. Recognizing both human agency and the role of unforeseen events ("human purpose and choice as well as chance happenings" [32, p. 16]) is essential when expanding this work to more generalized populations.

By focusing in depth on Mac's journey in this pilot study, the various factors that shaped his transitional experience from teaching to software engineering emerged which provide a fuller understanding of the potential benefits and challenges one may face when following an alternative engineering pathway. A future research goal of collecting more stories of mid-career transition-ers to engineering can then be compared to one another, ultimately creating a mosaic of experiences that may potentially provide insight into the various ways individuals may circumvent barriers to an engineering career and what they entail. Mac's success in transitioning careers, while not representative of every transition-er, does provide insight into the many factors and experiences that make up a career transition that could be similar to others' stories. Specifically, Mac's story is the first step in understanding the commonalities and differences across the currently available alternative pathways.

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