Trust me, I'm an Engineer: Exploring engineering Identity and concepts of expert versus novice in the aerospace engineering industry

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Abstract

In this work in progress, we explore what skills and experiences help engineering graduates transition from novices to expert engineers in industry. To achieve success in industry, recent engineering graduates may rely on applying tools from their undergraduate education related to problem recognition and asking questions when they lack expertise. By contrast, senior engineers emphasize that soft (professional) skills like being able to lead a team and proficiency in change management are central to career advancement. This difference in perspective exists because entry level engineers are novices while senior engineers are experts. The goal of this study is to identify how the transition from the novice stage to the expert stage can be expedited. To do so, the researchers will be interviewing engineers at six different aerospace companies with four to twelve years of work experience who fall somewhere between the expert and novice stages. Interview questions will cover what challenges they faced entering the workplace, how they tackled them, and what made them feel like engineers during this process. These interviewees were chosen because they have graduated from universities recently enough to remember their undergraduate experiences but also have worked long enough as engineers to have perspective on what was challenging and what was easy about entering industry. Existing literature focuses on entry level and seasoned engineers, leaving the population in this paper largely unstudied in terms of what contributes to building their identities as engineers. In person and virtual interviews will be conducted and recorded to generate an audio transcript that will be thematically analyzed through inductive and deductive coding. Prior work done by the researchers suggests that peer mentorship and robust onboarding practices will be mentioned as critical to success in industry. Additionally, the team anticipates that milestones related to technical work will be cited as experiences that made interviewees "feel like engineers". Broader implications for the results of this study are to help engineering faculty and engineering managers understand what helps students and young professionals identify as engineers earlier in their careers.

Introduction

Experts in any field "develop through years of experience and by progressing from novice, advanced beginner, proficient, competent, and finally expert" [4]. To understand the difference between a novice and an expert, a study examined how different individuals examined an aquarium. The population consisted of middle school students, teachers, and aquarium specialists. Results indicated that "novices' representations focused on perceptually available, static components of the system, whereas experts integrated structural, functional, and behavioral elements" [3]. Looking at engineering, the same idea applies; expert engineers are those that understand how the elements of a given system operate together, whereas the novice engineer will see individual parts of a system and observe their standalone functions. An example would be looking at a hydraulic schematic: the novice engineer sees a bypass valve, a check valve, and a pressure switch, while the expert engineer will understand why the three components must work together to direct hydraulic fluid as intended. While engineers with any position title can be an expert or a novice, the title itself can also influence how an engineer feels about their role and value in the workplace [5], but the groundwork is laid out in school. Engineering identity is formed for engineers through their experiences in engineering, typically while still in college [6]. Influences on identity can include things like internship experience and representation, particularly in the case of female engineering students, who cited having female role models as a source of inspiration [7][8][9]. Even referring to students as 'engineers' is important in developing their perception of themselves and reassuring them that they belong to a larger community of STEM professionals [10]. Beyond these factors, universities have set up specific undergraduate experiences like research and senior design to provide their students with a sense of community [11][12].

Literature Review

Undergraduate research opportunities provide students with a place to learn and feel more connected to their majors. Universities are tasked with taking high school students and transforming them into professionals with leadership prospects in the span of approximately four years. Making them competent requires experience beyond the passive learning that often comes in lectures. Research forces students to take initiative, normalize failures, and take pride in their work when they use engineering tools to make discoveries [13]. A study done by Tri-State University found that additional benefits of participating in research include "increasing [students'] confidence level towards scientific research, improving their attitude towards [their chosen] topics, and their written and oral communication skills. They also gained experience in "obtaining information from manufacturers and ordering research equipment" [14]. Most of the participants in the aforementioned study even went on to attend graduate school. The combination of research skills and an advanced degree resulted in higher wages, with the Bureau of Labor Statistics indicating that the weekly salary of people with master's degrees is on average $244 higher than those with bachelor's degrees [15]. Undergraduate research can even reach an international scale, such as in a 2017 study that allowed students to perform testing on different species of African wood to determine what material was best suited for construction in developing nations [16]. This study left students with "an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors" - one of the key student outcomes outlined by The Accreditation Board for Engineering and Technology (ABET) [17]. Research prepares students for the real world by improving their communication abilities, understanding of the research process, and connecting them to a global community in order to prepare them for entering the workforce. Undergraduate design projects are another way for students to hone their professional abilities.

In addition to undergraduate research, engineering students seek out opportunities for professional growth like senior design, and recent literature indicates that these design teams generally prepare them to begin their first year of work [18]. Students found that activities like participating in team meetings, project planning, and generation or refining of concepts on design teams were the activities that carried over into the workplace. An analysis of engineering job descriptions revealed that companies most frequently seek out students who are capable of problem solving, another skill reinforced by senior design [19]. The same study found that proficiency with computer aided design software and Microsoft Office were the most desirable technical skills sought out by engineering companies. Senior design projects also play a role in the development of engineering students' professional skills by engaging in presentations and collaborating with other students [20]. Professional (previously called soft) skills include reliability, teamwork, self-motivation, and a positive attitude, and have become the deciding factor in hiring and promotion at some engineering firms [21]. While senior design projects are generally serving students well, they still strive for constant improvement, such as in areas of project budgeting and increasing industry relevance, relying heavily on the desire of faculty to adopt new best practices [18] [22].To become more effective future employees, students gravitate toward senior design experiences, but achieving the professional development they seek depends largely on how the team forms and functions.

When it comes to teams, two types have been identified: high performance teams and teams that simply work well together. The difference between them is that high performance teams "focus on project objectives and take responsibility for achieving these objectives" while the latter type's performance is less strong when trying to aggressively tackle problems [23][24]. Professors can facilitate high performing teams by assigning teams based on diverse skill sets of students instead of letting students choose their teammates, thus making teams more effective [25]. Still, both types of teams appear in industry environments and exposure to each kind better prepares students for what they can expect in the workplace. Another critical area influencing the performance of both a school project team and a work team is the psychological safety perceived by group members [11].

Like senior design, a safe psychological climate in the workplace is critical to employee retention and scientific innovation. Employees that feel more psychologically safe are more likely to continue with a job, even if resources are stretched thin, thus helping to mitigate turnover and allowing them to build more expertise in a given field [26]. In engineering jobs specifically, a study in Nigeria found that there is "a tangible connection between robust psychological safety and heightened problem-solving abilities, amplified creativity, and a greater willingness to take risks" [27]. These three outcomes enable more innovative design breakthroughs to occur, meaning employees are better equipped to address the engineering grand challenges of the 21st century which have been outlined by the National Academy of Engineering [28]. The benefit of psychological safety in work environments is very clear, and further research has been done on what factors contribute to the comfort of employees. Studies performed with workers outside of the engineering industry suggest that ensuring employees have a work-life balance, showing employee appreciation, and strong relationships with co-workers all contribute to retention and psychological safety [29][30]. An investigation on agile software development teams indicates that psychological safety is fostered through clear leadership and collective decision making which make for more "openness" on teams [31]. High levels of psychological safety are especially important for retaining women in male dominated industries and executive level positions [32][33]. To the author's knowledge, little literature exists on what contributes to the psychological safety of engineers, male or female, in the aerospace industry specifically- a gap this study potentially aims to address.

Even before leaving school, students begin to feel anxiety about joining the workforce. Their concerns tend to fall into 3 categories: career, change and loss, and finding support [34]. Jumping from an academic environment into an entry-level engineering job is perhaps the biggest leap for graduating students since choosing to attend university, meaning they anticipate challenges with the areas previously mentioned. However, some challenges only become apparent after they have started. A study performed using interviews with seventeen Lebanese students working in engineering identified communication, responsibility, [and] self-confidence as the main struggles they faced while on the job [35]. Additionally, a study done in 2015 found that in terms of technical aspects, engineers most often struggle with "learning complex and fundamental concepts through simple problems, students having difficulty combining knowledge from different courses to solve realistic scenarios, or the lack of time students have to master these concepts" [36]. This leads to what Rhinehart identifies as a two-year gap for the engineer to be fully onboarded, once again highlighting the difficulty in helping recent graduates transition from novice to expert [37]. The aerospace industry especially has unique challenges due to the critical standards for assembly and safety that hardware must abide by. In 2022, researchers at Iowa State University conducted interviews with 26 entry level aerospace engineers, with each university lasting approximately an hour. The team developed a codebook to perform deductive and inductive coding on each interview transcript. The results indicated that 15 main challenges exist for entry level aerospace engineers and the participants were able to provide 13 solutions. The 15 challenges fell into four categories: intrapersonal obstacles, interpersonal obstacles, organizational obstacles, and third-party obstacles, and they ranged from difficulties obtaining the proper security clearances to understanding their job scope. Other difficulties included dealing with inefficient and outdated work practices, age or experience gaps with coworkers, personality barriers, and a general lack of engineering knowledge [38].

Extensive investigation has been done to better understand the experience of students from undergraduate study to their first jobs. Numerous surveys have been conducted on what they find helpful, where they struggled, and their identities as engineers. Some studies take the angle of understanding what is missing in undergraduate coursework by interviewing veteran engineers. However, a group whose perspective has largely been overlooked in this realm is what this study will refer to as "early-mid career" engineers- engineers who have been working for 4-12 years. These engineers have worked long enough to overcome the novice stage, so they have enough hindsight to identify what was truly challenging and what was just a difficulty that came with being new. At the same time, their university years were recent enough that they remember what the curriculum and environment was like. This group of engineers has been taught with much of the same technology as students who are just coming out of school so their comfort with modern technology is comparable to that of fresh graduates. The objective of this study is to understand what early-mid career engineers wish they learned in school, what the biggest difficulties are in joining the work place, and how courses should be set up to minimize the time it takes students to transition from novice to expert in industry.

Research Questions

This study is motivated by the following research questions:

R1. What types of workplace experiences do engineers encounter in their early-mid careers that make them feel accomplished?

a. Are there commonalities between experiences/accomplishments among people in this early-mid career stage which signal to engineers that they are transitioning from a novice to an expert?

R2. How do mid-career engineers approach workplace challenges as compared to new engineers?

R3. Do new engineers feel prepared for the challenges faced in entering the workplace?

b. If so, what aspects of their education helped them prepare?
c. If not, how could their education have better prepared them?

Research Methods

This section provides information on the study population, data collection, and how the data will be analyzed.

Study Population

Individuals contacted for participation in this study had to meet three criteria: have four to twelve years of experience working as an engineer, currently work in the aerospace industry in southern California, and hold a degree in a STEM related field. Restrictions were not placed on undergraduate institution attended or the specific major studied to allow for analysis of unique perspectives and to enable the formation of recommendations that are applicable to more universities. The researchers interviewed individuals from seven different aerospace companies, again, to ensure the results of this study are relevant to multiple workplaces. In total, three female engineers and ten male engineers will be included by the end of this study. Seven engineers have been interviewed to date. General participant identifiers are tabulated in Table 1.

Interviewee Number	Undergraduate Major, Institution	Years of Work Experience	Current Job Title
1	Mechanical Engineering, Purdue University	5	Avionics Engineer II
2	Chemical Engineering, University of Michigan	5	Industrial Engineer II
3	Mechanical Engineering, University of California Los Angeles	5	Hydraulics Engineer II
4	Mechanical Engineering, Cal Poly San Luis Obispo	6	Senior Manufacturing Engineer
5	Mechanical Engineering and Material Science and Engineering, University of California Irvine	5	Engineer III
6	Applied Math, Cal State Long Beach	12	System Engineer II
7	Mechanical Engineering, Caltech	5	Engineer II
8	Mechanical Engineering, Cal State Long Beach	5	Engineer III
9	Aerospace Engineering, Rensselaer Polytechnic Institute	5	Engineer III
10	Mechanical Engineering and Aerospace Engineering, University of California Irvine	10	Project Engineer

Table 1: Interview participants.

Data collection

Data for this study is being gathered through interviews. Interviewees have the option to select an in-person or virtual format, and interviews are recorded via UC Irvine's Zoom tool to generate an audio transcript. The interviews last thirty minutes to an hour and are all being conducted by the authors. Participation in the study is uncompensated and voluntary; the interviewees are informed prior to the interview that they may decline to answer a question or opt out at any time. All data is collected with the approval of the university's Institutional Review Board. Each individual is interviewed using the same questionnaire, heavily drawing on the questions asked in [1].

Interview Questions

Q1. Tell me a little bit about your job.

a. What are your typical responsibilities?

b. On a scale of 1–10, how prepared do you feel for these responsibilities?

Q2. Think back to your first engineering job after graduating.

a. What were your typical responsibilities?

b. On a scale of 1–10, how prepared did you feel for those responsibilities?

Q3: What was your biggest challenge entering industry?

a. What made it so challenging?

b. How did you approach this particular challenge?

c. To what extent did you feel prepared for this challenge based on your capstone/senior design experience? Based on your other experiences?

d. Is there anything you think your education might have done that would have better prepared you?

Q4: Were there other challenges at work that you felt particularly well or poorly prepared for? If so, please explain.

Q5: What was your most significant accomplishment since starting your career?

a. What made it significant?

b. Did anyone help you in achieving this accomplishment? If so, how did they help?

c. To what extent did you feel prepared for this accomplishment based on your capstone/senior design experience? Based on your other experiences?

Q6: Have there been any major changes in your job responsibilities since starting your career?

Q7: Looking back over the course of your career, were there any things in particular you did or experienced that made you feel like an engineer?

Data Assessment Methods

To analyze the data, the authors will utilize inductive and deductive coding and build a codebook to categorize interview responses. Inductive codes are codes that the researchers expect to see in the data and are thus defined prior to analysis. By contrast, deductive codes are themes discovered during the process of data analysis.

Prior to any qualitative analysis, the Zoom audio transcripts will be checked against the audio recordings to ensure they are accurate. Next, the authors will individually analyze one of the transcripts and compare their results to verify interrater reliability. After the researchers are aligned in their understanding of how each code should be applied, they will read and code the remaining transcripts. It is at this point in the process that the deductive codes will be generated.

Currently, the inductive codes being applied in this study are intrapersonal obstacles and solutions or accomplishments, interpersonal obstacles and solutions or accomplishments, and organizational obstacles and solutions or accomplishments. This preliminary codebook is a synthesis of the inductive themes identified in [38] and [1]. Deductive codes will likely include technical ability, professional skills, engineering tools/software, and mentorship.

Preliminary Results and Future Plans

Preliminary Results

Based on the literature review and the authors' previous work, we expect that participants will highlight technical accomplishments as their most significant achievements since starting their careers. In general, the results related to achievements are consistent with this expectation; the participants have stated that finding a solution to a technical challenge was a key accomplishment. Interestingly, it was the lasting impact of their solution that made it significant, as opposed to it being applicable to a single instance. The most significant obstacles to date seem to be more related to professional skills, but there is more variation than expected in the specific skills that participants struggled with. The final question of the survey asks the subject what has made them "feel like an engineer". One unexpected finding was that the participant with the most work experience stated they still did not feel like an engineer, in part because, despite their job title, their undergraduate degree was not in engineering. This opens a new discussion about how the word "engineer" may hold more weight to professionals than their specific job title or level.

Future Plans

Once all thirteen interviews are complete, the team hopes to provide a better understanding of what creates the engineering identity of mid-career professionals and how those factors can be instilled in engineers earlier in their career or during their undergraduate education. The researchers also hope to include narratives and direct quotes from the interviews to allow the participants' voices to be more central to the paper.

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