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'I think it's probably one of the most important skills we could ever know': insights from early-career engineers on the preparedness of undergraduate degrees for the aerospace industry

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ABSTRACT

Engineering education has evolved significantly in recent years, however, engineering graduates continue to encounter challenges during their transition to the workplace. There is a need to identify graduates' needs and gather their input regarding engineering education programs to enhance the preparation of engineering students for the workplace. This study examined how early-career engineers perceive their undergraduate engineering programs in preparing them for the workplace. Additionally, it investigated what domains the engineers identify for improvement in engineering programs. In this multiple-case study, we interviewed 26 early-career engineers from seven organisations in the Aerospace and Defense industry across the U.S. We employed open coding to examine their responses and derive common themes. The findings showed that early-career engineers view technical knowledge and skills, persistence, and personal development instilled through their programs as valuable takeaways. However, they also highlighted the need for teaching professional skills, fostering collaboration between different engineering departments, promoting lifelong learning, and enhancing collaboration between academia and industry. The findings highlight areas in which engineering education and organisations can collaborate to better prepare students for the workplace.

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Introduction

Over the years, engineering education has undergone significant changes, reflecting the growing interest among educators in shaping the future of the field and equipping students with the necessary skills for the workforce. Despite these efforts, a major gap remains between industry demands and engineering education (Broo et al. 2022). The evolving nature of engineering roles has made current programs less effective in preparing graduates for employer needs, compounded by teaching methods that do not align with industry demands, leaving graduates unprepared for modern job roles (Cuckov et al. 2022). As engineering roles continue to be influenced by societal, cultural, and

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technological shifts globally, there is a need for engineering programs to reconsider how to equip engineering students with technical and professional skills to changing work environments (Jonaitiene et al. 2023).

This study aims to enhance the preparation of engineering students for the Aerospace and Defense (A&D) industry by providing insights and recommendations from early-career engineers to address discrepancies between academic and industry expectations. As the A&D industry grows and evolves, driven by market trends and technological disruptions, it must adapt its talent strategies to shifting demographics and workforce expectations (Hall and Akbari 2023). This research addresses the following questions: 1) How do early-career engineers believe their degree prepared them for their engineering position, including experiences such as curriculum content, co– and extra-curricular activities, and professional development events? 2) What recommendations do early-career engineers provide for changing undergraduate engineering programs to better prepare students for the A&D industry?

We hope this study benefits students through peer insights, supports educators in understanding engineering practice and reevaluating their teaching based on real-world needs, and offers early-career engineers a platform to share their experiences. Additionally, it aims to foster collaborative opportunities for engineering education programs and engineering organisations to improve engineering education and facilitate the integration of engineers into the workforce.

Literature review

> We are currently preparing students for jobs that don't yet exist, using technologies that haven't been invented, in order to solve problems we don't even know are problems yet.
> –Richard Riley, Former US Secretary of Education,

This insight underscores the rapid technological advances, including automation and artificial intelligence, compounded by disruptions like the COVID-19 pandemic, which have drastically shifted the job market. The World Economic Forum reports that 60% of organisations identify skill gaps as the primary barrier to business transformation, necessitating a focus on reskilling and upskilling employees (Di Battista et al. 2023). Over the past century, engineering education has evolved from hands-on practice to incorporating more science and theory-based curricula, integrating cutting-edge technologies, and adopting social sciences pedagogies (Froyd, Wankat, and Smith 2012). However, as technology progresses and new job roles develop, there remains a critical ongoing need to reassess and update curricula to ensure that graduates are fully prepared for the challenges and opportunities they will face in the future workforce (Fan 2021). This emphasises the importance of continuously evaluating whether current engineering programs adequately equip students for their professional lives after graduation.

Essential skills for engineering graduates

Studies examining the disparity between university education and industry requirements reveal a notable skills mismatch. Brunhaver et al. (2018) and Jager and Pott (2022) found that young engineers primarily acquire professional and organisational knowledge and skills on the job, while their technical knowledge is gained through school. Roy et al. (2022) identified that recent graduates in the A&D industry need to acquire new technical and professional skills at work, including software usage, data analysis, test procedures, and communication, managerial, and writing skills. This highlights the misalignment between academic curricula and industry demands.

As engineers gain experience, the emphasis shifts from technical expertise to professional skills, highlighting the growing importance of non-technical skills in career progression (Brunhaver et al. 2018). Research by Male (2010) supports this transition, showing that experienced practitioners and supervisors value a balance of technical and non-technical skills, although teaching the latter poses challenges due to their perceived lower status within academia.

Prior research has documented the skills practitioners find useful and need in professional practice (Anderson et al. 2010; Froehle et al. 2022; Passow and Passow 2017). These studies identify crucial workplace skills such as professionalism, teamwork, problem-solving, creativity, and communication. In a systematic review, Passow and Passow (2017) highlighted essential skills including design and problem-solving, applying technical knowledge, collaborating with coworkers, clients, and suppliers, and managing performance. They emphasised that technical and non-technical skills are inseparable and should be taught concurrently.

The only initiative specifically addressing aviation skill needs is the International Civil Aviation Organisation's Next Generation of Aviation Professionals (NGAP). This initiative aims to ensure a sufficient supply of qualified professionals for the future international air transport system and is supported globally by various aviation stakeholders (Lappas and Kourousis 2016). Additionally, the New Skills for New Jobs (NSNJ) initiative in the European Union aims to address the skill needs in the labour market by improving the level, quality, and relevance of citizens' skills, promoting job creation, economic growth, and greater competitiveness, while also fostering innovation and social cohesion (European Commission 2010).

To better prepare students for the engineering workforce and bridge the current gap, it is suggested that engineering programs focus on life-long learning, transdisciplinary education, human–computer interaction, sustainability, resilience, and digital fluency (Broo et al. 2022). Given the rapid transformations in social, economic, political, and technological arenas, it is crucial for students to develop not only technical skills but also emotional, social, and ethical skills (Jonaitienė et al. 2023). The Organisation for Economic Co-operation and Development (OECD) Learning Compass 2030 highlights the importance of cognitive, metacognitive, social, emotional, physical, and practical skills for the twenty-first century. Additionally, skills such as innovation and creativity are increasingly vital in the workplace as the world evolves rapidly (Ghassoul & Messaadia 2023). These findings indicate that a holistic educational approach is required to address the skill gap and ensure that engineering graduates are proficient in the technical and non-technical skills essential for success in the evolving industry.

Changes in engineering programs recommended by recent graduates

Several studies have investigated what aspects of the undergraduate engineering experience should be revised based on feedback from recent graduates. Anderson et al. (2009) asked recent engineering graduates what lacked in their undergraduate education and found that graduates frequently mentioned hands-on activities, real-world problem-solving, business skills, and technical communication. Echoing this, Jager and Pott (2022) reported that graduates advocated for a stronger emphasis on financial, economic, and business content, enhanced industry connections, and greater focus on leadership, management, and interpersonal skills, recommending the integration of these skills into the curriculum before entering professional practice.

Further research by Martin et al. (2005) and Pott and de Jager (2021) supported these findings. Graduates identified leadership, practical preparation, management, and working with people from multi-disciplinary backgrounds as skills that need to be better nurtured during undergraduate programs. These findings collectively highlight a significant disconnect between engineering curricula and industry demands. Importantly, the skills identified as lacking by graduates are also considered critical by employers (Nair, Patil, and Mertova 2009). Thus, it is important to continually consider recent graduates' recommendations to enhance engineering training and better align educational outcomes with professional expectations.

Challenges during the transition to industry

Graduates still face significant challenges when transitioning to industry. The call to bridge the gap between university curricula and industry requirements remains strong (Trevelyan 2019). Previous research shows that graduates go through significant learning processes during the transition from school to work (Gewirtz and Paretti 2021; Lutz and Paretti 2021). This can be attributed to the contextual differences between the educational system and industry. These differences, as highlighted by Bjørn and Ngwenyama (2009), are multifaceted; industrial organisations focus primarily on the usefulness of products and technologies, whereas educational settings prioritise learning and reflection. Additionally, there are differences in hierarchy, leadership, resources, and reward systems between industry and education.

During the transition period, graduates face learning at the organisational, workgroup, and interpersonal levels in the social and cultural dimensions of the workplace, including forming relationships and navigating power structures (Lutz and Paretti 2021). Research by Kovalchuk et al. (2017) indicates that both curricular and co-curricular activities contribute to graduates' successful transition from school to employment. These findings highlight the significance of context, student activities, and social and cultural elements in the adaptation of new engineers to professional settings. In turn, there is a strong need to focus more on these dimensions in engineering education. The studies suggest enhancing the engineering curriculum by integrating social and contextual aspects to bridge the gap between academia and industry, thereby better preparing students for their transition to professional environments.

Another factor that contributes to the challenges in graduates' transition from academia to the professional world is how engineering students perceive engineering practice. Research indicates that students often see a divide between how engineering is practiced in school and in the workplace (Girotto and Oliveira 2022; Itani and Srour 2016). In academic settings, students typically prioritise mathematical and scientific skills, often underestimating the importance of collaboration and teamwork. However, recent graduates soon realise that collaboration, teamwork, and communication are, in fact, essential attributes in the workplace. Further insights from Bae, Polmear, and Simmons (2022) suggest that students frequently develop vital non-technical skills such as leadership outside the formal curriculum, attributed to the heavy emphasis on technical knowledge within engineering courses. These studies suggest that students often do not fully understand how school and engineering practice are interrelated. While they recognise the importance of professional and interpersonal skills, they do not see their relevance to actual practice. This gap highlights the need for educational reforms that integrate professional skills training into engineering curricula, preparing students more effectively for the workplace.

While most of the studies highlighted above concentrated on various engineering disciplines and industry contexts, they lacked a specific focus on the A&D sector. This study aims to investigate how undergraduate engineering programs prepare students for the workplace in the A&D industry, drawing on the insights of early-career engineers currently employed in this field. Specifically, we seek to determine which skills and knowledge these engineers believe were well-taught or need further emphasis in their education.

Method

Context

The A&D industry, a major sector employing over 2.2 million workers and influencing nearly 30% of U.S. economic activity, is expected to grow by 6% from 2022 to 2032 (Aerospace Industries Association 2023; the U.S. Bureau of Labor Statistics 2024). Similar to the U.S., Europe plays a crucial role in the A&D industry, hosting some of the largest companies. Europe, North America, and Asia-Pacific are projected to be the largest markets for the A&D sector between 2020 and 2039 (Placek 2024). Despite its significant impact, the industry struggles to attract, retain, and develop talent and is not often seen as a top choice for graduates. A&D employees are less likely to recommend their workplaces compared to other industries, indicating a need for better employee experiences and retention strategies (Hall and Akbari 2023). Additionally, the A&D industry is anticipated to experience significant retirements as its current workforce age (Kosmatka 2017).

In 2022, 50,000 positions in the A&D sector remained unfilled in the U.S. (Chewning et al. 2022). Europe faces a similar trend, with only 10,000 engineers choosing to work in the A&D industry out of 120,000 graduates (Thompson 2017). Additionally, a report by the Aerospace Industries Association (2023) highlights that the A&D industry is less diverse than the U.S. workforce as a whole, with a low percentage of women (25.6%) compared to all industries (47%) in 2022. To address these challenges, recommendations include collaborating with colleges on innovative training programs, expanding career development opportunities such as internships and apprenticeships, and fostering cooperative research agreements with leading research universities (Berckman et al. 2024).

Despite the size and impact of the A&D industry, research into graduates' perceptions of their education and workplace experiences is limited compared to other engineering fields. Additionally, Aerospace undergraduate programs have experienced a notable surge in interest and enrolment numbers following technological advancements and emerging prospects in both industry and government sectors. Despite being labelled the 'Aerospace and Defense' industry, companies operating in this sector hire professionals from a spectrum of engineering backgrounds, thereby establishing it as a multidisciplinary sector, that draws on knowledge from various disciplines while maintaining their distinct boundaries. Our decision to focus on participants from the aerospace field is based on the limited research on this sector compared to other engineering disciplines regarding the transition from academia to industry. Additionally, the A&D sector faces a growing demand for employees and lacks sufficient studies on graduates' first three years in the workplace. Thus, this study aims to fill these gaps by exploring how graduates in the A&D industry perceive their educational preparation and workplace experiences.

Participants

As part of a larger study, 26 early-career engineers were recruited from seven organisations in the A&D industry across the U.S. The participants included 15 male and 11 female early-career engineers, each with fewer than three years in a full-time position and experience in A&D companies. They held degrees in engineering and science from U.S. universities. The participants represented a diverse range of job titles, including quality engineer, project engineer, software engineer, systems engineer, manufacturing engineer, industrial engineer, and rotational engineer. The participants' companies serve various industries, including commercial and business aviation, military and defense, space, airports, air traffic management, energy, and intelligence. While all are focused on aviation, space, and defense, some also offer services in cybersecurity and maritime operations. Table 1 provides participant demographic information.

Data collection

This qualitative research employed a multiple-case study design (Yin 2009). The multiple-case research design allows researchers to conduct an in-depth inquiry into multiple cases and compare patterns of phenomena across cases. A case is typically a specific entity that serves as the primary focus of analysis, such as an individual, organisation, event, or phenomenon, and guides the data collection and analysis process (Yin 2012). In this study, each participant represents a case.

Prior to the participant recruitment, the researchers obtained approval for the study from the local institutional review board (IRB 19-529). For participant recruitment, we re-established connections from previous collaborations and engaged with industry board members from a very high research-activity university who distributed our recruitment flyers to their employees and human resources personnel. The industry board included professionals employed across various companies. We also asked participants to share the flyers with employees in their companies and personal contacts.

Alumni input has proven to be a useful tool for engineering curriculum development (Saunders-Smits and de Graaff 2012). Therefore, we interviewed early-career engineers with less than three

Table 1. Demographic information of the study participants.

Demographic characteristic	Participants ($n = 26$) A&D companies ($n = 7$) Universities ($n = 9$)
Gender	
Male	15
Female	11
Race	
White	23
Hispanic, Latinx, or Spanish origin	2
Asian	1
Employment duration (months)	
1–5	7
6–10	6
11–15	3
16–20	8
21–25	1
26–27	1
Undergraduate degrees	
Aerospace Engineering	14
Mechanical Engineering	5
Industrial Engineering	5
Computer Engineering	1
Computer Science	1
University location in the U.S.	
Midwest	3
Northeast	3
West	2
South	1
University type (according to the CC)	
Very high research-activity universities	6
Higher research-activity university	1
Doctoral university	1
Master's university	1

Note. *CC = Carnegie classification.*

years of employment, a critical period during which they form perceptions of their role and organisation, learn job requirements and expectations, and are the most aware of differences between school and industry (Korte, Sheppard, and Jordan 2008). Semi-structured interviews were conducted online and in-person in the fall of 2019 and spring of 2020. Each interview took an hour on average and was audio recorded.

Participants were asked questions including how successful their undergraduate programs were in preparing them for their current positions and what should be improved in engineering programs to better prepare students for organisational entry (see the appendix for the interview questions). Follow-up or clarifying questions were asked when participants provided a short response or did not answer the question. Each participant filled out a demographics survey before the interview and was given USD 99.99 for their time and participation.

Data analysis

All interviews were transcribed verbatim by an external transcription service. The transcripts were analyzed following Saldaña's (2016) open-coding approach. All transcripts were thoroughly reviewed by the researchers and an initial codebook was collaboratively developed. The initial stage of code development involved an in-vivo approach where we directly extracted codes from the participants' verbatim responses. These codes were then refined after a careful examination of each transcript. For instance, some initial codes related to RQ2 included *networking skills, communication, technical writing,* and *professional behavior in the workplace*, which were subsequently grouped under the broader code of *professional skills*. Some codes remained as the actual language

Table 2. Codes used in the study.

Category	Codes
Experiences in school that prepared them for the workplace	• Teaching of fundamental engineering knowledge & skills • Student development resources ○ Career service resources ○ Seminars ○ Student organisations ○ Internships • School contributed to personal growth and persistence
Recommendations to better prepare students for the workplace	• Collaboration between engineering programs • Software skills • Professional skills • Lifelong learning • Hands-on practice • Diverse experiences & knowledge • Teamwork among engineering students • Partnership between school and industry

used by the participants; other codes were refined, rephrased, or expanded as we analyzed the transcripts. A codebook was developed through several coding iterations by carefully examining the transcripts and refining the codes. Table 2 shows the final codes used in the study. The first author coded the transcripts; the second author independently reviewed the coded transcripts to address any discrepancies.

To ensure consistency in the coding process, weekly debriefings were conducted to resolve any disagreements between the researchers and revise the codebook accordingly. All coded transcripts were reviewed after the initial coding to ensure accuracy and consistency. Our overarching goal throughout this process was to identify and synthesise common themes emerging from the participants' responses. This involved identifying similarities and differences between the transcripts to ensure a comprehensive understanding of the data. The themes were developed based on the codes recorded in the codebook. For instance, the codes *collaboration between engineering programs, teamwork among engineering students* and *partnership between school and industry* expressed a concept of collaboration and became a major theme (theme 1 under RQ2). We followed Braun and Clarke's (2006) definition of themes, meaning our themes highlighted significant aspects of the data concerning the research questions and represented patterns of response or meaning within the dataset. We did not rely on quantifiable measures, as suggested by Braun and Clarke (2006), but focused on whether a theme captured something important in the data. We used MaxQDA Analytics Pro (2022) to code the transcripts.

Results

In this section, we present and discuss the themes that we identified from the participants' responses. Figures 1 and 2 summarise the themes in relation to research questions 1 and 2, respectively.

How do early-career engineers believe their degree prepared them for their engineering position?

Theme 1. Engineering degrees provide fundamental technical knowledge and skills needed in the engineering industry.

Twenty-five participants agreed that their undergraduate engineering program helped them gain fundamental technical knowledge and skills, including domain knowledge and problem-solving, critical thinking, and creative thinking. Those who stated that their program covered the 'basics'

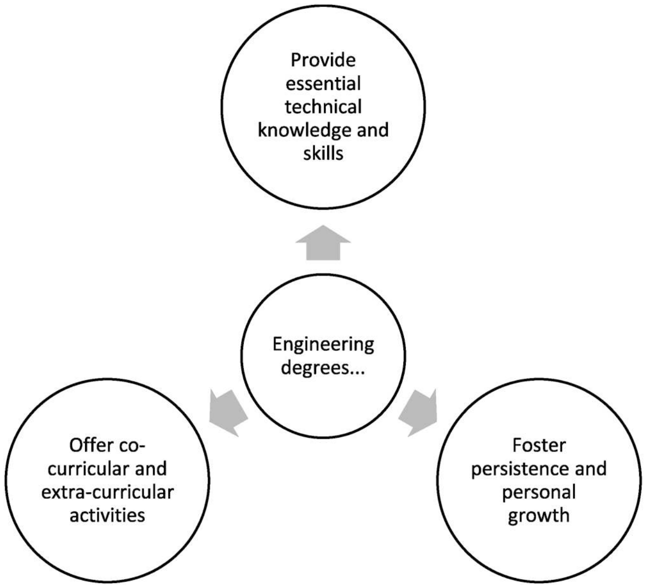

Figure 1. Key themes concerning how undergraduate degrees prepared early-career engineers for their A&D workplace.

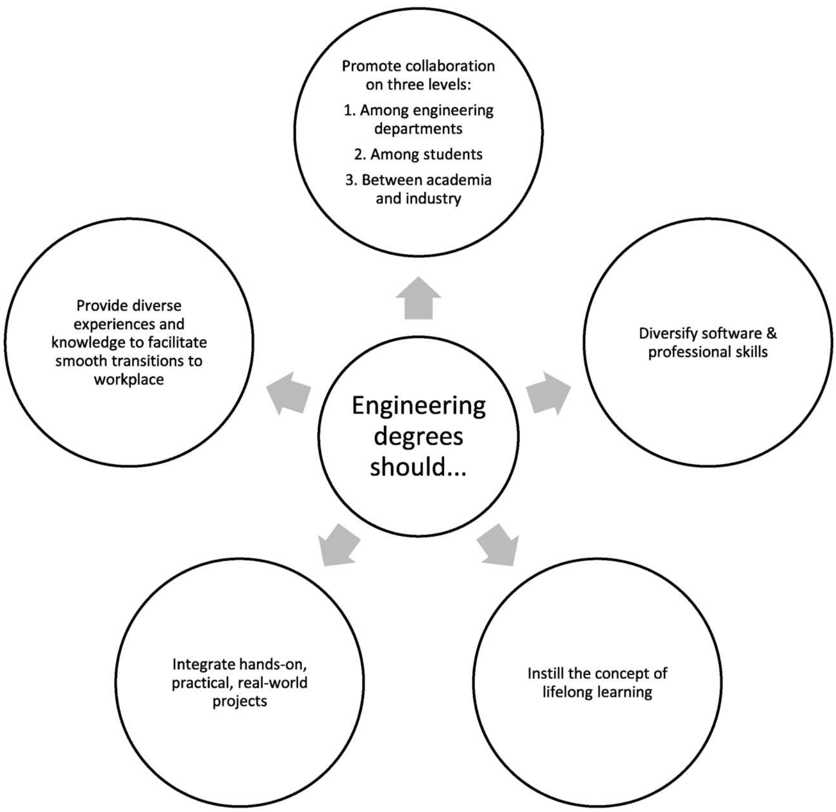

Figure 2. Key themes concerning what undergraduate degrees should offer or improve to better prepare early-career engineers for the A&D workplace.

of their discipline specifically mentioned the technical side of engineering, different verbiage, and the design process. Additionally, classes such as math and core engineering were highly beneficial and prepared them for their current role. One participant recounted:

> Specific technical stuff–like whenever anything technical arises, I know the answer because of my undergraduate degree. My degree is in aerospace engineering … I understand why we have to do certain things and how we have to do certain things.

Senior design courses played a particularly significant role in preparing early-career engineers for professional life. Such courses offer various opportunities to learn not only the technical side of engineering but also develop other skills, as explained by another participant:

> You're doing a little bit of technical, you're doing a little bit of finance because you have to keep your project on budget, you're doing a little bit of statusing your senior design supervisor, you're doing a presentation at the very end, you're working on a team. So that's the whole package and very similar to what you're going to see in a big corporate job and engineering, at least in an aerospace company. So I feel like it prepared me well.

Participants also reported learning how to solve problems using different problem-solving techniques, find information and think through a problem like an engineer, and use the fundamentals introduced in classes to solve problems. In addition, they stated that their programs helped them become better critical and creative thinkers and learner, as in the following example:

> I think it [engineering program] prepared me well. I mean there's technical classes that you took that I used on a daily basis … they definitely helped me think outside the box and develop my problem-solving skills, which I use on a daily basis.

As seen in these quotes, most early-career engineers felt certain that their undergraduate program provided them with the technical knowledge and skills needed in their current positions and prepared them for the engineering workforce.

Theme 2. Engineering degrees teach persistence and contribute to personal growth

When asked what helped them prepare for their current engineering role in their undergraduate program, three participants mentioned persistence instilled through the program. They believe their undergraduate degree prepared them for their current role, not through STEM courses, but by instilling persistence, which they lacked after high school and has been invaluable in their position. They stated that this is not a subject typically discussed in school and that working long hours seven days a week in a lab helped them understand how valuable it is. One participant recounted:

> … being an aerospace student at [institution] has instilled a really good work ethic in me, because you're on it 24/7 and you work a lot of hours in the lab so I think instilling a good work ethic was instrumental in this job.

One participant viewed the undergraduate experience as an opportunity for personal growth, being independent, and making decisions without having their parents next to them. They believed undergraduate education empowers individuals to make their own decisions and take ownership of their future, while serving as a crucial first step into independent life, fostering personal growth, and providing a foundation for future success. These results show that aside from acquiring technical knowledge and skills, developing persistence and a sense of responsibility as independent adults is a crucial component of undergraduate programs that aim to prepare students for professional life. However, it should be noted that only three participants brought up these aspects of engineering programs, suggesting that other participants may not have had similar experiences.

Theme 3. Career service resources, seminars, and student organisations contribute to preparing students for professional practice

Nine participants' responses revealed that professional development opportunities for students, such as seminars, workshops, career fairs, student organisations, and clubs, were useful resources that prepared them for professional practice. Practicing early engineers believed that using career services and attending career fairs were beneficial because they allowed them to meet engineering companies and talk with practitioners. They also mentioned that attending workshops through student clubs where they learned several things in different areas within engineering was useful, as shown in the following example:

> One of the workshops that I attended was the space flight operations workshop. I think that helped me think operationally in terms of engineering … You had to learn a lot of things on the fly and very quickly. You had to do a lot of stuff throughout the day physically and mentally.

Attending career fairs organised by engineering colleges helped participants research different engineering companies, understand where they would fit in, and interact with different companies through social events. Career fairs also enabled them to take part in mock interviews and find internship opportunities. Departmental events, such as resume 'roasts' where students could receive feedback from peers and engineering faculty on their resumes, also helped participants prepare for their current roles.

Another resource participants used was their faculty advisors. They mentioned that advisors talked to students about what classes would be more beneficial, listened to their concerns, discussed what they needed to work on, gave them career advice, and provided them with letters of recommendation. These examples indicate that besides what is taught in engineering classes, enabling students to meet with practitioners, interact with other students, and receive guidance and feedback contributes to preparing them for professional practice.

What recommendations do early-career engineers provide for undergraduate engineering programs?

Theme 4. Engineering degrees should involve more collaboration between engineering programs, enhanced teamwork among students, and increased partnerships between academia and industry

When asked about improvements for undergraduate engineering programs, participants highlighted the need for enhanced collaboration on three levels: between engineering disciplines, among students, and between academia and industry. Eight participants highlighted the need for more group projects among students. They stated that being a team member is essential in the workplace, so students should develop such skills early in their engineering programs. Participants recommended having students work together in groups rather than individually to help them learn how to achieve a goal together, similar to how work is conducted in engineering companies. Participants also suggested exposing students to a design process from start to finish and including them in every step of product design and teamwork to better prepare them for the workplace. One participant recounted:

> I think more projects that are either group or two person projects that are fully deliverable products, not just a project all alone with a little bit of writing, it's a fully documented deliverable refined product, would be a lot closer to what a company is looking for.

For seven early-career engineers, it was also important to have collaboration between different engineering departments in engineering programs. They noted that students work with engineers from different backgrounds when they start working in engineering companies. Therefore, particularly through senior design courses where students work with more multidisciplinary teams, students should learn how to communicate with people from different engineering disciplines and how 'their brain works'. One participant mentioned:

> For senior design it wasn't just an aerospace senior design. You had people from the electrical engineering department, the computer engineering department, the mechanical engineering department. You had a more multidisciplined team because in the real world when you go to your first job, you're not dealing with

> just aerospace engineers. You're dealing with people from all sorts of backgrounds and it's important to be able to understand where they're coming from and how to communicate with them properly.

This indicates that early-career engineers believe that developing problem-solving skills and solving problems in teams, particularly with people from different engineering fields, effectively prepare students for professional practice, including making them more comfortable working with others.

Although participants saw value in having students work in teams with people from different engineering disciplines, the suggested timing of such collaborations differed among participants. One participant stated that group projects where students are asked to work with people from other disciplines should not be introduced before junior year. This is because first-year and sophomore students do not have the necessary domain knowledge for effective teamwork. Other early-career engineers, on the other hand, believed teamwork opportunities should be offered earlier in the program and more than once. They stated that in a senior design course, they learned the process of designing a product and making it work but that it was their first and only exposure to teamwork. Thus, they noted that taking a design course in their sophomore or junior year would have better prepared them for the workplace.

These examples indicate that participants felt that collaboration between students and different engineering disciplines is vital and should be integrated into undergraduate engineering programs. However, some participants believed that such collaboration requires foundational field knowledge to enable effective collaboration among engineers from various areas. Thus, some participants wished to see more collaborative opportunities in the junior and senior years, while others preferred these classes to be offered earlier in the program and more frequently.

In addition to collaboration between engineering programs and students, eight participants identified a need to bridge the gap between academia and industry and suggested fostering close collaboration between engineering companies, engineering departments, and colleges. Particularly, they mentioned that industry professionals should engage with engineering students and share information about their work and employers' expectations. Participants believed that inviting practitioners from different roles to explain what different types of engineers do would help students understand what to expect from the workplace. They mentioned that having industry professionals teach students certain things, such as how to use the software they use through seminars, would make students feel more confident. Some participants stated that their professors invited practitioners to talk to students and felt that it was beneficial. They suggested such collaboration between academia and industry should occur on a weekly or monthly basis and be promoted at the department and college levels.

Participants believed that creating a bridge between academia and industry would benefit students in two ways. First, seeing workplace applications of the theories taught in engineering classrooms would allow students to make the connection between theory and practice and help them understand why they learn theoretical knowledge in school. Second, providing students with opportunities to talk to practitioners before they graduate helps them establish that link before they start working, thereby facilitating the adjustment period. One participant noted:

> I mean, honestly, just even having more people come in from … I would say graduates that are working in aerospace businesses and just explain what the atmosphere is like to the students directly. I don't think that's something that professors are really going to do a great job of, just because most of them have been professors in academia for a really long time, I don't think they've got that understanding.

These examples reveal that inviting practitioners to engineering classes as guest speakers formally, and having them work with students informally, could motivate students and be beneficial for them. It would allow students to observe engineers in different roles and understand how these professionals apply the theoretical knowledge and skills gained from their undergraduate program to practice.

Theme 5. Early-career engineers emphasised the need for undergraduate engineering programs to enhance software and professional skills

Early-career engineers emphasised the need for undergraduate engineering programs to introduce a variety of software programs and programming languages. Eight participants mentioned that these programs should include tools for modelling, structuring, and presenting data, such as Excel and basic Microsoft products. It was mentioned by participants that some engineers in their company lack lower-level software skills and that such basic technical skills (i.e. Microsoft Word and PowerPoint) are taken for granted in our lives and could be overlooked in engineering programs. They stressed that having software skills is essential, particularly when working with a customer or a product owner in the workplace.

Participants also advocated for exposing students to multiple programming languages rather than limiting instruction to just one, like MATLAB, which may not be widely used in the workplace. One participant suggested that understanding software skills like Linux and custom-built product testing environments can significantly benefit those in the aerospace industry. Participants suggested incorporating languages such as Python and C++ into the curriculum, as shared by one early-career engineer:

> I would love if we did more of C++, or Python or something. Because I came in really only knowing MATLAB, and figured out that MATLAB outside of all the GNC [Guidance, Navigation, and Control] group is not really used that much.

They also pointed out that more recent and relevant software tools should be taught and used in engineering classes. One participant emphasised that programming skills taught during their aerospace engineering program are outdated and not needed in the aerospace industry. They mentioned that no one at their large aerospace company uses the programming language they were taught. Instead, they suggested that a greater emphasis on 3D modelling, such as SolidWorks, would be more beneficial, as in the following example:

> Fortran, it's like a coding software that they used back in 1960 … It's basically some super archaic coding software that nobody ever uses anymore, but they were teaching it in an entire class … Instead, using SolidWorks or learning C++, or more relevant software would have been much more helpful for my career.

As seen in these examples, participants recommended exposing students to various software tools in undergraduate engineering programs and showing them how to use basic data organisation and presentation tools so that they enter the workplace with higher software proficiency. Participants were aware that some software tools are company-specific and that students cannot learn all of them in college. However, they still recommended introducing students to more than one tool since some software programs may lose their popularity by the time students join the workforce.

In addition to software skills, participants underscored the importance of acquiring professional skills. Fifteen participants noted that their programs focused primarily on technical knowledge, neglecting essential skills like technical writing, communication, and engaging in a professional setting. They believed taking technical writing classes during the undergraduate program is vital since technical writing is part of what they are expected to do in the workplace. Participants described the technical writing classes they took as generic and said there should be more real-world applications in such classes to demonstrate how they can better fit in with the skills they have. They mentioned that they learned technical writing only after they started working and suggested teaching engineering-specific writing classes in college, as in the following excerpt:

> I think they should have classes on technical writing. I myself am not a huge English person, but I think an engineering specific writing class would be very helpful because that is something I've had to learn rather quickly here.

Participants also believed learning about workplace structure before getting a job is important. They mentioned that university and professional environments are different; thus, they suggested adding content on how business is conducted and how to conduct oneself in a professional environment to the engineering curriculum. In addition to grasping workplace structure, the importance of social and networking skills, including communication with co-workers, was repeatedly highlighted. They viewed interaction with others in professional settings as equally important as technical proficiency. Furthermore, they emphasised the importance of building relationships, collaborating on group projects, and helping others. Success in these areas, they suggested, can complement technical skills and make challenges less daunting, as there are always colleagues available for assistance. Thus, they recommended offering courses on communication skills and navigating professional environments, as one participant recounted:

> If you're not taught good communication skills, when you come out of college, you can really hurt your career by how you interact with others. I think it's probably one of the most important skills we could ever know, because even if somebody graduated engineering and then went a completely different route with their life, they still need to know how to talk to people. I don't think it's really taught in school.

Participants recommended integrating professional skills into engineering classes, as they believed these abilities could effectively resolve conflicts in the workplace. One participant highlighted a potential conflict between design and manufacturing engineers in the workplace stemming from differing priorities, indicating that these issues are not adequately addressed in traditional engineering curricula. They suggested introducing team-building activities in courses like senior design to better equip students for real-world scenarios where they need to collaborate with colleagues holding different priorities.

Overall, early-career engineers suggested offering courses specifically focused on teaching communication, writing, and other professional skills for engineering students close to graduation. They put a great emphasis on teaching professional skills and suggested engineering programs should prioritise such professional development opportunities more.

Theme 6. Engineering degrees should teach students that learning is continuous and is not limited to the undergraduate degree

For early-career engineers, it is important to know that learning will continue after earning their college degree and that many new topics will be learned on the job. To achieve lifelong learning, seven participants mentioned the importance of being willing to learn new topics, even those that are not of interest to be successful in the workplace. Participants believed that the faculty plays a vital role in creating this mindset in students, as described by one participant:

> I think a lot of my professors did a really good job of making sure we knew that going into a company, you are not going to know everything … I think they did a really good job of setting us up to know that we are going to have to do some leg work to learn all of those things before we can even really to start to apply what we learned in school.

Participants noted that having learned flexibility in school, meaning that being aware that what they learned in school could be done differently in the workplace and that they will have opportunities to learn new ways to approach problems, helped them grow and develop as engineers. They also mentioned how specialised companies could be and that covering everything related to engineering in undergraduate programs might be challenging. Thus, they highlighted the importance of helping students develop a learner's mindset as they will continue to learn new topics throughout their careers. One participant recounted:

> Don't treat this education as a means to an end. Don't treat it as you're going to learn it, get the degree, you're not going to use it … Having the opportunity, as a human, to learn, is a powerful one.

As evident from these excerpts, educating students about the significance of lifelong learning for their professional growth and emphasising the role of the faculty in fostering this mindset is crucial.

Theme 7. Engineering degrees should expose students to hands-on, practical, real-world projects

The need to provide students with opportunities to gain hands-on experience was viewed as particularly important for early-career engineers. Participants stated that practice is much more necessary than the memorisation of technical information. Given the advancements in technology, they explained that they could easily gain engineering-related knowledge on the Internet, whereas exposure to hands-on practice remained challenging to attain:

> I think there just really weren't or just too much theory and not enough practical example problems that one would see in the industry … All of that is accessible to you. You can carry a textbook around in a workplace, or you can have a PDF file on your computer. So, I think more utilization of those theories, and practicing problem solving is very important.

Ten participants suggested the implementation of industry-related projects in engineering classes, involving case studies that require students to make company visits and research their methods and processes. They noted that during their undergraduate studies, they lacked exposure to practical problems commonly encountered in the workplace. Given the daily problem-solving demands of their current roles, they advocated for teaching students how to apply theories and practice practical examples similar to real-world scenarios, facilitating a smoother transition into professional environments. They proposed offering more senior design courses earlier in the program to facilitate the effective application of knowledge.

It is noteworthy that participants used venues outside the engineering classroom to gain hands-on experience to prepare for the workplace. These involved participating in student organisations and clubs. Their responses indicate a need for the integration of hands-on learning into engineering programs, supported by real-world engineering problems where students can apply what they learn in the classroom.

Theme 8. Engineering degrees should expose students to a wide range of experiences and knowledge for easier transition to the workplace

Twenty three early-career engineers considered the exposure to different experiences and varied knowledge starting in the first year as essential to preparing students for professional practice. They raised the need to include topics such as regulations and laws, safety requirements, and the operational differences between government and industry in engineering courses. This is because they believed they did not learn as much about these topics in school compared to theoretical knowledge. One participant described:

> So I guess maybe exposing freshmen engineers or new engineering students to all the different things. The defense sector has these pros and these cons; commercial has these pros and these cons; private industry has these pros and cons. If you want to work for the government, these are the things. Maybe even something to do with the FAA showing that those regulations exist and how to navigate those websites. I think just opening up and showing all the options would be really beneficial.

One suggestion made by female early-career engineers concerning curriculum improvement was to create more programs such as the Society of Women Engineers, which provides students with networking opportunities. Such organisations are especially important for female students to interact with other female students and practitioners more openly and easily. Participants mentioned that learning different tools in the undergraduate program, including the terminology used in engineering, is also essential.

Nine participants saw taking more classes in different engineering fields that are not necessarily required as valuable for gaining more background knowledge and feeling more prepared for the workplace. In addition, they considered elective courses as necessary and suggested that some topics currently offered as electives could be included briefly in required classes or offered as shorter elective courses with fewer credits to provide students with more opportunities to learn a wider range of subjects.

Participants believed that informing students about different engineering fields and what their roles and responsibilities are through classes and mentorship programs may help them decide which way to head after graduation. Additionally, they considered professional development opportunities as essential to engineering programs. Participants suggested creating seminars, courses or workshops for students to practice becoming comfortable defending themselves, acting when intimidated, and sharing how to overcome challenges as young engineers. They also suggested being involved in student clubs and internships, which they believed might help students get out of their comfort zones. Overall, participants viewed an engineering degree as a whole package, involving taking courses, doing internships, participating in student clubs, and attending professional development workshops, namely filling up their toolboxes, to prepare them for an easier integration as full-time engineers.

In summary, early-career engineers felt that their undergraduate engineering degrees provided foundational technical knowledge that equipped them for their current roles. Participants highlighted the importance of core courses, senior design projects, and technical workshops, all of which contributed to their technical proficiency and problem-solving skills. Additionally, they emphasised the significance of career services, internships, faculty advising, and student organisations in preparing them for workplace expectations. While recommendations varied, there was a consensus on the need for more collaborative opportunities for students from different engineering disciplines, exposure to diverse software tools, and a focus on professional skills such as communication and teamwork. Moreover, participants advocated for stronger academia-industry partnerships to bridge the gap between theory and practice, and they underscored the importance of instilling a mindset of continuous learning.

Discussion

The present study examined the aspects of engineering programs that are useful in preparing engineering students for professional practice (RQ1). It also analyzed the recommendations and improvements suggested by early-career engineers for better preparing undergraduate engineering students for the workplace (RQ2).

Regarding RQ1, all participants except one believed their programs provided the necessary technical knowledge and skills, consistent with the field's focus on scientific content (White and Davis 2013). Additionally, participants highlighted the importance of co-curricular and extracurricular activities in enhancing communication with industry professionals and gaining practical knowledge, which contributed to their industry readiness. These findings align with Kovalchuk et al. (2017), who noted that co-curricular activities help in acquiring technical and social skills, understanding workplace norms, and building professional connections. Furthermore, the findings support Agrawal and Harrington-Hurd (2016), who found that extracurricular activities allow students to apply classroom concepts to real-world projects, effectively developing their knowledge and skills.

Another finding related to RQ1 was that early-career engineers believed their undergraduate experiences contributed to their personal growth, instilling independence and persistence. This finding aligns with Weigold et al. (2021), who identified college as an opportunity for growth. However, despite the value our participants placed on persistence and long hours cultivated during their undergraduate programs, it is important to acknowledge that such traits may have negative implications on the engineering work culture. For instance, certain aerospace companies are known for imposing demanding work schedules, often ranging from 80 to 120 hours per week, inclusive of weekends (Forbes Article 2017; Hendricks 2016). This rigorous work culture, lacking work-life balance, can create isolating dynamics within the industry. It sends a signal to potential employees that only those who can comply with such demanding schedules are suitable candidates, thus excluding individuals who have additional responsibilities such as caring for their children. As a result, this type of work culture creates barriers for specific groups of people, preventing them from pursuing careers in certain parts of the engineering industry.

While participants highlighted independence as a positive aspect of undergraduate education, it is essential to recognise that not all student groups share the same perspective. Research indicates that underrepresented undergraduate engineering students often find concrete advice, resources, emotional support, and encouragement from their parents to be crucial for their persistence in their majors (Puccia et al. 2021). Likewise, first-generation engineering students value their familial relationships and consider the emotional support they receive from their families as critical to their success in engineering programs (Martin et al. 2020). This underscores the fact that, unlike the participants in our study, not all students value complete independence from their families and making autonomous decisions.

With regards to RQ2, participants emphasised that professional skills were lacking in their engineering programs. Thus, they recommended that engineering programs place greater emphasis on professional skills. This recommendation is supported by previous studies, which have shown that social interactions (Ahn et al. 2023; Dong et al. 2021) and human performance are central to engineering practice (Travelyan 2010), yet often neglected in engineering curricula (Winberg et al. 2020). This might result from the contextual and non-universal nature of professional skills, making them difficult to fully integrate into the curriculum (Flening, Asplund, and Edin Grimheden 2022). Moreover, the aviation industry's significant shift toward globalisation, exemplified by outsourcing services internationally and enabling team members to telecommute on the same project, underscores the pressing need for enhanced communication and collaboration skills. The design and production of complex projects further highlight the importance of communication in engineering practice (Lappas and Kourousis 2016).

Early-career engineers recognised that it is impossible to teach all the necessary knowledge and skills within engineering programs. Therefore, they emphasised the importance of instructing students on the necessity of continued learning in the workplace. This view aligns with prior research (Johri 2022; Martinez-Mediano & Lord 2012), which has identified lifelong learning as an educational goal in both the U.S. and Europe and recommended integrating lifelong learning into engineering curricula and teaching students to be independent learners. While participants acknowledged the importance of lifelong learning, they also suggested that students should be taught various software skills and programming languages. This seems to contradict their view on continuous learning. As Sobral (2021) pointed out there is no consensus on which programming languages should be introduced to students due to changing trends, teacher preferences, accessibility, and the relationship with other courses. Therefore, students should master essential programming concepts, enabling them to adapt to various languages throughout their careers, as they are unlikely to use the same programming language for their entire career. Atkins (2014) points out that while covering multiple programming languages in aerospace programs may be beneficial, the focus should be on teaching students the concepts of computational thinking at a higher level, starting from K-12.

Participants emphasised the importance of collaboration across engineering disciplines. However, the literature suggests that a more comprehensive approach to collaboration is needed, which includes the involvement of social sciences, humanities, and arts to address the complex problems of society and generate socially, environmentally, and economically responsible solutions (Fealing, Incorvaia, and Utz 2022). The absence of this interdisciplinarity (i.e. combining knowledge and methods from different fields, employing a synthesis of approaches) in participants' responses may be attributed to cognitive barriers that students face in interdisciplinary contexts. Richter and Paretti (2009) note that students often struggle to see between their field and other disciplines, find it challenging to approach problems from multiple perspectives, or fail to see the value of multiple perspectives. Additionally, cultural expectations, lack of awareness about information needs of other fields, and lack of integrative knowledge and abilities within and across disciplines are barriers to interdisciplinarity collaboration (O'Brien et al. 2003). Given that our study participants had between three and 27 months of industry experience, they may have had limited exposure to such collaborations.

Our findings on integrating more hands-on work for students align with the recommendations of Sorby, Fortenberry, and Bertoline (2021), who emphasised the importance of incorporating more practical work and developing a comprehensive approach to engineering education that focuses on professional goals. Participants also suggested providing students with diverse knowledge, skills, and experiences, including courses from different engineering disciplines, professional skills training, and participating in out-of-class activities like student clubs and career fairs. This supports the findings of Agrawal and Harrington-Hurd (2016), who noted that students believe that the true value in engineering education lies in a holistic mix of classwork, practical assignments, and extra-curricular activities that develop both technical skills and essential soft skills, rather than in isolated theoretical learning experiences.

While new models and methods have emerged, traditional aerospace course content persists largely unchanged, with no consensus on the optimal curriculum for aerospace students' preparation across industry, government, and academia (Atkins 2014). Atkins (2018) suggests improvements, such as condensing course content, offering technical elective choices, and integrating computing and information technology into aerospace programs. However, it is essential to explore how these changes can be implemented and taught effectively. Who will be willing participants in this effort? Faculty are urged by Atkins (2018) to consider removing some content to accommodate new material, aligning with evolving ABET standards. Yet, Riley, Henry, and Leighton (2013) indicate faculty resistance to change in engineering education, influenced by factors such as research prioritisation, reward structures, communication gaps, and institutional norms. Conversely, Heileman and Abdallah (2019) reveal how ABET accreditation is often used as a justification to resist changes in engineering curricula, often through broad interpretations or misapplications of accreditation criteria. The reliance on ABET accreditation as an excuse overlooks the evolving needs of students and the potential for improvement and stifles conversations about improving curriculum efficiency and innovation. Understanding the motivations behind early-career engineers' advocacy for these changes is important, as is integrating recommended components consistently into formal curricula. However, given these barriers, discussions on how these changes will be implemented and by whom, as well as which stakeholders will be involved are also vital considerations.

Limitations and future research directions

This study offers insights from 15 male and 11 female newly hired engineers across seven A&D companies. Given the sample size, future studies could involve a larger and more diverse group of early career engineers, including those from other engineering disciplines, to capture a broader range of perspectives. Considering that our study mostly consisted of White participants and the lack of diversity in the A&D industry, examining the experiences and suggestions of underrepresented new engineers would be beneficial for identifying additional areas of engineering education that need improvement.

Additionally, as participants attended diverse institutions with different locations, types, and engineering programs, their individual undergraduate experiences may have influenced their responses. Therefore, the perceptions of our participants are not reflective of the experiences of all practicing engineers but do reflect the viewpoints captured in this study. In future studies, further exploration could also focus on examining how the various aspects of participants' undergraduate programs contribute to their success in the workplace, as this aspect was not extensively covered in some participants' responses.

Conducting longitudinal studies that observe participants for an extended period, including experienced engineers with over three years of experience, could help determine whether their perceptions and recommendations for improving engineering programs change over time and with experience. In addition, focusing on engineers with distinct roles and exploring how they describe their responsibilities, how their undergraduate education contributes to their job, and what improvements they recommend, might clarify the connection between specific engineering positions and their requirements.

Finally, future research and engineering institutions can use our identified themes by transforming them into meaningful questions or by adopting our interview questions to assess how well they prepare students for their future careers. These questions can be instrumental in evaluating the effectiveness of their educational programs in preparing students for their careers. Moreover, these same questions can be employed when interviewing recent graduates to gain insights into how well they were equipped for their current roles. This approach aligns with the continuous improvement goals advocated by engineering education.

Conclusion

Our study highlights the multifaceted nature of engineering education and the need for a balanced approach that includes both technical and professional skills. The results presented in this paper demonstrate that the technical knowledge and skills taught in engineering programs, as well as the co-curricular and extracurricular activities play a significant role in preparing engineering students for the workplace. The suggestions for change in engineering education from early-career engineers largely align with those made by engineering educators over the years. These suggestions include teaching lifelong learning, and professional and interpersonal skills, as well as creating opportunities for hands-on learning and engaging in co-curricular and extracurricular activities.

However, there remains a gap in the teaching of collaboration between engineering and non-engineering disciplines. Given the A&D sector's multidisciplinarity, there is a clear imperative for both engineering education and A&D organisations to engage in discussions and collaborative efforts to address this difference. Integrating more diverse teams, including students from both engineering and non-engineering disciplines, particularly in capstone courses, may better prepare students for the A&D industry. This approach introduces students to collaboration in diverse teams, reflecting the industry's practice of hiring professionals from a wide range of backgrounds. Additionally, creating more internship opportunities for students and involving practitioners in engineering programs to explain the various engineering roles in the A&D industry, including expectations and how to apply theoretical knowledge in practice, may help the sector attract and retain the talent it currently struggles to secure. This collaborative approach could facilitate the development of educational experiences that better equip graduates to transition into the workplace and perform their responsibilities.

Lastly, this study underscores the importance of actively listening to the insights of recently hired engineers to gain a deeper understanding of their experiences and recommendations. Studies like the one reported in this paper offer valuable insights into the perspectives of recent engineering graduates, fostering discussion about the goals and assumptions of both universities and engineering organisations. In this collective endeavour, engineering education and engineering organisations bear the responsibility for enhancing engineering education and nurturing a robust, diverse engineering workforce.

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Appendix

Interview Questions

I will ask your opinion on how undergraduate engineering education programs can be improved to better prepare new engineers for organisational entry. I will also ask how aerospace and defense organisations can improve their current practices to better assist new engineers with workplace onboarding, orientation, and socialization.

1. In hindsight, do you believe your undergraduate degree helped you prepare for your current position? If so, how?
2. What could be improved or changed in undergraduate engineering programs to better prepare students for organisational entry?

   [prompts]:

a) What suggestions do you have for your undergraduate engineering program to better prepare students for work entry?
b) What skills and knowledge need to be taught in undergraduate engineering education programs to prepare students for their first position?
c) What career resources (such as career training centre, workshop, seminars, etc.) have you experienced when you were in your university? [If the participant presented some resources] Do you think the resources helped you?
d) Are there any other classes, seminars, or workshops that should be offered? What topics, should they include?
e) What advice would you give to an engineering student currently enrolled in an undergraduate engineering education program and are wanting to enter aerospace organisation?