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Exploring shifts in engineering students' understanding of engineering work during their co-op experiences

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Abstract

Context

Engineering students often struggle when they enter the workforce after graduation due a lack of workplace readiness. Cooperative (co-op) programs are experiential educational programs that provide workforce experience prior to graduation, improve employability, provide exposure to workplace culture, and help bridge the disconnect between engineering work and academia.

Purpose or Goal

Well-designed co-op programs enhance student learning by providing a balance of challenge and support. To effectively support students, it is helpful to understand how their perceptions and experiences of engineering work shift during the co-op. Therefore, we aim to understand: How does students' understanding of engineering work shift during their co-op rotations?

Methods

During Fall 2022, 639 engineering students from a large public U.S. university enrolled in the co-op program. 295 students from the co-op program participated in an online survey where we asked them to reflect on their progress toward their goals during their co-op. We analysed this reflection data using a two-step approach: open coding followed by thematic analysis.

Outcomes

We found that students' perceptions of engineering work changed as they gained industry-specific knowledge and skills, dealt with open-ended, ill-structured problems, and worked in teams. Our analyses also revealed that students improved their technical skills, adapted to workplace cultures, took ownership and initiative on projects, and acquired interpersonal skills to accomplish their tasks.

Conclusion

Our study identifies how understanding students' perception of engineering work can inform the design of experiential learning programs. We also provide insights on how co-op programs can ease students' transition to the workforce by considering skill development but also changes in understanding of what engineering work entails. Our results can help educators support students in experiential learning programs that bridge the gap between industry and academia.

Keywords—*co-op education, thematic analysis, student experience*.

I. INTRODUCTION

There is a growing demand for engineers capable of developing innovative solutions to address the grand challenges that lie ahead of us (Mote et al., 2016). To address these grand challenges, it is important for universities to develop competent engineers that are workplace ready and prepared to solve these problems (Ehlert & Orr, 2020). However, prior research shows that engineering students lack workplace readiness and often struggle after they enter workforce (Brunhaver et al., 2018; Huff et al., 2016). Additionally, positive academic achievement in engineering may not necessarily translate into required workplace readiness (Parsons et al., 2005). Therefore, it is important for engineering students to acquire workplace experience prior to graduation.

Co-op programs are experiential learning programs that help prepare engineers for workplace readiness and develop their required competencies (Ramirez et al., 2016). Additionally, these experiences also help students understand what engineering work is and provide opportunities to learn about engineering as a profession (Brunhaver et al., 2018). Therefore, we investigated how co-op experiences helped students shift in their understanding of what engineering work entails. Furthermore, this study will also help with intentional design of experiential learning programs so that students are better prepared for a career in industry upon graduation.

II. LITERATURE REVIEW

When engineering students graduate, they typically have a narrow understanding of the activities involved in engineering practice (Brunhaver et al., 2018). Most students perceive engineering to be technically oriented and based on concepts and equations they learned in classrooms (Anderson et al., 2010; Trevelyan, 2010). In reality, engineers also require professional competencies like communication skills, teamwork skills, creativity, lifelong learning, etc. (ABET Engineering Accreditation Commission, 2020). As a result, there is a disconnect between the expectations of engineering education and practice. This misalignment can cause engineering graduates to feel unprepared and face difficulties when transitioning from academia to industry (Huff et al., 2016; Korte et al., 2015; Trevelyan, 2014, 2019). To minimize this misalignment, it is important to study the workplace preparedness of engineering students prior to their graduation.

Prior work suggests that experiential learning strategies like project-based learning (Bielefeldt et al., 2010), and service-learning (Bielefeldt et al., 2013) help bridge this gap by preparing students for a career in engineering. For instance, Huff et al. (2016) found that enrollment in service-learning

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programs helped graduates bridge the gap between industry and academia, acquire workplace experience, and develop professional skills required to work in industry after graduation.

Other experiential learning techniques like Cooperative education (co-op) and internships also help bridge the gap by providing hands-on industry experience (Gardner & Motschenbacher, 1997; Jin & Fabretto, 2019; Main et al., 2020). Co-op programs are defined as experiential learning opportunities that help integrate classroom education with planned and supervised work experience in an industry setting (Garavan & Murphy, 2001). Co-op experiences can improve students' chances of employability by providing them with technical and professional skills, industry experience, and exposure to the workplace culture (Ramirez et al., 2016). In addition, students' participation in co-op programs can positively impact their academic performance (Blair et al., 2004) and ABET learning outcomes (Parsons et al., 2005).

In summary, previous research suggests that co-op programs offer a variety of employability benefits and help engineering students develop skills that will prepare them for engineering practice. Moving beyond skill development, however, co-op experiences have the potential to shift students' perceptions of engineering work (Brunhaver et al., 2018). Less research has focused on this outcome, despite the fact that such perceptions may inform students' career choices and persistence in engineering after graduation (Gilmartin et al., 2018). Based on experiences like co-op, students may make an assessment of their preparedness for engineering workforce (Baytiyeh & Naja, 2012; Martin et al., 2005). Students may also develop a more realistic understanding of the expectations that employers have from working engineers. Understanding students' perceptions of engineering work can help educators better support students before, during and after their co-op experiences. Therefore, we addressed the following research question in our study: How do students' perceptions of engineering work shift during their co-op rotations?

III. Methods

To address our research question, we qualitatively analyzed students' open-ended survey responses on a survey completed at the start and end of their co-op programs. A qualitative research methodology was chosen for this study because we wanted to understand student perceptions and beliefs about engineering work without limiting their potential responses through the use of closed-ended survey questions.

A. Participants

In Fall 2022, 639 students from various undergraduate and graduate majors enrolled in an experiential learning course. Engineering students are required to take this course while completing a semester-long co-op rotation in an engineering company (See Table I for breakdown as per major for 295 students who completed at least one of the course surveys). 33.56% students in this study were completing their first co-op, whereas others had prior co-op experiences. In the co-op program at Purdue University, students gain practical experience before graduation by working with the same employer for 3-5 work sessions lasting 12-22 months. With every co-op term, students take on increasing responsible roles that determine their professional and personal goals for the rotation. Our project has been approved by the Purdue University IRB as an analysis of existing data because the survey responses were collected as part of the continual assessment for the experiential learning course.

B. Data Collection

An online survey was distributed as a class assignment at two points in time: the start of their co-op rotation and the end of their co-op rotation. At the start of the co-op rotation, we asked students to state their goals for the co-op experience, and at the end we asked them to reflect on their progress towards these goals. We asked students to reflect on their co-op rotation goals because reflection and goal-setting are best practices for supporting and assessing student learning during experiential learning (Chan, 2022). 295 Students responded to the following prompts in the online survey assignments:

TABLE I
Breakdown of Co-op students Who Completed At Least One Survey by major

Engineering Major	Undergraduate	Graduate	Percentage for major
Mechanical	83	22	35.59
Industrial	14	25	13.22
Biomedical	36	0	12.20
Aeronautical & Astronautical	28	1	9.83
Chemical	25	4	9.83
Electrical	17	0	5.76
Computer	13	0	4.41
Civil	8	0	2.71
Materials	8	0	2.71
Multidisciplinary	3	0	1.02
Biological	2	0	0.68
Environmental & Ecological	0	2	0.68
Engineering (undecided)	1	0	0.34
Manufacturing Technology	1	0	0.34
Mechanical Technology	1	0	0.34
Agricultural	0	1	0.34
Percentage	81.35	18.64	

1. Start of co-op survey: Set two professional growth or work-related goals for your next work experience/co-op rotation using the SMART (Specific-Measurable-Achievable-Relevant-Timebound) format. Include a metric which can be used to later measure the success of

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achieving your goals.

2. End of the co-op survey: Reflect on your progress towards the goals you set at the beginning of your most recent experience/co-op rotation. Elaborate on any successes, challenges, new insights, or changes in goals. How have you grown professionally or personally to meet your goals? Reference your beginning of session survey responses sent to your email to recall your goals.

Prior to the start of co-op survey, students were given training on different ways they could set their goals for their co-op rotation. This training helped to ensure that students identified specific measurable goals that they could evaluate and reflect upon at the end of their co-op term. Students were encouraged to complete the training and online survey assignments to help them track their progress and get the most out of their co-op experiences. However, as it was a zero-credit course, students' responses were completely voluntary, and they did not receive any points for completing the training modules and survey assignments. Nevertheless, 295 students completed at least one of the surveys (pre or post) and 287 completed both out of 639 total co-op students. This represents a response rate of 44.9% for completing both surveys.

C. Data Analysis

To address our research question, we conducted a thematic analysis. The key advantage of using a thematic analysis is that it is driven by the research questions and helps identify major themes associated with the research questions from the data (Braun & Clarke, 2006). Because we wanted to focus on students' perceptions for this study, thematic analysis was a logical choice. It allowed the student voice to be centered in our analysis as the key themes were developed through detailed reading of the students' survey responses.

We followed the thematic analysis process described by Braun & Clarke, (2006). We began our analysis by familiarizing ourselves with the data and documenting memos and ideas commonly discussed in student reflections. In the next step, we generated an initial coding scheme by open-coding thirty randomly selected student reflections. We discussed this coding scheme to reach a consensus on the final codebook and the definition for each code. We then coded the remaining responses using the predefined coding scheme and identified the potential themes that emerged from our coding for each research question. We subsequently reviewed these potential themes to generate a final set of themes. We completed this analysis using Nvivo Release 1.

D. Limitations

The reflection assignment was not mandatory for students in the experiential learning course, which may have led to some of them not completing the survey. Additionally, as the survey consisted of multiple open ended and close ended responses (we analyzed only open-ended reflections), the time students spent on each question may be limited. As a result, some responses lacked detail and depth of reflection which may have limited the research team's understanding of the students' perceptions.

IV. Results

The purpose of this study was to investigate how engineering students shift their perception of engineering work over the course of their co-op rotation. In this section, we present the results of our thematic analysis of 295 student reflections. We have summarized the themes and subthemes for our research question in Table II. The two main themes were *Nature of Engineering Work* and *Skills Needed to Succeed in the Workplace*. We present each theme in its own sub-section with descriptions of the sub-themes and representative quotes.

A. Nature of Engineering Work

The first major theme that emerged from our thematic analysis was the *Nature of Engineering Work*. This theme depicted students' perception of engineering work such as understanding the day-to-day work of engineers, the challenges they face, experiencing how engineering work is different from academic work, and developing insights into the requirements of engineering work. Our analysis revealed that while discussing this theme, students focused on seven major subthemes (organized from most common to least common): (1) *Acquire niche knowledge required by job role* (2) *Apply knowledge and skills gained from school/work to work projects*.

TABLE II
THEMES AND SUBTHEMES PREVAILING FROM STUDENT REFLECTIONS

Theme	Subtheme*
Nature of Engineering Work	▪ Acquire niche knowledge required by job role. ▪ Apply knowledge and skills gained from school/work to work projects. ▪ Real-world problem solving ▪ Hands-on work ▪ Develop/work with engineering tools. ▪ Work in teams ▪ Developing documentation about processes and projects
Skills Needed to Succeed in the Workplace	▪ Upskilling/improving existing skills. ▪ Communication Skills. ▪ Take ownership or initiatives at work. ▪ Be a team player: Collaboration and Teamwork. ▪ Be organized: Scheduling and Time management. ▪ Be adaptable and flexible at workplace.

*Organized by most common to least common subtheme

(3) *Real-world problem solving* (4) *Hands-on work* (5) *Develop/work with engineering tools* (6) *Work in Teams* (7) *Developing documentation about processes and projects*.

1) Acquire niche knowledge required by job role.

The first subtheme*, acquire niche knowledge required by job role,* highlights that students felt a need to acquire industry-specific knowledge to complete their job responsibilities.

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Students learned the fundamentals of various technical concepts during their education. However, upon entering the industry, they realized that they must acquire niche technical knowledge specific to their industry and position. Upon realizing this need, students took steps to gain knowledge that will help them complete their on-job tasks and responsibilities. One students explained the benefit of acquiring niche knowledge required by their job role said:

"During the 3rd rotation of my co-op, I spent time every week with the Demand Planning team to understand their processes, tools and systems. I also worked with them on the forecasting cycles from October to December. This helped me develop an understanding of Demand Planning and how its role is crucial in Monthly Production Planning at a plant level." [Par. 143]

Similarly, another student undergoing co-op discussed how challenges they faced during tasks helped them gain industry-specific knowledge. They said:

"My second goal was a "reach" goal, where I would need to put in a lot more work just for a chance of accomplishing it…The challenge of this goal was that it would require me to learn about our materials at a much more technical level and be able to vet ideas for their feasibility to be run. So, I did a lot of research, watched videos, talked to expert coworkers with lots of experience on the asset/ the materials and products it can make. I ended up deciding that it might be worth it to try running a wipe base sheet material." [Par. 22]

Thus, we observe that students had to identify areas in which they did not have specific technical knowledge and acquire that knowledge in order to fulfill the requirements of their jobs.

2) Apply knowledge and skills gained from school/work to work projects.

The second subtheme, *apply knowledge and skills gained from school/work to work projects*, refers to the application-oriented nature of engineering work. Engineering practice requires engineers to apply the concepts and skills they learned in school or the workplace to projects. As a result, students entering the co-op noticed that their job roles emphasized the application-oriented nature of engineering work. One student discussing how they applied their knowledge from engineering courses said:

"I applied all the techniques learned and templates developed during the preparation of my Lean Six Sigma exam and the project management course to create a training and communications plan to ease operations in my current company." [Par. 13]

This subtheme can also be considered as an extension of the previous subtheme because students often *apply* the knowledge they acquired during co-op to accomplish their job goals. One student described how they applied the knowledge gained from the industry to solve production issues by saying:

"Reflecting on my initial goals I think this was a successful experience since I was able to understand the process of battery manufacturing in depth and develop multiple root cause analyses that highlighted problems in the production line with faulty equipment that was generating many scrapped parts that only had false failure" [Par. 163]

These statements indicate how students emphasized the application-oriented nature of engineering work and how acquiring skills and knowledge about their tasks helped them apply what they learned.

3) Real-world problem solving

Our third subtheme focuses on how engineering workplace problems are different from problems that students encounter in the industry. During their co-op students came across different facets of engineering problems like ambiguity, detail-oriented, complexity, open-endedness, and dealing with failure. In addition, they had to learn to grapple with various constraints like deadlines, limited resources, changing priorities of goals, etc. This dynamic nature of engineering problems helped students become aware that real-world engineering problems are different than close-ended linear problems they encountered in their classrooms. Describing the differences between real-world problems and classroom problems, a student noted:

"*The biggest challenges and change from college I had was not having all the answers with me. At school, we are given problems with answers. All the H.W, theory questions or engineering problem have an answer. However, while I was working on my project, I realized that a lot of things might not have an answer and it might take a lot longer to figure it out. Since I was so used to getting answers quickly, my biggest trouble was understanding that it is okay not to have all the answer and I need to continue to persevere and dig deeper to get to the bottom of the problem.*" *[Par. 218]*

Another student explained how engineering work problems involve challenges making these problems complex and dynamic. They said:

"*The first was to run an entire experiment. I was able to complete this goal during my extension term, but I did run into some challenges. The experiment became a much more complex design that I had initially thought it out to be, so the maintenance and lab work became excessive and at some points overwhelming." [Par. 72]*

Furthermore, students also discussed various constraints that must be accounted for while working on engineering projects. One of the students discussing time and hierarchical constraints and their influence during engineering problem-solving said:

"*The challenges to achieving this goal mainly involved the timeliness of releases and iterations. I realized that in the industry, changes and releases are done quite slowly compared to projects I have worked on in the past due to the different levels of approval and management that deliverables must pass through. Accounting for this challenge, I was still able to mostly see the lifecycle of a deliverable that I was involved in the engineering of.*" *[Par. 277]*

Observing the reflections, we noticed that students encountered real-world problems, developed a sense of how these problems are different from classroom problems, and identified ways to work through challenges associated with the problems. Further, students' reflection also illustrates that real-world problems are complex, have higher stakes and implications, and may involve external factors that are beyond their control. However, these reflections also indicate that an essential element of engineering work is to account for these factors while addressing problems.

4) Hands-on work

The fourth subtheme corresponds to the hands-on nature of engineering work. We define hands-on engineering work as participating actively and being involved *firsthand* in the operations of engineering work. Hands-on engineering work encompasses various participatory roles like working in the laboratory, conducting experiments, testing, process improvement, coding, etc.

Upon entering the co-op programs, several students found that much of engineering work is hands-on and requires active involvement by an individual to produce desired results. A student describing how their hands-on work will help improve the production line said:

"My main project involved the installation of modifications to the production line to accommodate both the current and new models running simultaneously and autonomously. The modifications that I have made will be long term changes to the production line and will likely make the accommodation of future models easier going forward." [Par 9.]

Another student who grew to realize the importance of the hands-on nature of engineering word mentioned:

"I didn't run into any challenges, but an insight that I made during these trials was that the manufacturing process, especially on machines as large as we have, is not as simple as pressing a few buttons to make the machine work. The machines require an entire team to properly operate and fix any hiccups that arise. This made me appreciate the more hands-on side of our business because without all the people at the mills with deep technical knowledge and experience in the business, our trials would not have been successful." [Par. 22]

From the above descriptions, we notice that students grew to understand that hands-on work is an integral part of engineering practice.

5) Develop/work with engineering tools.

The fifth subtheme, *develop/work with engineering tools,* depicts how co-op students recognized the role of computational tools in facilitating engineering work. A large part of engineering work today requires engineers to design and develop computational engineering tools and use these tools to solve a variety of multifaceted problems. Our analysis indicates that students frequently discussed using engineering tools to solve problems and accomplish the tasks assigned to them, and thus recognized the role of computational engineering tools in engineering work. One student explaining the role of computational tools in the industry said:

"*My second goal is to become more familiar with as much of the engineering software as possible. This is a great opportunity to be able to experiment with common industry software that would typically be out of reach outside of an engineering workplace. By having access now, I will come into a new job with that experience*" *[Par. 144]*

From the response, we notice that engineering students also recognize that computational software are used in the industry and many of these tools may not be available to learn in an academic environment. Thus, co-op programs also offer opportunities for students to learn and work with industry-specific computational tools.

6) Work in Teams

Our sixth subtheme suggests that working in teams is an inherent part of engineering work. Students during their co-op had to coordinate and work with different teams to complete their job tasks. Working in teams included reaching out to people from different teams, accounting for recommendations and insights from different teams while solving a problem, discussing, and working with people from their own team, etc. As students worked in teams, they understood that engineering work has many moving parts that can function well when teams collaborate and work together. Further, students also encountered challenges related to teamwork that impacted their project tasks and deliverables. One of the students discussing about their teamwork experience said:

"Halfway through the internship, an FDA audit initiated the development of a very high priority hierarchy that I was assigned to lead. This required coordination and collaboration with multiple teams, providing valuable experience in managing complex projects. However, the reliance on other teams also led to challenges, as some teams were unable to complete their documentation on time, ultimately hindering the completion of the project" [Par. 98]

Another student explained how working in teams contributes to the success of the company by saying:

"My second goal was to learn how post-market engineering impacts the company on the whole. I also was able to achieve this goal through speaking with my teammates as well as individuals on other teams. I can now see how tasks as simple as a print change are able to help clear backorder and promote continuity. Without the team I was a part of, thousands of dollars of inventory would be locked up or would continue to be made in a manner that is non-conforming." [Par. 54]

Therefore, we can say that though working in teams comes with its own set of challenges, it is an important component of engineering work that contributes significantly to the success of an organization.

7) Developing documentation about processes and projects

Our last subtheme reveals that engineering work requires students to understand, interpret, document, and communicate processes and projects they work on. As students worked on projects in cross-functional teams, they had to document the data (like problems, processes, anomalies, operating procedures, and findings) and communicate them to other departments in their organization. Students undergoing their co-op thus experienced that working with information and documenting it was an important component of engineering work. One student discussed how their main project of developing reports was useful to the organization. They said:

"My main project was to automate a process of creating Problem Follow-up Sheets to issue Design Investigation Reports more efficiently. I was able to save about 40-50% of the time to issue DIR's which is a success. However, it is still in the prototype phase so it can definitely be improved upon." [Par. 157]

Our analysis reveals that students identified various components that makeup engineering work. However, in order to succeed in their engineering tasks at work, they would need to acquire relevant skills. Our next major theme looks at different skills that students identified and learned which helped them prepare and succeed during their co-op.

B. Skills Needed to Succeed in the Workplace.

This theme explores the skills students believed were important for them to succeed at their workplace. Based on their perception of engineering work, students identified several skills that will help them successfully complete their job tasks and work in the industry. Therefore, this major theme, *Skills Needed to Succeed in the workplace,* is centered around the different professional and technical skills students described in their reflections. This theme on skills can be further divided into the following subthemes: (1) *Upskilling/improving existing skills* (2) *Communication Skills.* (3) *Take ownership or initiatives at work* (4) *Be a team player: Collaboration and Teamwork*. (5) *Be organized: Scheduling and Time management* (6) *Be adaptable and flexible at the workplace*

1) Upskilling/improving existing skills.

After observing and experiencing the nature of engineering work, students realized that they had to improve their technical skills and learn new industry/role-specific skills during their co-op. Our first major theme indicated that students had to acquire domain-specific knowledge or skills and apply them while working. As a part of this process, they needed to gain new skills and use these skills to accomplish the tasks assigned to them. Therefore, many students mentioned that their goals for co-op rotation were centered around gaining job-specific technical skills and using them to complete their tasks. A student describing industry-specific skills they learned said:

"*One example of a new skill I learned was soldering. Up to this point, I have not had to ever solder anything, and I was given the opportunity to learn to this semester, so I did. I am still not great at it, but we all have to start somewhere. Another example of a practical engineering skill I learned this year is how to make engineering drawings. While we touch on this in the classwork I have taken thus far, there is a lot that is not covered that is needed if you are actually sending a part to get machined." [Par. 95]*

Additionally, students also mentioned they worked to hone their existing technical or software skills as it helped them progress towards their work goals. One student explaining the benefit of working on their technical skills said:

"I was really focused on developing CAD experience, and I have been able to gain a lot of skills in using AutoCAD during this co-op. At first, it was difficult to navigate through the program and picture ideas in a 2D form, when being used to 3D. However, during this rotation, I was able to develop AutoCAD drawings of new workstations and flow in the factory, as well as communicating ideas on floor load ratings in the mezzanine using AutoCAD" [Par. 248]

From the above reflections, we notice that students worked on developing their existing skills and gained new skills that helped them comply with the requirements of their work.

2) Communication skills

Along with improving their technical skills, students also felt that being able to communicate effectively was an important skill in the engineering workplace. Our prior analysis suggests that communicating findings or information is a crucial part of engineering work. Furthermore, as engineers work in teams, they need to be able to communicate effectively with their colleagues and other different teams about their work and also form relationships with them. To work effectively in such settings, many students mentioned that they had to overcome their fear of public speaking by developing their communication skills. One student discussing about their public speaking abilities mentioned:

"I want to develop my presentation skills. I have never been strong at public speaking…. Moving on to presentation skills, not only was I tasked with giving a presentation to Delta operations leaders at the end of my rotation but also I would frequently speak in the bi-weekly update my manager gives to leaders detailing progress on the application. I would honestly say I did not have the best public speaking skills coming into college, but through my experiences at both Purdue and now Delta, I feel much more confident went giving presentations to a large audience" [Par. 152]

Another student mentioned the need to develop their communication skills when they interacted with people from different disciplines. People from other disciplines may not be aware of technical engineering jargon, which may require the engineer to communicate their work in simple language. Explaining a similar scenario, the student said:

"Another goal is to get better at communicating my work to non-technical people and people who are unaware of my work. I find it difficult to provide context and explain background information when talking about my work with colleagues. I would like to improve this as it a necessary skill for any engineer." [Par. 265]

In the context of developing their communication skills, students also indicated that asking questions was beneficial for them and helped them perform better at their workplace. One student realizing the value of asking questions said:

"In my first term, I struggled to be proactive and ask for help when facing a problem that I didn't understand. I was too concerned with appearing competent, and worried that my coworkers would think less of me if I struggled. In this term, I had more confidence in my abilities coming in, and did not feel

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ashamed to ask for help and be proactive when planning my projects. This helped me to be more productive when working on my projects." [Par. 63]

Thus, we observe that students felt the need to improve their communication skills by pushing themselves to speak up, reflecting and recognizing the limitations of their existing communication skills, and being proactive at their workplace by asking questions.

3) Take ownership or initiative at work.

Though co-op students worked in teams, they found that they had to take initiative and ownership of the tasks they were assigned. Engineering work requires each individual to be responsible and accountable for their work, and hence, the individual needs to take ownership of their own task. This ability to take ownership proved to be a great learning experience for students as it helped them develop their leadership skills. Realizing the importance of taking ownership of a project, one student reflected:

"I have participated in quite a few multi-week projects that apply prior knowledge, so the length and nature of the project should not have been the emphasis of the goal. Instead, I should have challenged myself to INDEPENDENTLY complete a project that requires knowledge in the energy field. This would have not only pushed me to learn, but also to apply my learning." [Par. 6]

Another student who actively took ownership and leadership on tasks explained the importance of this skill. They said:

"My second goal was to develop my skills as a leader. I served as the co-op president this term and was able to hold co-op and co-op council meetings as well as be a point of contact for the co-ops on site. Over the course of the term, I learned to handle conflict, address uncomfortable issues, and make decisions on behalf of the group. It was a rewarding experience, and it allowed me to develop into a good leader." [Par. 205]

Thus, we noticed that actively taking ownership and initiative helped the students develop leadership skills and understand the intricacies of managing people and deliverables.

4) Be a team player: Collaboration and Teamwork

Our prior analysis revealed that a major component of engineering work required co-op students to work in teams. Upon realizing that teamwork is an integral part of engineering work, the students mentioned that they actively engaged in working on their teamwork skills and contributed to the company's goals by working with their teammates. We defined teamwork skills as the ability to work in teams, work with diverse sets of coworkers, and be open to feedback and suggestions from one's teammates. Reflecting on their experiences of teamwork and receiving feedback from colleagues, one student mentioned:

"Always share your projects with your colleagues; their constructive criticism will enable you to refine both your work and the project." [Par. 73]

Another student recognized the potential of teamwork skills and how discussing project issues with co-workers and supervisors helped provide insights about a problem. They said:

"*After I failed on my first try, I reached out to co-workers and my manager who is more proficient than I am and set up zoom meetings where I explained the problem with as much depth as I could, and they offered up meaningful advice that took me a long way." [Par. 87]*

Students also recognized how building relationships with their teammates was beneficial for them to gain confidence in their engineering work. One student said:

"I made a genuine attempt to connect more with my teammates and ask them for their guidance and help. I was able to get to know them a lot more personally and I think it made a huge impact on the quality of my work as I was able to work with a lot more knowledge and confidence knowing that people won't hold my mistakes over me." [Par. 29]

Reviewing these student responses, we observe that reaching out to co-workers and peers and collaborating with them in teams was valuable for students and helped them understand the importance of teamwork skills.

5) Be organized: Scheduling and time management.

To complete their designated tasks and comply with the constraints of the projects, students felt the need to develop a system that helps them organize and manage their workloads. In addition, students recognized that they needed to learn to prioritize their tasks without compromising the quality of their work. As a result, students employed various scheduling and time management strategies to stay on track for their projects and accomplish tasks on time. One student explaining their organization strategy said:

"*I have made progress toward my goals that I set. One of my coworkers introduced me to how good OneNote is for organization of notes. I was able to use OneNote to keep all of my information organized, and keep track of different work I wanted to complete on a day-to-day manner which was one of my goals I set at the beginning.*" *[Par. 124]*

Therefore, we observe that students felt the need to develop new organization systems and gain skills that help them manage the requirements of their role.

6) Be adaptable and flexible at the workplace.

When students entered their co-op rotation, they had to adjust and adapt to the company culture and be open and flexible to changes and requirements of the tasks they were assigned. Furthermore, if students were working on their co-op abroad, they had to adapt to the local culture, learn a new language to communicate with their peers and adapt to a new working style based on the location of their company. One of the students who was completing their co-op abroad mentioned how they had to adjust to their new location and work culture. They said:

"My language skills are only improving as I continue to immerse myself living here, I'm growing accustomed and adapting to a new culture of working, and I'm ready to tackle travelling on business as well! Overall, I am quite proud of the progress I have made on the goals I set for myself, which were to improve my Spanish language skills, adapt to a new way of working, become comfortable with business travel, and become

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more self-aware as to my professional interests and strengths/weaknesses" [Par. 31]

Another student discussed being flexible in the context of engineering work as deadlines and other uncertainties related to the project milestones can occur. This student said:

"My biggest take away from this goal would be that it is definitely wise to go in with this mentality to remain focused and diligent, yet the ability to be flexible is equally as important because the timing and schedule of project work can be shifted or put on hold to afford time for others." [Par. 179]

Therefore, we observe that students acquired the ability to be flexible and adaptable at their workplace during co-op rotation.

V. Discussion

Our study explored the experiences of engineering students while undergoing their co-op rotation to understand how they shift in their perceptions of engineering work. Our findings revealed two major themes (i) Engineering students had a better understanding of the *Nature of Engineering Work* after their co-op rotation (ii) Engineering students identified professional and technical *Skills Needed to Succeed in the Workplace*.

Our first major theme *Nature of Engineering Work* aligns closely with prior research findings on engineering practice. In particular, our subthemes on *acquiring niche knowledge required by job role* and *applying knowledge and skills gained from school/work to work projects* align with prior research on technical work (American Society for Engineering Education, 2020). Barley and Orr (1997) found that engineering practice requires acquisition and application of knowledge from formal education as well as through workplace peers. In addition to formal education and learning from peers, our theme also highlights that gaining and applying industry specific knowledge is possible by learning on the job using company training and other available resources in the organization.

Our subtheme of *real-world problem solving* echoes previous findings by suggesting that engineering problem solving is ambiguous, sociotechnical, ill-structured, and open ended with a lot of uncertainties (Downey et al., 2006; Jonassen, 2000). As a result, we suggest that engineering education must work on developing students with abilities to solve complex sociotechnical problems (Author et al., Year; Grohs et al., 2018; Smith et al., 2021). Further, our subtheme draws attention to bureaucratic aspects like layers of approval, resource constraints, changes in business decisions, etc. that influence engineering problem solving and decision making.

Finally, our subtheme *work in teams* reiterates that engineering is not just technical but has social components such as working in diverse teams (Trevelyan, 2007). Accordingly, efforts must be focused on exposing students to similar settings during engineering education through approaches like project-based learning and teamwork activities (Dym et al., 2005). Our subtheme also emphasizes that teamwork in an industry is different from university setting. Teamwork in the industry has unique challenges like collaborating across teams and adapting to other teams' working styles. These factors may also impact project success. Therefore, future work must try to expose students to similar real-world settings and explore how cross-team collaboration and competence can be developed.

Our next major theme, *Skills Needed to Succeed in the Workplace*, indicates that upon understanding the nature of engineering work, students identified specific professional and technical skills that they needed to develop. Companies and industries required students to gain job specific knowledge and thus, students discussed specific technical skills that they developed during the co-op experiences. Further, we noticed that students had to *upskill* their technical skillset as per the requirements of specific their role. This finding suggests that it is important to help students develop life-long self-learning abilities before going on their co-op experiences (and especially before graduation) so that they can adapt their skills for their specific work environment (Martin et al., 2005).

Along with technical skills, professional skills are an equally crucial component of engineering work (Baytiyeh & Naja, 2012; Brunhaver et al., 2018; Korte et al., 2015; Martin et al., 2005; Trevelyan, 2019). Prior research indicates that employers expect new graduates to co-ordinate and communicate with people from different disciplines, collaborate with peers and teams, and manage projects (Brunhaver et al., 2018). However, research also indicates that students often feel that they lack these professional skills upon graduation (American Society for Engineering Education, 2020; Baytiyeh & Naja, 2012; Martin et al., 2005). Our study revealed that co-op helped students acquired professional skills like *Communication skills*, *Be a team player: Collaboration and Teamwork*, and the ability to *Take ownership or initiative at work which* helped them meet the expectations of their employers. Additionally, our findings from the collaboration subtheme highlight that building relationships with colleagues and teammates was beneficial in improving student's workplace confidence and help them feel prepared for practice.

Our data also provided additional evidence of the multifaceted nature of engineering work. Students in our study began to recognize how technical and professional skills are integral to engineering work and how they will need to use all of these skills together as part of their engineering careers (Brunhaver et al., 2013; Martin et al., 2005). Therefore, we recommend that professional skills should not be taught in isolation from technical skills. Rather, these skills can be taught in tandem by embedding them in technical coursework and increasing student involvement in extracurricular activities and experiential learning programs (American Society for Engineering Education, 2020). Because co-op programs and similar experiential learning experiences require students to use professional and technical skills together, they can be important experiences in helping students feel prepared to enter the workforce. Building on our work, future research on co-op experiences could explore students' ability to integrate technical and professional aspects of engineering work and how life-learning abilities can be fostered in students before, during, and after their co-op programs.

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