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Student Perceptions and Attitudes Towards Engineering Design in Work-Integrated Learning Contexts

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1 Introduction

To continue enhancing student learning, many institutions are implementing work-integrated learning programs (WIL) to aid in the development of work-ready graduates [1]. WIL integrates academic studies with experiences within a workplace or practice setting [2]. These experiences can take many forms including collaborative research projects, apprenticeships, co-operative education, entrepreneurship, field placements, internships, professional placements, service learning, or work experiences. WIL programs are very common in undergraduate engineering programs and have more recently expanded to graduate programs, as well as many arts and science programs [1].

With the widespread use of WIL programs, it is critical that engineering education researchers pay attention to how participation in WIL contributes to student development [3], including design skill development. It is this broader need that motivates this work, focusing specifically on the affective domain of student self-efficacy development in WIL settings. We focus on affect specifically, because affective (emotional) outcomes – e.g., collaboration, motivation, sense of belonging - are known to have a large effect on students' professional development [4]. Additionally, in much of the existing literature, considerations of the engineering learning environment focus solely on the academic environment and do not include the (often) external stakeholders that are central in WIL settings. This work, then, seeks to highlight some features of the affective environment that students experience in a design-focused work environment to assist engineering educators with preparing students for these environments.

The paper presents findings from a larger study that explored experiences of students immersed in a four-month design-centered WIL setting. The research comprised of a thematic analysis conducted on a series of weekly semi-structured interviews that spanned the duration of the students' WIL experience. The themes that are specifically discussed in this paper center on the students' affective domain, providing insight into their emotional responses to being engaged with design tasks in a WIL setting. The remaining sections of this paper are a background on self-efficacy domains and their development in WIL settings, the research methods employed in this exploratory study, results, discussion and conclusion.

2 Background

2.1 Self-efficacy and affect in learning

A key factor in skill development is self-efficacy, which refers to a person's belief in their capacity to succeed at a task. Self-efficacy beliefs vary across tasks and situations, and can change over time, for better or for worse. Bandura [5] describes four mechanisms to develop one's self-efficacy beliefs:

1. Mastery experiences – persevering through challenges, completing difficult tasks, learning from failure instead of getting discouraged
2. Social modeling – seeing peers succeed at challenging tasks contributes to one's beliefs that they will also be successful

3. Social persuasion – people can be persuaded to believe in their own abilities
4. Physical and emotional states – self-efficacy beliefs are affected by emotions like anxiety, as well as physical strength and stamina, and one's ability to regulate emotions

The first three mechanisms - mastery experiences, social modeling, and social persuasion - are all common elements of project-based learning. For example, cornerstone (i.e., a project which appears early in a curriculum to serve as a foundational experience for students), capstone, and other long duration projects are typically challenging, and frequently include public demonstrations and presentations to peers; all means by which students can develop self-efficacy beliefs while they practice and demonstrate their technical and professional skills. Frequently, however, descriptions of pedagogies which target student self-efficacy development do not describe the fourth mechanism - physical and emotional states of the participants - no doubt in part due to the complexities of assessment.

The emotional domain of learning, also frequently called the affective domain, has been a feature of learning theory for decades. Bloom's original Taxonomy of Learning Objectives included the cognitive, affective, and psychomotor domains. The specific handbook on the affective domain was published in 1964 and focused on students' attitudes, values, and interests, and how those are developed through teaching and learning methods [6]. In the engineering context specifically, the affective domain frequently focuses on collaboration, confidence, curiosity, persistence, motivation, and professional ethics [7] [8]. Wilson, in their essay in [4, p. 57], refers to affective outcomes as the "great mediators of engagement", and argues specifically that students' sense of belonging and feelings of academic fulfillment can lead to improved academic performance. Improvements to student affect in the classroom can quickly erode when transitioning to new environments, like the workplace: "the road of affect is continually in need of repair and upgrading to keep engineering professionals engaged and contributing in the workplace." Universities must create and maintain environments where students can experience positive affect, and train students to be aware of their affect, including developing their emotional intelligence to assist their future peers with their affect [4].

2.2 Self-efficacy in WIL contexts

To date, most of the research on the benefits of WIL programs for engineering students have focused on outcomes rather than experiences [3]. For example, Blair and colleagues [9] investigated the impact cooperative education had on engineering graduates across three dimensions, GPA, duration of time in school and starting salary. Their findings indicate that students who participated in co-op earned higher GPA's, had higher starting salaries but took longer to complete their undergraduate programs [9]. Similarly, Fogg & Putnam [10] found that the earnings of bachelor's degree recipients who were employed full time after graduation were significant influenced by the quality of co-op jobs. In a large multi-institutional survey, Anderson and colleagues [11] identified that participation in WIL influences students' academic choices to better align with career choices and has a positive impact on their overall satisfactions and success.

Unfortunately, descriptions of student experiences engaged in design tasks during WIL opportunities are scarce; Litster et al. [12] highlight that there are very few publications that focus on students' experiences of design in the existing design literature. As such, they conducted a secondary analysis of the publications reviewed in [3] to identify reported instances of design learning occurring during a WIL experience. They found some limited evidence in those publications of students designing elements, systems or processes using the engineering design process and students recognizing the broader impacts of their design with respect to health, safety, and other ethical considerations [12]. They conclude their discussion with calls for more in-depth exploration of student design learning during WIL with hopes of informing future engineering education pedagogies that support students [12].

The affective domain – largely investigated in the field of social psychology – describes key characteristics that help us understand human behavior [13]. This domain includes constructs like attitudes, values, self-concept, interests, and of particular importance for this work, self-efficacy. As described above, self-efficacy is the self-appraisal of ability and is believed to be one of the key factors in a student's achievement and persistence having influence over behavior and effort [1] [14]. In WIL contexts, self-efficacy can directly impact what someone chooses to pursue, how likely they are to persist in the face of challenges or failures, and their expectancy of success or failure in future endeavors [15]. Unfortunately, the push to make graduates 'work-ready' with cognitive-oriented graduate attributes largely has resulted in the neglect of these characteristic in the affective domain [16].

More specifically, work self-efficacy describes those behaviors and practices that develop students' beliefs in their ability to handle the social and technical requirements necessary for success in the workplace [17]. Some authors suggests that performance accomplishments, like using skills, abilities, and coping strategies to perform tasks, increase this kind of self-efficacy [17] [18]. To develop the conceptual underpinnings of workplace self-efficacy further, Bandaranaike and Wilson [16] operationalize emotional-intelligence (e.g., the capacity for organizing our own feelings and motivations to manage our emotions and relationships) in the workplace by introducing the concept of 'emotional work-readiness'. Emotional work-readiness is a concept that incorporates emotional and social attributes of the workplace. These attributes (e.g., drive for achievement, emotional awareness, self-control, etc.) enable students to build their work readiness capacity for future employability.

Students and educators perceive workplace learning as valuable – it connects theory with professional practice and contributes to students' professional identity development [19]. WIL opportunities help students transition into full-time work more easily, helping them overcome the 'reality shock' attributed to first job experiences for uninitiated novices [17]. Unfortunately, however, some authors identified that those students who participate in WIL experiences do not expect the amount of complexity of the problems they were facing as engineers on the job [20]. Further recognition of the affective domain's importance, and in particular work self-efficacy development, over the course of WIL experiences will alleviate some of those issues. There are strong reasons to suggest that these affective ways of operating are crucial for harnessing engineering students' cognitive skills [16]. Educators who use WIL should consider linking explicitly the cognitive and affective domains for greater student engagement and learning in WIL and for subsequent work readiness/employment [16]. With these ideas in mind, we now turn to our own exploratory investigation of student experience of design in a WIL context.

3 Methods

The interview protocol was an exploratory, semi-structured approach adapted from the ECHO method [21]. This approach is well suited to gathering rich contextual descriptions of the participants' experiences. Participants were asked about design challenges they encountered, and prompted to identify specific examples of how people and technical factors from their design context affected the situation being discussed. This method of prompting minimizes recall bias by focusing the participants descriptions on concrete examples as opposed to generalized descriptions.

The participants described in this paper worked for a unit called the Engineering Ideas Clinic within the Faculty of Engineering at the University of Waterloo which develops new design teaching activities for all 14 engineering programs at Waterloo (hereon referred to as "design clinic"). Three participants were recruited via email from a population of 12 co-op students working at the design clinic in the winter term of 2022. All three participants worked on real-world design activities for internal and external clients. The participants were all in the first half of their engineering programs, meaning that they had undertaken a cornerstone design project course, but had not yet begun their final year capstone design project. All cornerstone design projects undertaken by the participants had occurred in a virtual environment as a consequence of the COVID-19 pandemic.

Each participant attended a series of ten weekly interviews, starting in week six of their co-op term and concluding in the final, 16th week. The first interview asked them to reflect on the first six weeks of their term. Interviews two through nine had them reflect on the previous week's events, and any ongoing design issues that they worked on over several weeks that were still the focus of their attention. In the final week, the participants were asked to reflect on their overall experience of designing that term, and what they learned over their co-op. Altogether, this resulted in a dataset of 772 minutes of transcribed interview data, with an average of 257 minutes of transcript per participant.

The interview transcripts were analyzed using an iterative thematic analysis approach [22]. The dataset was iteratively coded using a CAQDAS software package (DeDoose), with the initial passes being primarily inductive. Common topics were identified within the transcript excerpts, reviewed against each other and the transcript data to iteratively converge on a set of themes. This process proceeded until the set of themes met the double criteria of internal homogeneity (data within a theme is coherent) and external heterogeneity (clear distinctions between codes) [23]. To improve the verisimilitude of the presentation, extensive use of participant quotes has been used throughout [24]. These quotes have been only lightly edited to ease understanding while attempting to maintain the original voice of the participants.

3.1 Researcher Positionality

The analysis was performed by a research assistant experienced with qualitative research methods, who had previously completed undergraduate and postgraduate degrees in engineering at the institution. This background provided the research team with first-hand experience of the engineering co-op program and allowed the results to be analyzed with an understanding of the underlying context of the co-op system. The other members of the research team are the manager of the WIL setting under study who is also a design education researcher, a faculty member who is a capstone design course instructor and design researcher, a faculty member who has 15 years of experience teaching first-year cornerstone design courses and engineering education researcher, and a PhD student in engineering education who completed 2 prior degrees at the institution described in this study. The research team has extensive experience in design education, design education research, and design research as well as qualitative research methods.

3.2 Study setting

This study took place at the University of Waterloo that has nearly 9000 engineering undergrads in 14 engineering programs. All 14 programs have a mandatory co-op component: students need to complete five paid work terms to graduate, each work term four months in length. The design clinic hires between 6 and 12 co-op students each semester to develop new activities; these students are researching, prototyping, testing, and refining new design pedagogies for the Faculty of Engineering (see [25] for an overview of one of these pedagogies). This development frequently requires the design and construction of new equipment across a wide spectrum of domains; often in partnership with industry [26]. Prior research on co-op student learning outcomes in this work environment has shown this environment is conducive to student technical and professional skill development by providing opportunities for “deliberate practice” of engineering skills [27]. The results presented in this paper are part of a larger study; an earlier publication of results from this research focused on aspects of the work environment which differed from participants’ classroom experiences [28].

4 Results

The interviews provided a large and rich dataset, which was analyzed under multiple lenses. In this paper we report on key themes that fell under the top-level theme of the “affective domain” of the co-op students’ experience. This theme covered the attitudes and emotions expressed by the participants, self-identified stressors, the designers’ ability to empathize with other designers and users, and the designers’ confidence in how their previous design education prepared them for their experiences on this co-op. The results presented in this paper seek to describe the emotions participants felt while working in this environment. This focus on the affective domain seeks to highlight an understudied area of student development that is not always present in traditional classroom learning, and one where the nature of work integrated learning is well suited to its study due to the challenge and complexity of the problems faced, and the length of time that students are engaged with design tasks.

A total of 626 excerpts were coded within our dataset, of which 112 excerpts relating to the affective domain were coded within the 4 themes and 9 “sub-themes” shown in Table 1 below. The “sub-themes” provide further detail on specific aspects of two of the four themes, where the data corpus under the theme was broad enough to make more nuanced distinctions. These sub-theme distinctions refer to the conceptual targets of the designers’ self-highlighted attitudes and emotions, and the perceived sources of the designers’ self-identified stressors during their WIL design experience.

In the following subsections we describe each of the themes and illustrate key points with direct quotes from the participants. For ease of reading, we refer to the study participants as "designers" or "student designers" to differentiate them from the students who in this case are in their study term participating in the learning activities, and thus the intended "users" of the designs.

Table 1 Summary of identified themes and sub-themes

Theme	Sub-themes
Designers' **attitudes and emotions** towards…	…Uncertainty and novelty …Authority and expertise …Adversity and failure
Designers' **self-identified stressors** due to…	…Fixation and iteration …Clarity and consistency of design goals …Availability of information …Environmental factors
Designers' **ability to empathize** with…	…Other designers
Designers' **confidence** in..	…Their design skills and knowledge from prior education

4.1 Attitudes and emotions

Over the course of the ten interviews the designers described their attitudes towards a wide range of factors, both internal to the design problem and in the broader context they were working in. In our thematic analysis, we grouped these attitudes by their target, arriving at three categories: attitudes towards uncertainty and novelty, attitudes towards authority and expertise, and attitudes towards adversity and failure.

4.1.1 Uncertainty and novelty

Three responses were noted in the designers' descriptions of their experiences encountering novel problems and having to make decisions under conditions of uncertainty. First was that the designers relied on design decisions they had previous experience with and could therefore estimate the impact of, instead of exploring alternative options that had the potential to result in a superior design.

> *"Something I might have done instead would be to waterjet [cut] that out of like aluminum or something. But I was like unsure of sort of the timeline of sort of acquiring plate of aluminum and then going to like the machine shop to waterjet it. So this is sort of the more familiar route so I [was] more comfortable to do it in that time."*

Another response was to avoid progressing with elements of the design project in the face of uncertainty. The following example was tied to uncertainty around regulations and procedures that the designer needed to adhere to:

> *"… I haven't really done anything yet because I don't know where to put [the chemicals] after, or even put it in the first place because the sensor doesn't reach into the bottle. But then it's not like I can just pour it down the sink.. it's chemicals."*

Lastly, one of the designers indicated a level of excitement to encounter novel problems and use novel techniques to resolve them, as a means of further developing their own knowledge and skills:

> *"I'm also realizing that I want to … get to that point because I'm interested… to learn about that… when I have talked to… one of the co-op who's seemingly like more experienced in this field than I am, he's like…, you just do X, Y, and Z ... And I was sitting there like, don't know what X is, might have heard a bit about Y, and don't know what Z is. So it's certainly something that I want to learn ..."*

4.1.2 Authority and expertise

Over the course of their co-op terms the designers were working relatively independently but had reporting lines to both a supervisor/advisor and a manager who had input on design decisions. Additionally, some of the projects had other co-op students working alongside them, and the projects all had clients or users involved in shaping the project. This structure differed from the structure within the designers' classroom design projects, whether group or individual, primarily through the addition of external stakeholders and reporting lines.

The designers described a range of attitudes to those additional stakeholders when engaging in decision making ranging from relatively passive deference and reliance to more active collaboration and attempts to prove independent capabilities. Deference occurred when more senior stakeholders with perceived expertise made design decisions. The designer felt that it wasn't their role to suggest alternatives, even when the decision ended up causing significant challenges later in the project (albeit challenges that the designer themselves did not predict).

> *"I didn't really research the different options. Basically, we were in a team meeting between [manager, supervisor], myself, and other co-ops… And basically, [this professor] suggested it and everybody else agreed. So then it was just up to me to learn about it versus choose different options."*

The designers also indicated that they felt they should abdicate design decisions that would have an impact beyond the temporal scope of their co-op term.

> *"…my supervisor, [] they all work for the University and sort of oversee the [design] clinic and run all these projects that are going on. So yeah, any changes that happen in the future all basically come from what they want, what they have in mind."*

External expertise and resources were also utilized by the designers to support their decision making, predominantly through market research and searches for online guides. The designers preferred to search for a "pre-solved" design problem that they could apply within their own projects, to offset the need to understand the underlying functionality of the solution.

> *"But yeah, I just kept on looking at the Wi Fi idea, even though that we weren't using it. I was kind of just looking for answers in there. Because everything that I could find online… always used Wi Fi and never used Ethernet."*

However, some of the participants noted that this deferential approach towards perceived authority when making design decisions did not provide them with the level of insight into design rationale that they wanted.

> *"I'm not entirely sure why [that feature is] there, doesn't mean that it's not important, especially if a previous group has said it is. But it's definitely more helpful to know why we're doing something."*

Another response to the presence of perceived expertise within their project teams and the design clinic was to actively leverage that expertise to learn from and develop their own design knowledge and skills.

> *"So my biggest action that I took that helped me gain knowledge was just asking questions. I asked the other co-ops who are already familiar with it, I asked them about how things work and things like that. And I did learn a lot just within the first few days. […] But I'd always, if I ever thought of anything I just asked questions, even if it seemed like a dumb question or something, I wasn't afraid to just ask."*

When the designers did take responsibility for making design decisions, often the decision-making process became a collaborative endeavour. This allowed the designers to propose ideas, and have senior figures assess those ideas with their expertise, providing scaffolding for the designers to assess the relative "quality" of their ideas without needing to spend significant effort researching or prototyping and testing.

Towards the later interviews some of the designers discussed situations where the collaboration became more of a dialogue, as they would expand and alter suggestions from senior figures before returning with their own suggestions.

> *"So originally, my supervisor had suggested a [mechanical] stop…. But then I pointed out that the actual housing that I had already made, was already stopping it. So I just suggested to sort of make it have a little more contact area just so it's more certain that it will stop it and won't miss it."*

Some of the participants noted that they felt that the expectations of independent decision making were higher in the co-op setting than in the classroom.

> *"I definitely do try to always go back with progress… I think, with co-op, there's more of a responsibility to do that… when you're in the classroom setting, if you're lost from the very beginning, it's more of a split responsibility. In terms of the [teaching assistants] and professors are there to help you get started... Versus in the co-op setting, I find it is more so on you to have a good sense of where to start or what to do and to go back and ask questions if you get stuck later on down the line."*

When multiple attempts to resolve design problems independently resulted in repeated failures or design issues the designers turned back to more senior designers and experts, relying on them to help resolve the issues and move the design project forward.

"This week, I'd say I definitely reached out more, because I was kind of at my breaking point. I was kind of stuck. I didn't know what to do… I was like, if this doesn't work I can't really think of anything else other than replacing the sensor."

4.1.3 Adversity and failure

The designers were working on design projects that were open-ended and reasonably complex, leading to the potential for design solution iterations that did not meet the requirements. When the designers encountered these situations, they were predominantly perceived as "failed designs" or "failures". This engendered a significant degree of frustration in the participants.

"I feel like I fix one issue and it leads to another issue. And it just kept on changing along like that… last week, I was testing it on the oscilloscope, and then when I used it in the actual system, the ground wasn't working on one of the pins. And then when I fixed that, the actual sensor itself was dead. So I needed to replace the sensor… And so it was just one issue after another that just kept on going on until it finally worked."

After having experienced a series of interrelated problems while troubleshooting a design, the designer expressed signs of relief when a component of their design functioned as intended on the first trial:

"It's just been plug and play, plugging it in and it starts reading, which has been fortunate. Because honestly, I'm getting sick of all the issues that we're having. So it's good that it's actually working as intended. Just needs calibration."

It is interesting to note that one of the participants reflected in their final interview that they learned how to use iteration to progress the design project and learn about their design.

"I took away from this whole co-op term is that, yes, it's okay to design something and for it not to work because you'll learn something that you didn't previously know about the design, and also, it will give you another chance to improve it and to explore new opportunities to make whatever you're making better."

4.2 Sources of stress

Over the course of the study the students self-identified several stressors that impacted their attitudes towards their design solutions, their design projects, and the co-op term. These stressors were grouped into three sub-themes: iteration in the design (or lack thereof due to fixation), the clarity and consistency of the design briefs and requirements, and factors in the working environment and norms that affected their designing.

4.2.1 Fixation and Iteration

The open-ended design problems presented to the designers in our study often required iterative design cycles, where elements of the design solution were ideated, prototyped, tested, and adapted or improved based on the results of the testing. This iterative approach to design exploration and solution generation was not something the participants had been exposed to in their classroom design education to date. The designers tended to be frustrated by this iteration as discussed in the previous section on their attitudes towards adversity and failure and exhibited a desire for their first solution or decision to be "perfect" or capable of achieving "perfection" relative to the design specification.

> *"I had sort of a perfectionist mentality going into it where if I made one design it had to work the first time to avoid the waste materials and everything like that."*

The fixation extended to the exploration of alternative design paths when making design decisions, where the participants' desire to rely on expertise, both internal to the clinic and external in online guides, to make decisions had them fixating on the first solution they generated, received, or discovered. This in turn resulted in further frustration when the first solution was not functioning or successfully fulfilling the design requirements.

> *"I guess I haven't really been too efficient with figuring out how to solve problems. Like I got into like a kind of loop where... this is working, why isn't this one? And I couldn't figure out why, so I kind of just kept staring at it and not look for other solutions that could have worked."*

4.2.2 Clarity and consistency of design goals

As a feature of working directly with real clients on open-ended problems, the design specifications the designers received were not as well-defined as in typical early-year design courses. The designers noted this difference, and discussed how having a client with well-defined goals and requirements made their job easier.

> *"[The client] knew what [they] wanted the project to be. So [they] being able to provide us with directions to go in for the project made it easier for us, especially since we were still given the liberty of how we wanted it to work."*

However, on that same project there were competing requirements driven by different needs between the intended end user of the design, and the client who was driving the design project. This divergence of stakeholder aims was not modelled in the design classes the designers had taken to date. Coupled with the organisational constraints such as the deadlines presented by a real project, this uncertainty and inconsistency in design requirements had the designer expressing feelings of stress.

> *"with the timeline and everything like that, the last-minute change a few days [ago] that we provided [the client] with to make [the design] seem a lot easier to use was actually not what [they] wanted. So that was a challenge, not because of the [client] themselves, but just because the way everything lined up being two days before it was due, and we had to make major changes to it, in addition to testing all the hardware, that was certainly a challenge that was imposed, not by the [client], but because of the situation."*

4.2.3 Availability of information

The design projects undertaken by the designers involved many sources of information both internal (e.g., transition documents) and external (e.g., supplier catalogues). Given the relative complexity of their designs and the transitions between work terms, the students were frustrated when needed information was not readily available.

> *"without the documentation, it's hard to progress. So having the deadlines there, but not being able to progress just adds extra stress, and you have to work faster."*

Conversely, the complexity of the design problems they dealt with also meant that excess information, in the form of constraints and requirements, also challenged the designers' capabilities and caused them to feel stress.

> *"Yeah, kind of that there was so much information that it was kind of hard to make design decisions without... that would like conform to every one of those sources."*

4.2.4 Environmental factors

The cohort of co-op students that participated in this study did so under the conditions of COVID-19's disruption to higher education. While all of the participants had the opportunity to work on-site within the design clinic over the term, one of them noted that they started the co-op term working remotely. This student noted that in the remote environment it was more challenging to get acquainted with the transition materials on one of their projects, as they were solely reliant on documentation with limited ability to ask clarifying questions.

> *"I did kind of struggle at the start of this term, because it seemed... especially being remote, it was hard to understand sort of where the project was"*

4.3 Empathy for other designers

One of the most prominent differences between the student designers' classroom experiences of design and the experience in the design clinic was that project scopes extended across multiple co-op terms [28]. This necessitated project transitions, and since the co-op terms do not overlap those project hand-offs between designers were in the form of documentation and design artifacts. All three designers had at least one of their projects handed off to them, and in turn handed off at least one of their projects in an unfinished state. Recognizing from their own experience of taking on a partially completed project, they made some decisions that attempted to smooth the transition for their successors.

> *"Yeah, that was like, I guess the goal that I've set out to get done for this co-op term was basically get all the sensors up and running. So that next term, other co-ops can start the actual automation process."*

However, despite having indicated their own frustration with incomplete or hard to interpret transition documentation, some of the designers made a conscious decision to not make explicit the rationale underlying elements within their design.

"It's mostly just the general recommendations, like I'm not including, like, a function name or a list of all the variables. Because I'm just trusting that the variable names kind of explain themselves."

Some of the designers' comments also indicated that they held a constrained view of their role and influence on the project. They made limited efforts to forecast what design decisions would need to be made by future designers and did not make their own design decisions with those future decisions in mind.

"Like from my end? …I don't know a lot about what they plan for the future, so I just made things with what information I had. So there wasn't a whole lot of consideration for what features they wanted to do with [the design in the future] just because I didn't know enough about that."

This mentality extended to designers working concurrently with them on other aspects of the design, and limited their consideration for how their design decisions would affect the overall integration of the design solution.

"It hasn't been much of a concern for me. Pretty much what I've been doing is just like, placing where the motor will be, and making sure it can actually move the arm I think all the like actual preciseness of how much it's going to move and everything is going to be done later, because all the sort of electronics… is getting redone by someone else."

4.4 Confidence

The previous results indicate that the designers encountered many challenges over their co-op terms. As a part of the interviews the designers were asked to self-assess whether they felt prepared for those challenges by their previous design education and experiences. In the majority of instances, they indicated that they did feel their background adequately prepared them.

"I think most of the tasks I've been given so far [that have] required a design component have been fairly simple. So all the knowledge I have was enough to carry out that task with some input from like my supervisors to get feedback on sort of what they envisioned the design to be."

In some instances, this confidence in their capabilities extended to skills where they were not actually sufficiently prepared. For example, one student had a positive experience creating a part in the machine shop one day when they had the support of staff in the shop, but struggled to complete the task independently the following day:

"When I started using the drill press the first day went well. And then we went back the second day, and I was using on my own and like the first hole I was drilling the chuck fell out. […] But after that happened, like it was just, I just really was feeling really confident having used it properly the first day."

When the designers did indicate that they felt underprepared for a design challenge they only highlighted technical skills they were not confident in, such as programming.

"More so towards the beginning, I was very intimidated by the code. Because as someone who with not much coding background, coding in a new language that I never seen before, it was hard to just open up hundreds of lines of codes and two different documents and learn it. So at the start, I did kind of pass it off, or I avoided the responsibility of looking at the code or touching the code."

5 Discussion

As noted in this paper, the research presented here was exploratory in nature: the researchers set out to understand the experiences of students in a design-focused WIL setting. When originally framing this research, the researchers were not necessarily expecting results relating to students' affective domain, and so the interviews were not intentionally designed to collect these data. It is the hope of the researchers that this paper could serve as one starting point for a deeper exploration of students' affect in other WIL settings.

WIL experiences have become common in engineering education, yet most previous studies on engineering skill development in WIL have taken quantitative approaches (e.g., large surveys) that largely focus on outcomes. This study aimed to explore WIL in engineering education from a different perspective, providing a rich picture of the experience of students involved in WIL. While the study was based on the experiences of three participants, the methodological approach – weekly interviews with three students all engaging with design projects within the same WIL setting, for a total of 30 interviews – produced a large qualitative dataset, that traced the student perceptions and attitudes through the duration of their 16-week co-op term.

The thematic analysis of the interviews resulted in four themes related to the affective domains, two of which were especially dominant. The first dominant theme comprised of the student designers' attitudes and emotions towards various human, technical, and non-technical influences in their work. Specifically, the students spoke of how they experienced dealing with uncertainty (including novel problems), engaging with multiple supervisors and various stakeholders that offered varying levels of expertise and authority, and handling adversity (and even failure) in the face of complex design projects. The second theme spoke to various stressors that impacted the student designers, which included being immersed in highly iterative design processes and at times having to let go of any notions of reaching "perfect" design solutions (a common fixation). These design projects lacked the clarity and consistency of goals that the students had become accustomed to in their course projects, requiring students to source missing information, navigate potentially contradictory goals, and learn to manage large volumes of information. This is not to say that the sub-themes on student empathy for other designers, or their views on their confidence are less important to study, simply that there was a larger corpus of data that spoke to the first two themes. Further study could target these theme areas specifically to explore what other insights could be gleaned from WIL students.

The study findings have important implications for engineering education. While the student designers felt they had the academic training necessary to complete their design tasks in the work environment, the findings also suggest the need to develop resilience in students, preparing them to embrace failure and iteration in design, as opposed to striving for a perfect result and getting trapped in fixation loops. To that end, constraints of the classroom environment, or perhaps the expectations and demands of the students themselves, may not be placing the students in the right context for certain elements of design learning and self-efficacy development. Summative, high stakes design practice in the classroom may not create the right environment for students to practice developing resilience. This was no doubt made worse by the Covid-19 pandemic, where social modelling and social persuasion were challenging to incorporate in online instruction. Students are more likely to successfully avoid these challenges in course projects, which are team-based, limited in complexity, typically scaffolded by the course design, and heavily time bound. Students are less likely to take technical risks due to the potential academic fallout if it goes badly (though teaching team members can help mitigate this risk) and can fall back on to their strengths instead of using the design project as an opportunity to improve on their weaknesses. There was also some evidence of over-confidence, perhaps stemming from the Dunning-Kruger effect, like the designer who was attempting to use equipment in the machine shop after only one day of training.

While the focus of this paper is on the preparation of students to enter WIL environments, the student comments do raise some areas of interest for employers. In contrast to the typical university learning environment, the more complex and time-consuming tasks in a real work environment may not give students the same freedoms to avoid challenges as mentioned in the previous paragraph. The design clinic placements described in this paper provide an opportunity for students to confront challenging emotions like frustration and feelings of inadequacy. The challenge is in constructing the environment, and on managers to support the students as they work through these emotions. Communication is crucial to identifying and correcting unhelpful emotions, and in removing potential sources of frustration for students (like the student who did not consider future implications of their work due to a lack of knowledge of where the project might go). In the study, the students were more honest with their feelings and challenges with the interviewer than with their manager, no doubt due to the perceived impact that speaking openly with their manager might have had on their performance evaluation at the end of the term. As students enter a co-op placement, they transition in their identity from learners to workers, and may need "permission" to continue thinking of themselves as learners in this setting. This may help them cope with some of the pressures of performing in a new work environment.

6 Conclusion

This paper presented a longitudinal, exploratory investigation into the experiences of student designers in a work integrated learning environment. The student designers were interviewed weekly in each of the last 10 weeks of their 16-week work term and were asked about design challenges they encountered, and prompted to identify specific examples of how people and technical factors from their design context affected the situation being discussed. This paper presented a summary of responses which were grouped under the "affective domain" theme. This paper presented the designers' attitudes and emotions towards uncertainty and novelty, authority and expertise, and adversity and failure; their self-identified stressors due to fixation and iteration, clarity and consistency of design goals, availability of information, and environmental factors; they ability to empathize with other designers; and their confidence in their design skills and knowledge from prior education. For engineering educators, the study findings show that the designers felt they had the necessary academic training to complete challenging design tasks, but they may not have developed sufficient resilience in their prior experiences to prepare them for the challenges of the work environment. The students described experiencing challenging emotions like frustration and feelings of inadequacy in the work environment; and they may need help overcoming these feelings to continue working at the levels that they are capable of.

7 References

[1] M. T. B. Drysdale, M. L. McBeath, K. Johanseen, S. Dressler and E. Zaitseva, "Psychological attributes and work-integrated learning: an international study," *Higher Education, Skills and Work-Based Learning,* vol. 6, no. 1, pp. 20-34, 2016.

[2] CEWIL Canada, "What is Work-Integrated Learning (WIL)?," November 2021. [Online]. Available: https://cewilcanada.ca/CEWIL/CEWIL/About-Us/Work-Integrated-Learning.aspx?hkey=ed772be2-00d0-46cd-a5b8-873000a18b41. [Accessed 21 January 2024].

[3] Q. Liu, D. Reeve, C. Rottmann and E. Moore, "Examining Workplace Affordance and Student Engagement in Engineering Co-op and Internship Literature," *Canadian Journal of Science, Mathematics and Technology Education,* vol. 20, no. 1, pp. 116-129, 2020.

[4] R. Adams, D. Evangelou, L. English, A. D. De Figueiredo, N. Mousoulides, A. L. Pawley, C. Schiefellite, R. Stevens, M. Svinicki, J. M. Trenor and D. W. Wilson, "Multiple Perspectives on Engaging Future Engineers," *Journal of Engineering Education,* vol. 100, no. 1, pp. 48-88, 2013.

[5] A. Bandura, "On the Functional Properties of Perceived Self-Efficacy Revisited," *Journal of Management,* vol. 38, no. 1, pp. 9-44, 2012.

[6] D. R. Krathwohl, B. Bloom and B. Masia, Taxonomy of Educational Objectives: the classification of educational goals (Affective domain, handbook II), vol. II, D. McKay, Ed., New York, 1964.

[7] H. Khan, "Teaching To Design, Build, And Test In Senior Projects: Learning Outcomes In The Cognitive, Affective And Psychomotor Domains," in *ASEE Annual Conference*, Montreal, 2002.

[8] E. Stapleton-Corcoran, "Bloom's Taxonomy of Educational Objectives," University of Illinois Chicago, Center for the Advancement of Teaching Excellence, 25 January 2023. [Online]. Available: https://teaching.uic.edu/blooms-taxonomy-of-educational-objectives/. [Accessed 13 March 2024].

[9] B. F. Blair, M. Millea and J. Hammer, "The impact of Cooperative Education on Academic Performance and Compensation of Engineering Majors," *Journal of Engineering Education,* vol. 93, no. 4, pp. 333-338, 2004.

[10] N. Fogg and M. Putnam, "Conisdering the Needs of Different Stakeholders: The Impact of Co-op Job Quality on Post Graduation Earnings," in *Handbook for Reserach in Cooperative Education and Internships*, Routledge, 2003, pp. 229-249.

[11] E. Anderson, N. Johnston, L. Iles, N. McRae, N. Reed and J. Walchli, "Co-operative Education and Student Recruitment, Engagement and Success: Early Findings from a Multi-Institutional Study in British Columbia," *Journal OF Coperative Education and Internships,* vol. 46, pp. 58-76, 2012.

[12] G. Litster, A. Hurst and T. J. Pretti, "Surveying Design Skill Development in Work-Integrated Learning Experiences: A Review of the Literature," in *International Conference on Engineering Design (ICED 21)*, 2021.

[13] D. B. McCoach, R. K. Gable and J. P. Madura, Instrument Development in the Affective Domain: School and Corporate Applications, New York: Springer, 2013.

[14] D. Malicky, "A Literature Review On The Underrepresentation Of Women In Undergraduate Engineering: Ability, Self Efficacy, And The "Chilly Climate."," in *ASEE Annual Conference and Exposition*, Nashville, 2003.

[15] M. T. B. Drysdale and M. McBeath, “Motivation, self-efficacy and learning strategies of university students participating in work-integrated learning,” *Journal of Education and Work,* vol. 31, no. 5-6, pp. 478-488, 2018.

[16] S. Bandaranaike and J. Willison, “Building capacity for work-readiness: Bridging the cognitive and affective domains,” *Asia-Pacific Journal of Cooperative Education,* vol. 16, no. 3, pp. 223-233, 2015.

[17] J. A. Raelin, M. B. Bailey, J. C. Hamann, L. K. Pendleton, R. Riesberg and D. L. Whitman, “The Effect of Cooperative Education on Change in Self-Efficacy Among Undergraduate Students: Introducing Work Self-Efficacy,” *ournal of Cooperative Education and Internships,* vol. 45, no. 2, pp. 17-35, 2011.

[18] J. K. Fletcher, “Self-Esteem and Cooperative Education: A Theoretical Framework,” *Journal of Cooperative Education,* vol. 26, no. 3, pp. 41-55, 1990.

[19] A. Dehing, W. Jochems and L. Baartman, “The Development of Engineering Students Professional Identity During Workplace Learning in Industry: A study in Dutch Bachelor Education,” *Engineering Education,* vol. 8, no. 1, pp. 42-64, 2013.

[20] K. Ehlert and M. Orr, “Understanding How Co-op Students View Their Learning,” in *ASEE Virtual Annual Conference*, 2020.

[21] A. Bavelas, “A Method for Investigating Individual and Group Ideology.,” *Sociometry,* vol. 5, no. 4, pp. 371-377, 1942.

[22] V. Braun and V. Clarke, “Using Thematic Analysis in Psychology,” *Qualitative Research in Psychology,* vol. 3, no. 2, pp. 77-101, 2006.

[23] M. Q. Patton, Qualitative Research and Evaluation Methods, 4th ed., Sage Publications, 2015.

[24] J. W. Creswell and C. N. Poth, Qualitative Inquiry and Research Design: Choosing among five approaches, 4th ed., Thousand Oaks: Sage Publications, 2018.

[25] C. Rennick, G. Litster, C. Hulls and A. Hurst, “Curricular Hackathons for Engineering Design Learning: The Case of Engineering Design Days (pre-print),” 25 August 2022. [Online]. Available: https://www.techrxiv.org/articles/preprint/Curricular_Hackathons_for_Engineering_Design_Learning_The_Case_of_Engineering_Design_Days/20514015. [Accessed 24 Feb 2023].

[26] C. Rennick, E. Li, M. Lenover, W. Blankespoor and S. Bedi, “Industry Hubs: Integrating Industry Perspectives in Design Education,” in *ASEE Annual Conference and Exposition*, Minneapolis, 2022.

[27] C. Rennick, M. Lenover, E. Li and S. Bedi, “Co-Designing Design Activities with Undergraduate Students,” in *ASEE Annual Conference & Exposition*, Minneapolis, 2022.

[28] J. Nickel, C. Rennick, G. Litster, C. C. Hulls and A. Hurst, “A Qualitative Investigation of Undergraduate Students’ Design Experiences in a Work-Integrated Learning Setting,” in *International Conference on Engineering Design (ICED 23)*, Bordeaux, 2023.