University of Nevada, Reno

Expansion of Motivation Models of Engineering Doctoral Student Populations

A dissertation submitted in partial fulfillment of the requirements for the degree of

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By

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Abstract

Research has shown that most STEM doctoral students are not prepared for their future careers. To address this gap, this dissertation explored and made sense of engineering doctoral student experiences related to their development as early career professionals with a variety of future career interests. One consideration embedded throughout the research is the default of graduate education is to train students for academic careers, such as tenure track faculty positions, despite nearly 75% of students being interested in non-academic careers. Through quantitative and qualitative methods, I found that students' development toward future careers is driven by student-specific (e.g., student future career interests) and programmatic factors (i.e., faculty advisor and graduate programs). Results from this work indicate that students were more likely to feel prepared when they have an internalized self-set reason for going to graduate school, have a specific future career goal, have a plan for reaching their future career goal, and receive feedback and support from faculty advisors and others in their program related to their future career goal. Recommendations for intervention guided by the data in this dissertation include encouraging students to explore their future goals, embedding career-aligned feedback and support into graduate programs, and encouraging multiple sources of mentoring to improve engineering doctoral students' perceptions of career preparation.

Dedications

I want to dedicate this to my family, in particular my wife Morgan and daughter Charlie who have made significant sacrifices for me to finish. A tremendous thank you to my parents, grandparents, and cousins who continue to be proud of my progress and listen to me talk at length about the strangest parts of my research.

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1. Introduction

Science, technology, engineering, and math (STEM) graduate programs aim to equip students with the skills and knowledge to prepare them for high-caliber and highly credentialed positions. With newly acquired knowledge and experience, these students are uniquely qualified to drive research and action to address pressing issues, such as the Grand Challenges of Engineering (NAE, 2015). However, the National Academy of Science, Engineering, and Medicine (NASEM) reports that many doctoral students are unprepared to meet the requirements of their future employers (NASEM, 2018). While there is societal value and autonomy afforded by getting a doctoral degree, there are often significant sacrifices (i.e., time, financial, mental health) made by graduate students (Blaney et al., 2022; McGee et al., 2019). The idea that students make these sacrifices and struggle to find a career postgraduation is egregious and a potential failing of the graduate education system. Thus the fact that many doctoral programs are not adequately preparing their students for the careers that students are interested in needs to be addressed (AAU Graduate Education Committee, 1998; Ehrenberg & Kuh, 2008; Golde & Dore, 2001; Nerad et al., 2006; Nyquist, 2002; Nyquist & Woodford, 2000; Smith et al., 2002; Wendler et al., 2012).

Current research in graduate education career preparation has shown that students struggle to make plans beyond graduating with their doctorate (Gelles, 2019; Hocker et al., 2019; Satterfield et al., 2022; Tsugawa, 2019). Preliminary evidence argues that students struggle to make plans because they do not know how to develop goals (Hocker et al., 2019); receive incorrect information from their advisors (Allum et al., 2014); and lack the time, programmatic supports, and the resources to think about their future

(Satterfield et al., 2022). When students cannot think about plans beyond their time in graduate school, they are unlikely to identify and develop the skills and abilities that will ensure their future success (Hilpert et al., 2012; Husman et al., 2016; Husman & Lens, 1999; Kirn et al., 2014; Kirn & Benson, 2018; Nelson et al., 2015). With these outcomes in mind, a more comprehensive understanding of how students in engineering doctoral programs plan and prepare for their future is needed.

To address the gap in knowledge, I applied future time perspective (FTP) and goal setting theory as the foundation for this work (Husman et al., 2016; Locke et al., 2015; Locke & Latham, 2013; Tsugawa, 2019). While FTP has been used previously to study how doctoral students think and take action based on future goals (Perkins, Tsugawa, et al., 2019), the FTP model of doctoral student motivation only focused on goals that students have, not their development or commitment to these goals. Therefore, this work includes goal-setting theory to address this gap. By leveraging a sequential multiphase mixed methods research design, this work seeks to develop a conceptual model of engineering doctoral student motivation and provide evidence for how to improve students' perceptions of career preparation.

1.1. Research Purpose

This research aims to develop a conceptual model of engineering doctoral student future-oriented motivations and provide evidence for how to improve students career preparation. By combining the theoretical frameworks of future time perspective and goal setting, future research can examine the process of developing future goals and how students operationalize that goal in planning and preparing for their future careers. The primary outcome of this project is to provide guidance on how to align students' career goals and training in engineering graduate programs.

Research Questions. Throughout this work, the goal was to understand how engineering doctoral students plan and prepare for their future careers through the following research questions:

RQ 1: In what ways do engineering doctoral students describe their future goals?

RQ 2: How do goal setting and future time perspective predict engineering doctoral students' perceptions of graduation and career preparation?

RQ 3: In what ways does feedback and support influence students perceptions of career preparation.

1.2. Positionality

As a white, cisgender, heterosexual, middle-class, married man from a nuclear family, I strive to conduct human-centered research that improves the experiences of the populations that I research with, not on. Because of the identities I hold, I also strive to bend my privilege wherever possible to support and amplify the voices of those with traditionally underserved identities. Therefore, in this project, my primary goal, motivated by my own experiences with struggling to develop and act upon future goals in an engineering program, is to drive change within engineering graduate education to improve graduate education and its utility for other students. I leveraged a pragmatic worldview to develop and apply the most appropriate research design in this work. My pragmatic worldview was applied when leveraging theory and methods. Throughout this project, my priority concern was the research findings' reliability, validity, and legitimization.

1.3. Project Overview

In this sequential multiphase mixed methods research design, the research involved three phases, outlined in Figure 1.1. The first phase of this project reexamined previously collected qualitative data about engineering doctoral student motivation to develop survey items that give a comprehensive view of not only how students take actions based on future goals, but how they develop their goals as well. The second phase took the newly developed survey items, combined them with current FTP survey items, and developed a predictive model using exploratory structural equation modeling. The project's third and final phase collected student interview data related to where they perceived having the most career-aligned feedback and advising, and was guided by the results of the exploratory structural equation model from Phase 2.

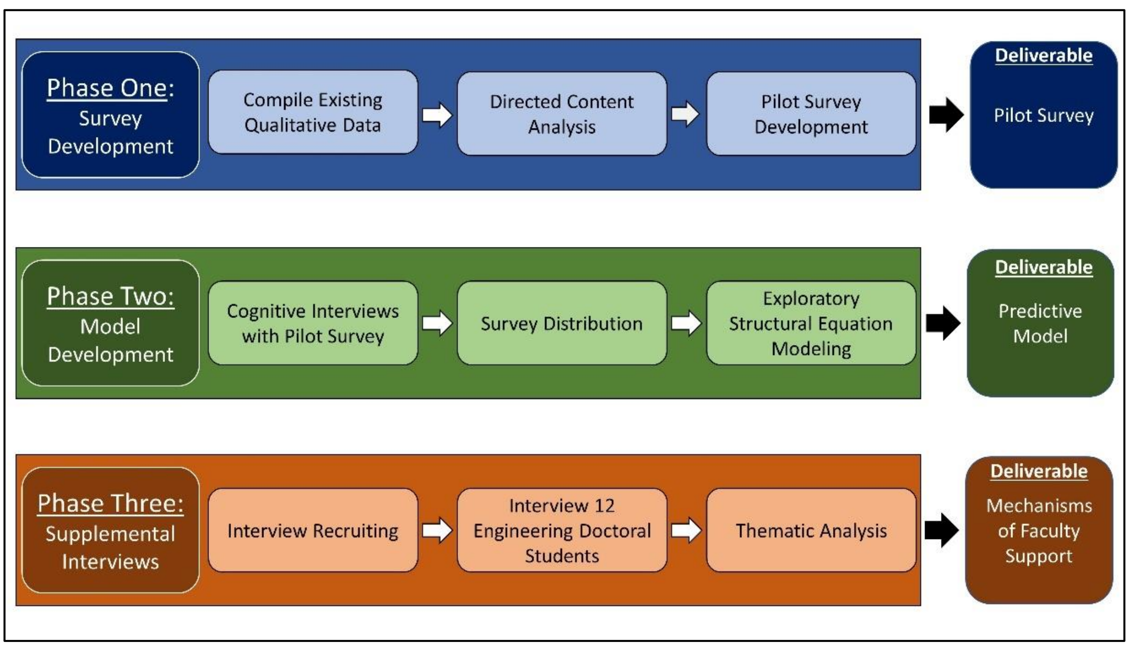

Figure 1.1 Research Plan with Deliverables.

1.4. Background

1.4.1. Graduate Education

Students' career prospects and interests are constantly subject to change (Blaney et al., 2022; Gelles, 2019). Without the ability to measure and appropriately shift to meet the needs of students as they prepare for their future beyond the academy, the efficacy of graduate education is unable to be effectively evaluated. Due to the cultural and motivational differences specific to engineering doctoral students, there is value in examining engineering separately from science, technology, and mathematics graduate education (NASEM, 2018; National Center for Science and Engineering Statistics, 2017; Peters & Daly, 2013). Researchers must also be responsive to students' needs, particularly those who are undercut by instances of bias and discrimination (Allum et al., 2014; Bahnson, Perkins, et al., 2021; Bahnson, Satterfield, et al., 2021; Blaney et al., 2022; Burt et al., 2018; Edwards & Gordon, 2006; McGee et al., 2016). This work develops tools and models that can be used to make responsive, data-driven changes both within individual students' career development pathways and engineering doctoral programs.

To effectively develop tools and models for student motivation, I must consider that engineering doctoral students' reasons for entering and persisting through graduate school are unique compared to other STEM graduate education fields. Unlike other STEM graduate education programs, engineers are not motivated in the same ways to pursue a graduate degree (NASEM, 2018). Specifically, engineering students are less motivated by financial incentives (National Center for Science and Engineering Statistics, 2017; Nettles & Millett, 2006; Szelényi, 2013). Research has shown that engineering graduate students are motivated by research interests, wanting to become a professor, recommendations of others, and career development (Brailsford, 2010; Churchill & Sanders, 2007; Main et al., 2020; McGee et al., 2016; Peters & Daly, 2011, 2012, 2013; Satterfield et al., 2022; Spaulding & Rockinson-Szapkiw, 2012). These differences in motivation affect how engineering doctoral students think about their future and ultimately influence their ability to plan and prepare for their future careers.

Further influencing the ways engineering doctoral students are motivated by their future career goals is the structure of graduate education. In the apprenticeship model that graduate education leverages the faculty advisor serves as the primary source of information; not just on technical or engineering content, but also on career advice and professional development (Edwards & Gordon, 2006; Golde & Dore, 2001; Newstetter, 2005). Since faculty are the primary source of career guidance, problems arise when the guidance and mentoring students receive from their advisor are not perceived as helpful, incorrect, not aligned with students’ career interests, align more with research requirements, and neglect the students' developmental needs (Allum et al., 2014).

Believing that you can be successful is closely related to the support and recognition that is given by others, such as faculty advisors (Geesa et al., 2020; Noy & Ray, 2012b). When advisors neglect their students' needs and are discriminatory, students are less likely to persist (Bahnson, Hope, et al., 2022; Burt et al., 2018; McGee & Martin, 2011). This behavior of neglect is often discussed by traditionally underserved students in engineering who describe their environments as hostile and isolating. When faculty reduce students' access to information and support, their development as professionals and engineers is severely undercut (Burt, 2020; Burt, McKen, et al., 2019; Burt, Williams, et al., 2019). These experiences are not uncommon. For example, results of a national project on instances of bias, discrimination, and exclusionary practices enacted on engineering graduate students across the nation showed that nearly one in five students experienced unfair treatment from their primary advisor (Bahnson, Satterfield, et al., 2021). By ignoring the power of these cultural effects operationalized by faculty advisors, particularly for traditionally underserved students, we will continue to not make responsive, data-driven changes to both students' career development and their engineering doctoral programs.

1.4.2. Engineering Doctoral Student Professional Development

The ability to conduct novel and innovative research is a skill that will continue to push the boundaries of human knowledge and provide pathways into a number of different careers for engineering doctoral students. For students who have conceptualized future careers, depending on the size of their research group a main source of professional development is their faculty advisor or informal mentors (Allum et al., 2014; Bahnson, Hope, et al., 2022; Barnes, 2009; Burt, 2020; Noy & Ray, 2012a). Due to many faculty's experiences and social network residing within academia, they struggle to mentor students whose interests reside outside academia, to the point of reducing students ability to find employment (Allum et al., 2014). When students lack role models who share similar intersectional identities, they struggle to find mentorship for academic and non-academic careers (Burt, 2019, 2020; Noy & Ray, 2012a). Due to the demands of graduate school some students are unable to or do not take time to consider what future careers they are interested in, reducing the ability of mentors and faculty advisors to provide guidance and resources. Because faculty's experience and training often reside in academia, the direct mentorship and enculturation into the culture of academia that graduate education provides can unknowingly push uncertain students towards being prepared for a career within academia (Satterfield et al., 2022); despite only approximately 1 in 5 students pursuing those careers (National Science Foundation, 2019). Without ways to measure and evaluate students' future goals and the ways students are being mentored by their faculty advisor in relation to those goals students may continue to be prepared for a career path that is oversaturated and not in line with students desired future career.

Despite how interwoven faculty advisors are in doctoral student experiences during and beyond graduate school, they are not the only sources of professional development. Other people that students point to as sources of professional development, are their peers (Crede & Borrego, 2012; Golde, 2005; Holloway et al., 2022), professionals already in the field (Holloway et al., 2022), and program-based professional development events (e.g., guest speakers, career fair) (Louis et al., 2007). While peer support has traditionally been connected to persistence to degree (Gardner, 2010), it has also been shown to support students professional development in larger research groups (Crede & Borrego, 2012). Additionally, while some students are supported by peers within other research labs, the majority of students peer support comes from students in their research lab (Crede & Borrego, 2012). Peer support only goes so far as other students have not achieved positions in the careers students are interested in, which is why professional connections from faculty or events that are supportive of students' professional development are crucial (Holloway et al., 2022). Further, these peers can easily be just as detrimental to students' development when they enact exclusionary or discriminatory behavior (Bahnson, Satterfield, et al., 2021). With all the various sources that students can be guided and influenced by, a need exists to understand the contribution these different populations can have on students perceived career preparation and to suggest directions for program level interventions to support student development.

To understand how these various sources are related to students' perceptions of career preparation, measures to make sense of what students' future-oriented goals are needed, their plans aligned with reaching that goal, and the environment they reside in. Future-oriented motivation theory is key in measuring how students think about their futures, and understanding how different sources of advising, mentorship, and professional development are aligned with students' future goals.

1.4.3. Engineering Graduate Student Motivation

Research on engineering graduate student motivation has examined how engineering graduate student behaviors or willingness to complete a task are influenced by their expectations and values (Peters & Daly, 2013), future goals (Perkins, Bahnson, et al., 2019; Tsugawa, 2019; Tsugawa et al., 2017), advisor selection (Artiles et al., 2023), and their imagined future self (Kajfez et al., 2016; Kajfez & Matusovich, 2017). Across the research, results indicate that students' time in their graduate program has many influences on motivation that are internal and external to the student.

Due to the primary interest of this work on the intersection of students future-oriented motivations and perceptions of career preparation I focus on operationalizing the framework of future time perspective as applied in graduate education (Perkins, Bahnson, et al., 2019; Tsugawa, 2019). In this operationalization of the theory the undergraduate framing was recontextualized and applied in a latent profile analysis, wherein five latent motivation profiles were found (Perkins, Tsugawa, et al., 2019) and are unpacked in more detail in CHAPTER 2.

Additional research related to students' future-oriented motivation leveraging data from the GRADS project was conducted by Dr. Tsugawa as part of her dissertation research. Using timeline data alongside directed content analysis interviews, Dr. Tsugawa developed the identity-based motivation conceptual framework (IBMCF) to understand how past experiences and future-oriented goals integrate together to understand students' motivation and identities (Tsugawa, 2019). This work validated the following FTP constructs with graduate student populations: *career connectedness, perceived instrumentality, near-future goal attainment,* and *future possible selves*. The factor loading structure of the FTP constructs is presented below in Figure 1.2.

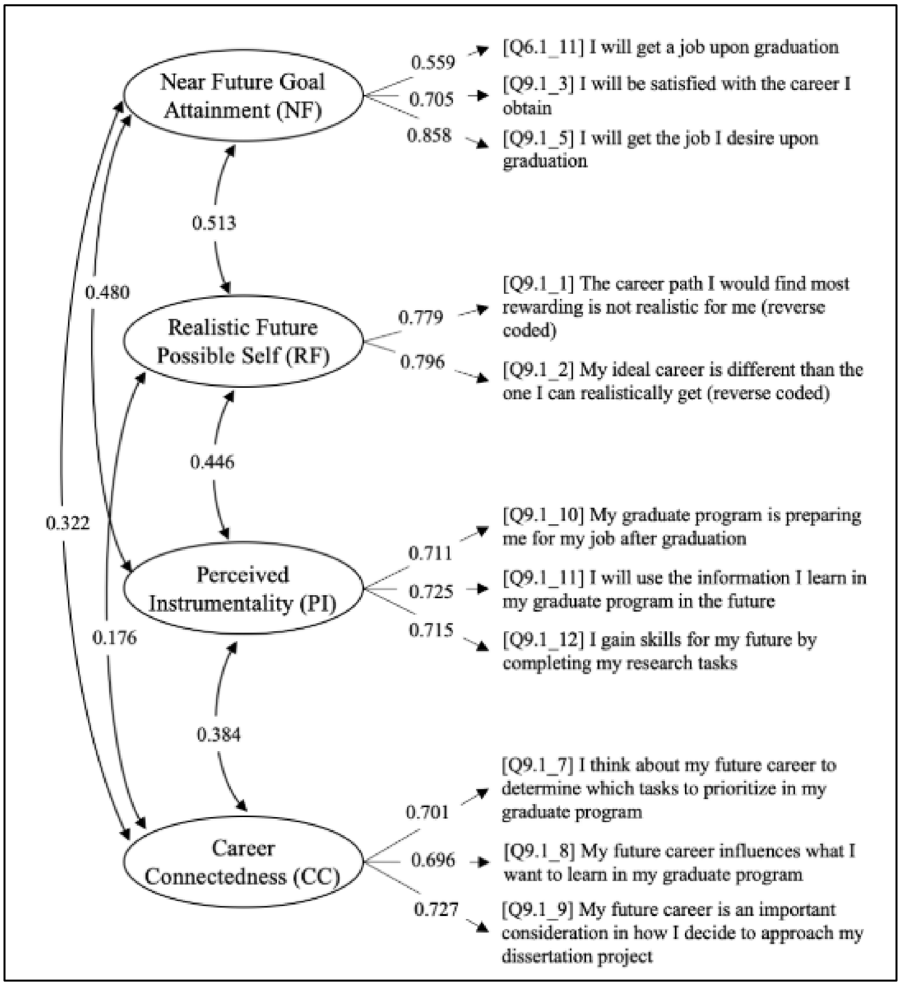

Figure 1.2 Factor loading structure of FTP constructs [taken from (Tsugawa, 2019, p. 86)]

1.5. Theoretical Frameworks

Before unpacking the theory of future time perspective (FTP), I describe why motivation theories are an appropriate theoretical lens for this study. Motivation in the context of this study is defined as “the process whereby goal-directed activities are instigated and sustained” (Schunk et al., 2014, p. 5). Because doctoral engineering education and the subsequent future careers aligned with having a doctoral degree require sustained action to be successful, a future-oriented framework built around sustained action is well-aligned for engineering doctoral populations. An additional consideration is that historically this theory has been conducted using an interpretivist paradigm in engineering (Hilpert et al., 2012; Husman et al., 2016; Husman & Lens, 1999; Kirn et al., 2014; Kirn & Benson, 2018; Lens, 1986; McGough et al., 2018; Puruhito, 2018). As a pragmatist and a doctoral student researching doctoral students, applying an interpretivist paradigm that leverages the researcher-as-instrument during qualitative phases of the research will be more effective than a constructivist paradigm requiring more intellectual and emotional distance. In the following section, I present the historical and philosophical foundation of FTP as it aligns with this research.

1.5.1. Future Time Perspective

The conceptualization of future time perspective used in this work has foundations from educational psychology and engineering education in which the authors used an interpretivist paradigm to examine how students talked about their future and make sense of how future-oriented goals encouraged completion of tasks in the present (Hilpert et al., 2012; Husman et al., 2016; Husman & Lens, 1999; Husman & Shell, 2008; Lens, 1986; Kirn et al., 2014; Kirn & Benson, 2018; Puruhito, 2018). The results of this work with engineering undergraduate students highlighted four motivation profiles that characterized how students thought about their future. These four profiles varied based on their perceived utility, perception of the future, and the temporal distance of their goal(s) (Kirn & Benson, 2018; McGough et al., 2018; Spence, 2022). The primary outcome relevant to this work was that when students were more motivated (i.e., had a well-developed future time perspective), they were more engaged in relevant tasks, retained more future-aligned knowledge, and were more likely to persist on task (Kirn & Benson, 2018).

The GRADS project as, a mixed-methods study using an interpretivist paradigm, showed that graduate students thought about their future in distinct ways from how undergraduates conceptualized their future (Kirn & Benson, 2018; McGough et al., 2018; Perkins, Tsugawa, et al., 2019). While undergraduate students focused on engineering roles where their title included engineer, students in graduate education often balance different roles as scientists, researchers, and engineers, requiring examinations on multiple domain-specific identities (Kajfez & McNair, 2014; H. L. Perkins et al., 2018). While undergraduate engineering motivation research established four motivation profiles, five emerged within engineering graduate education (Perkins, Tsugawa, et al., 2019). The difference in motivation profiles between undergraduate and graduate students was more significant than a new profile emerging. Instead of centering on the temporal distance (2-15 years) and perception of time, in graduate engineering education the motivation profiles instead focused on the types of futures available and how well the knowledge and opportunities afforded in graduate education experience aligned with that future (Perkins, Tsugawa, et al., 2019). The reason this difference in motivation profiles is important is that when considered alongside research showing that students feel unprepared, the variation being based around available futures and knowledge indicates that there is a need to provide better support in how students develop, learn about, and explore their future careers. To measure the extent of this gap, preliminary work explored integrating goal setting to explore additional aspects of how students thought about their futures (Satterfield et al., 2022).

1.5.2. Goal Setting

Goal setting is a theoretical framework used by occupational researchers to examine the relationship between demands (i.e., prescribed goals) and performance, with several mediators and moderators of the relationship leading to the outcome variable, satisfaction. Locke and Latham (1990) developed this theory using an interpretivist paradigm to make sense of their inductive synthesis of over 400 research articles spanning field and laboratory settings and multiple occupational contexts. Using their synthesized findings, they developed and validated the High-Performance Cycle (HPC) goal-setting model, shown in Figure 1.3. Researchers have since tested the relationships between the mediator (i.e., explaining the relationship between variables) and moderator variables (i.e., only affecting the strength and direction of the relationship) and validated their use in the contexts of social psychology and business management research (Latham et al., 2005). The key outcome of the applied theory and model is that it predicts employee satisfaction based on performance on organizational demands and the rewards for performance.

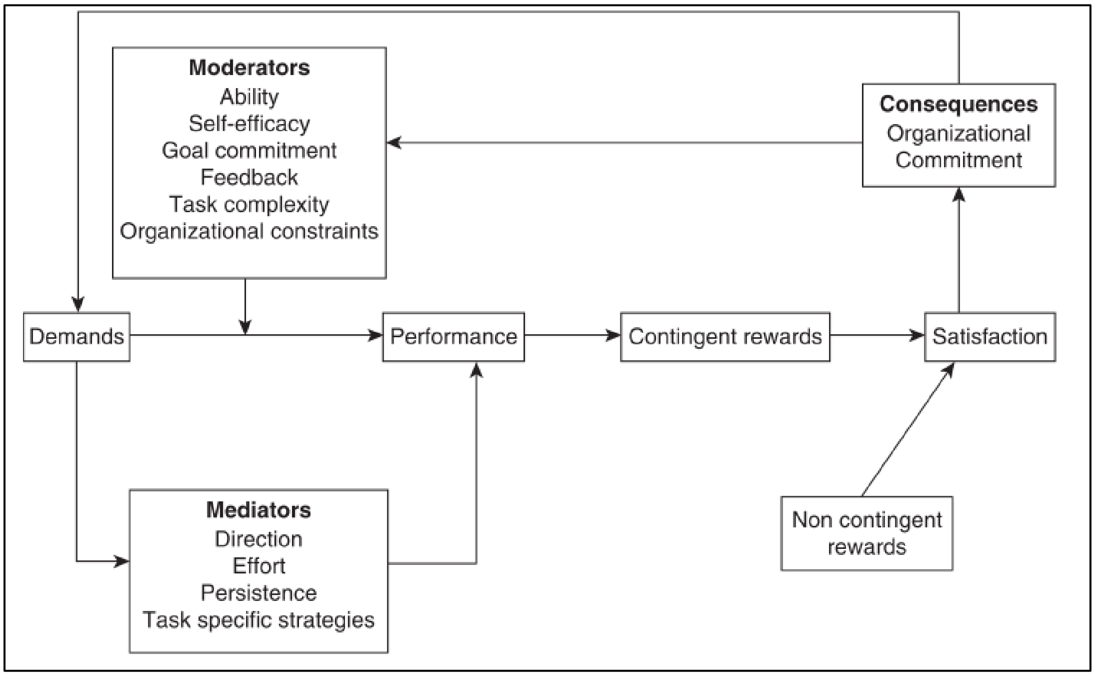

Figure 1.3 The High Performance Cycle (HPC) developed by Locke and Latham (1990) [taken from: (Borgogni & Dello Russo, 2013, p. 271)].

The HPC model has been used in multiple contexts within occupational research contexts including human resource management (Latham, 2004), sports (Munroe-Chandler et al., 2004), and gerontology (Rapp et al., 2006). Across the research applying the HPC model researchers have shown that performance increases when goals are specific, appropriately difficult, coupled with feedback, and the individual is involved in setting the goal (Locke & Latham, 2013, p. 11). These findings are well-aligned with graduate education research exploring the difficulty of tasks, and how students talked about their future career goals, (Satterfield et al., 2019; Tsugawa, 2019).

In this research I operationalize the conceptual model developed in an Italian context due to its streamlined focus on performance rather than satisfaction as the primary outcome. To contextualize this model for this work, the population in the original study involved two samples, as described below in a passage from Borgogni & Dello Russo (2013, p. 274).

> "*The first sample consisted of 322 middle managers in a telecommunications organization. This sample consisted of 23% females and 77% males. Sixty-one percent of them ranged in age between 36 and 45 years old; 92% had more than 6 years of tenure in this organization… The second sample consisted of 173 employees and managers from a multinational insurance company. The sample comprised 35% females and 65% males. Forty-four per- cent were 45 years old or more; 47% had between 1 and 5 years of tenure in the organization."*

Using exploratory factor analysis on a 53-item survey tool, Locke and Latham created a conceptual model to explain how organizational constraints mediated performance on demands. After validating the initial factor structure, they conducted a second study to examine the relationships between the factors. This involved also adding the measurement of performance which they define as "*the percentage of goal attainment at the end of the year, as a composite of the quantitative goals (maximum three) assigned to each manager"* (p. 279). Finally, they tested the structural equation model using a sample of 101 telecommunications managers from the previous sample. While their use of the same participants in both studies is limiting, the results of their model align with the theoretical model posited by Locke and Latham (1990).

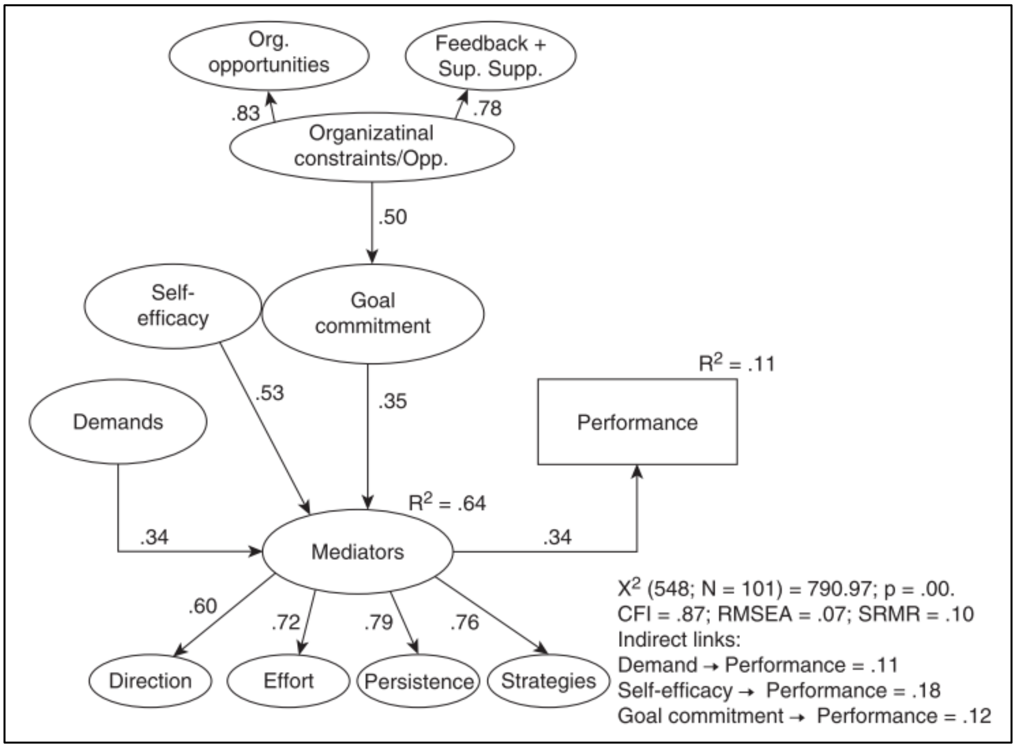

Figure 1.4 Empirical model of goal setting High Performance Cycle [taken from (Borgogni & Dello Russo, 2013, p. 280)].

Leveraging the conceptual model in Figure 1.4, there are crucial distinctions needed for how this model informs the current work. The first is that in Borgogni & Dello Russo (2013), planning, goal commitment, and support are moderators and influence the strength and direction of the relationship between demands and performance. Because the occupational research model is based on demands (e.g., prescribed goals by the organization), the measures cannot be directly applied in graduate contexts due to the scope of this research on making sense of self-directed future goals, rather than those set by others. The importance of this distinction on the source of the goal is further described in CHAPTER 2. For students who set self-directed goals I posit that these moderating variables become mediators, meaning they explain the process by which the two variables are related (e.g., goal commitment will have a significant relationship with the goal).

The next key point is that this work only applies aspects of goal-setting HPC model. Specifically, the constructs of *direction, effort, rewards, self-efficacy*, or *task complexity* are not used. These constructs are removed for several reasons. First, the construct *direction* was removed due to its longitudinal focus on guiding future direction within the career the individual is already in, not where they want to be in the future. This measure is not appropriate because the desired outcome is not to stay a student (i.e., current career), and any connection to future careers is already measured by the construct of career connectedness. Next, *effort* was removed due to its overlap with the existing construct of instrumentality from FTP. *Reward*s were removed because graduate education does not have compensation structures (e.g., bonus or incentives) and was found to be insignificant in the original HPC model. *Self-efficacy* was removed due to its overlap with instrumentality and perceptions of career preparation. Finally, *task complexity* was removed as it was insignificant in the HPC model.

In summary, there are components of goal-setting theory that align well with gaps uncovered in preliminary research, particularly around commitment and plans for future goals (Satterfield et al. 2022). The model presented in occupational research differs from my conceptualization in the relationships between the goal and intermediate measures that predict the outcome variables of perceptions of career preparation and perceptions of persistence. Nonetheless, the foundation of goal setting that posits individual planning and systematic support structure are related to performance and persistence outcomes is central to my preliminary model.

1.5.3. Theoretical Overlap

To address the lack of career preparation within engineering doctoral education this work will leverage FTP and goal-setting to develop and validate measures related to students commitment to their future goal, the plans they have for their future goal, and the feedback and support they receive. The addition of these measures will help to connect existing research that looks at the impact of the graduate education environment on students' experiences (Bahnson, Hope, et al., 2022; Bahnson, Satterfield, et al., 2022; Burt, McKen, et al., 2019; McGee, 2016; Perkins, Bahnson, et al., 2019; Tsugawa et al., 2019)to research related to students motivation in their program (Artiles & Matusovich, 2020; Satterfield et al., 2021; Kajfez & Matusovich, 2017; Perkins, Tsugawa, et al., 2019). To help contextualize the addition of these measures and support the integration of these theories together I present the overlap of how these theories strengthen and extend each other.

The novelty of integrating goal-setting theory and future time perspective is that the systematic support constructs (feedback and supervisory support, and organizational support) specifically look at how the environment around the students support or hinder their perceptions of the future. This is crucial because existing FTP only had measures focused on the individual, or had double-barreled questions that blended student beliefs and environmental factors (e.g., I think about my future career to determine which tasks to prioritize in my graduate program) (Tsugawa, 2019). By applying items that specifically look at the environment and develop a predictive model outlining the relationship, I can extend ongoing and future work. Included in Table 1.1 are all the FTP, goal-setting, and outcome items as they relate to constructs and the overall theory.

Table 1.1 Compiled measures and constructs of FTP and goal-setting theory.

Theoretical Foundation	Model Level	Construct	Survey Items
FTP	Future Career Goal	Career Connectedness	I think about my future career to determine which tasks to prioritize in my graduate program.
			My future career influences what I want to learn in my graduate program.
			My future career is an important consideration in how I decide to approach my dissertation project.
FTP	Future Career Goal	Near-Future Goal Attainment	I will get a job upon graduation.
			I will be satisfied with the career I obtain.
			I will get the job I desire upon graduation.
FTP	Future Career Goal	Future Possible Selves	The career path I would find most rewarding is not realistic for me.*
			My ideal career is different than the one I can realistically get.*
FTP	Future Career Goal	Multiple Futures	I am interested in three or more future careers after graduating.
			There are multiple futures I am interested in after graduating.
			I am only interested in one future career after graduating.*
			I imagine many career paths I can take depending on available opportunities when I graduate.
FTP	Plan	Instrumentality	What I learn in my graduate program will be important for success in my future career.
			I will use the information I learn in my graduate program in the future.
			I am developing skills for my future by completing research tasks.
Goal Setting	Plan	Goal Commitment	It is hard to take my career goal seriously.*
			Quite frankly, I do not care if I achieve my career goal.*
			I am strongly committed to pursuing my career goals.

Theoretical Foundation	Model Level	Construct	Survey Items
Goal Setting	Plan	Strategy	I have a strategy for attaining my career goals.
			I reflect on the most suitable strategy to follow before taking action towards my career goals
			I usually feel that I have an effective action plan for reaching my goals.
Goal Setting	Systematic Support	Organizational Support	Graduate program policies here help rather than hurt my goal attainment.
			My graduate program provides sufficient resources (e.g., time, money, equipment, co-workers) to make goal setting possible.
			My graduate program treats all graduate students fairly.
Goal Setting	Systematic Support	Feedback and Supervisory Support	My advisor updates me regularly concerning my advancement towards my goals.
			I am told both the positive and negative aspects of my performance.
			I get regular feedback concerning how I am performing in relation to my goals.
			In one-on-one meetings with my advisor, problem-solving rather than criticism is stressed.
			My advisor is supportive with respect to encouraging me to reach my goals.
			My advisor gives me all the information necessary to perform well on my job.
			My advisor is supportive when I face obstacles in my job.
N/A	Outcome	Perceptions of Career Preparation	I will be prepared for the career I want when I complete my doctoral degree.
			I will be able to effectively complete the tasks required of my

Theoretical Foundation	Model Level	Construct	Survey Items
			future career.
			I am taking steps to prepare for the career I want in the future.
			My time in this doctoral program is preparing me for my future career.
N/A	Outcome	Perceptions of Persistence	I strive to achieve my goal even when I'm faced with obstacles
			In my graduate program I keep trying even when things are not going well.
			In my graduate program, I intensify my efforts after failure.

*=item is reverse coded

When integrating future time perspective and goal setting together, the overlap of theory exists in two places. The first place in which overlap exists is temporally, FTP and goal setting examine the impact on present actions (Latham et al., 2005; Locke & Latham, 2013; Satterfield et al., 2022; Tsugawa et al., 2017). The future time perspective measures leveraged in this work focus on students' perceptions of the future (multiple futures, future possible selves, and near-future goal attainment) related to present actions (i.e., career connectedness and instrumentality). Meanwhile, goal setting focuses on past support (i.e., feedback and supervisory support, and organizational support) and dedication to achieving the required tasks in the present (i.e., goal commitment and strategy) related to performance in the present (Locke & Latham, 2013). They examination in this work of past support applied from goal-setting supports previous FTP research looking at past experiences (Tsugawa, 2019) and connects existing research related to advisor experiences (Bahnson et al., 2022; Burt, 2019) to future careers. Together these measures will strengthen our understanding of the factors affecting motivation on present tasks, while also incorporating feedback on past performance to support future planning and future perceptions of career preparation and persistence.

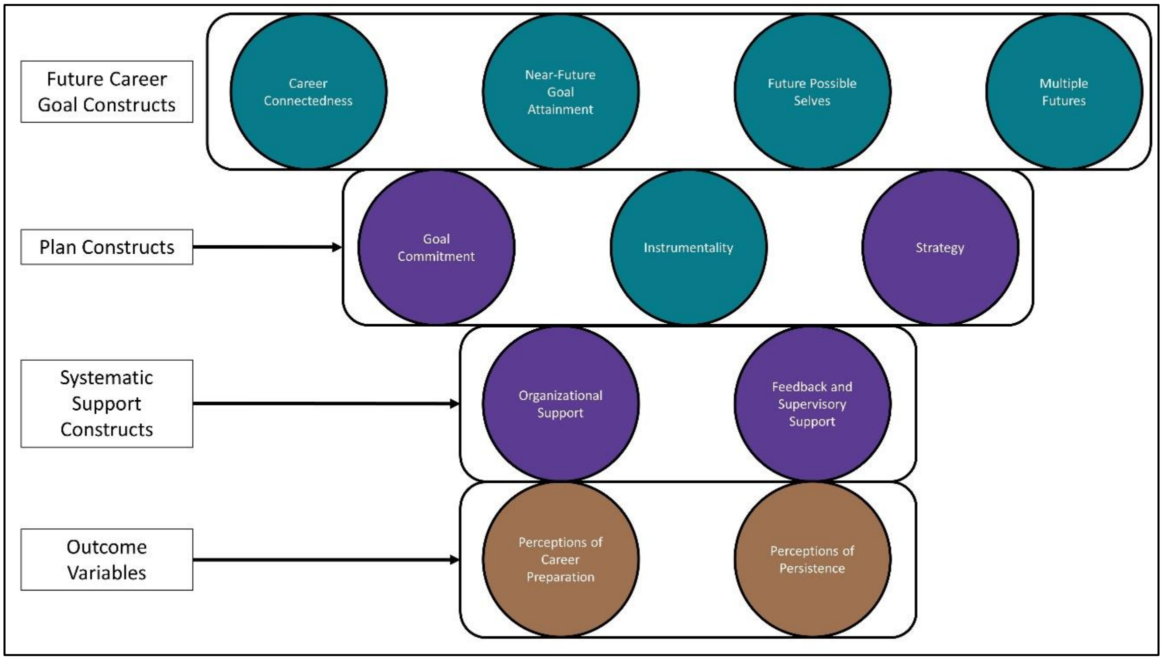

Figure 1.5 Preliminary model of graduate students' FTP (teal) and goal setting (purple) are related to their perceptions of persistence and career preparation.

The second area of overlap exists within the preliminary model in Figure 1.5. This model was developed based on how support aligns with having a plan (Satterfield et al., 2022), and to have a plan you must first have a goal. The building of these superordinate factors on each other results in the model presented. Due to the structure of this preliminary model, the goal-setting constructs are expected explain the process of how future time perspective measures and the outcome variables of persistence and career preparation perceptions are related (i.e., mediate the relationship). This can be seen in how the purple circles representing goal-setting separate FTP and the outcome factors. This overlap is theoretically backed by goal-setting theory, which posits a positive relationship between performance and goals and persistence and goals (Locke & Latham, 2013). A key deviation from traditional goal-setting theory is that in the original model organizational constraints influence commitment. Because within graduate education students are ideally setting the goal instead of the organization, the relationship is reversed in this application, meaning that a student's commitment influences the feedback and organizational support they receive.

1.6. Intellectual Merit

The primary outcome of this work was to improve engineering doctoral student career preparation by examining the environmental influences from engineering doctoral programs on student motivation and future perceptions. To this end, this work has focused on expanding measures on engineering doctoral student motivation, examining faculty advising related to professional development, and embedding environmental measures alongside existing motivation measures. Across the research conducted there are a few novelties and ways in which this work informs and supports other graduate student motivation research.

- Generated a conceptual model that defines the relationships between student planning and systematic support on perceptions of persistence and career preparation.
- Developed an exploratory structural equation model of engineering doctoral student future time perspective and goal setting as predictors of perceptions of persistence and perceptions of career preparation.
- Examined the intersection of engineering doctoral student motivation and faculty advising related to students' professional development in their graduate program.

1.7. Broader Impacts

Improved career planning support structures for engineering doctoral students has multiple implications for academia. Specifically, having a survey tool, and predictive model allows practitioners (e.g., faculty advisors, graduate program directors, and graduate program deans) to make targeted data-driven decisions in mentoring students and developing program initiatives.

- Provided preliminary tools for implementing targeted inventions specific to the needs of the students and graduate programs.
- Advocated for a shift from research-centered advising to student-centered models that leverage multiple sources of mentorship aligned with student's future career interests to improve faculty and student experiences.

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2. The Influence of Engineering Doctoral Students' Experiences on Their Perceptions of the Future and Preparedness for Graduation

This work has been published elsewhere as part of my dissertation process:

Satterfield, D., Parker, M., Tsugawa, M. A., Perkins, H., Bahnson, M., Cass, C., & Kirn, A. (*Under Review*). The Influence of Engineering Doctoral Students Experiences on Their Perceptions of the Future and Preparedness for Graduation. *Journal of Engineering Education.*

My contributions to this work included but were not limited to planning participant sampling, conducting interviews, analyzing the interview data, and writing up the research.

2.1. Introduction

Graduate education serves as specialized training for future scholars and researchers; however, the efficacy of graduate education has been called into question by students, employers, and national agencies due to students' lack of preparation for doctoral-level careers (NASEM, 2018). Areas where students are unprepared include but are not limited to communication skills, working effectively in teams, business acumen, and leadership competencies (NASEM, 2018). This problem is compounded by the default of graduate education that focuses on creating more academic faculty (Goldman & Massy, 2001; Maresi Nerad, 2004) rather than preparing students for the industry careers that 71.6% of engineering doctoral graduates are interested in (National Center for Science and Engineering Statistics, Survey of Earned Doctorates., 2022). Additionally, engineering doctoral education is rife with issues: high attrition rates (40-

60%; (Council of Graduate Schools, 2007), persistent racism and sexism (Bahnson et al., 2022; Burt et al., 2018), and poor faculty-student relationships (Berdanier et al., 2020; Burt et al., 2019) that undermine students' abilities to envision, plan, and prepare for their futures. By helping students envision, plan, and prepare for the future, we have the potential to foster increased persistence and performance throughout undergraduate and graduate engineering populations (Choe & Borrego, 2019; Godwin & Kirn, 2020; Hilpert et al., 2012; Kirn & Benson, 2018; Mosyjowski et al., 2017; Nelson et al., 2015; Peters & Daly, 2013; Tsugawa et al., 2017). However, limited research explores how engineering graduate students' future goals influence their perceptions of graduation and preparedness for future careers.

To improve persistence and workforce development efforts in the face of changing demands, particularly for advanced careers, research must examine and address gaps in how graduate programs prepare students for their future careers. We build off of existing work examining engineering graduate students' motivations (Artiles & Matusovich, 2020; Choe & Borrego, 2019; Kajfez & Matusovich, 2017; Mosyjowski et al., 2017; Tsugawa, 2019) to explore how students' experiences in their doctoral programs support or undercut their perceptions of graduation and preparedness for their future careers. By understanding the experiences that shape these perceptions, we can develop and implement targeted changes to doctoral engineering that addresses persistent problems.

2.2. Literature Review

The importance and autonomy afforded by a doctoral degree, as well as the social value in have doctoral degree holders has been shown internationally (Hancock, 2019). While some students who enter graduate education have goals which are subject to change throughout their time in graduate school, for many STEM graduate students their goals and motivations often do not extend beyond graduation; and when their goals do extend beyond graduation, they are often ill-defined, semantic, and have not been explored (Satterfield, 2022; Gibbs & Griffin, 2013). In order to reach the goal of producing more skilled engineers, we need to support the broad range of attitudes that exist in engineering (Bahnson et al., 2019; Burt, 2019; Perkins et al., 2019; Heather Perkins et al., 2021; Rohde et al., 2020; Tsugawa et al., 2017). While there is significant evidence for supporting undergraduate students, previous research has shown that engineering graduate students think about their future in distinct ways from how undergraduates conceptualized their future (Kirn & Benson, 2018; McGough et al., 2018; Perkins, Tsugawa, et al., 2019). While undergraduate students focused on careers where their title included engineer, students in graduate education often balance different potential careers as scientists, researchers, and engineers, requiring consideration of multiple domain-specific career types (Kajfez & McNair, 2014; H. L. Perkins et al., 2018). These differences necessitate targeted examinations of engineering graduate students' motivation and experiences.

Existing research has examined graduate students' motivations to better understand advisor choice, teaching practice, and decisions to return to graduate school

(Artiles & Matusovich, 2020; Berdanier et al., 2020; Kajfez & Matusovich, 2017; Miller et al., 2017; Mosyjowski et al., 2017; O McGee et al., 2019; Peters & Daly, 2013). In preparing students for academic careers and combating attrition rates ranging from 40-40%, this work shows the importance of developing competencies and socializing with peers and faculty. However this work does not examine how students think about their time beyond graduation, an exception being students dissuasion from academic careers due to the stress, personal values, and the culture of academic jobs (Burt, 2019; Roach & Sauermann, 2017). Thus, while students' navigation into graduate programs is well described, a gap exists in how students' experiences while in graduate school influence their motivation and perceived preparation for future careers.

2.3. Research Purpose

The purpose of this paper is to examine how engineering doctoral students' perceptions of career preparation are influenced by their time in graduate school. Currently, academia trains the majority of students for academia, despite 71.6% not interested in entering academia after graduation (National Center for Science and Engineering Statistics, Survey of Earned Doctorates., 2022). By making sense of the ways students think about and prepare for their future career, we can suggest data-driven decisions for programmatic change to better prepare students for their post-graduate career. To understand students' perceptions of their future careers, we conducted interviews with 15 engineering doctoral students to answer the following research questions:

RQ1: How do engineering doctoral students describe their future goals, perceptions of graduating, and preparedness for future careers?

RQ2: How do students' experiences in engineering doctoral programs shape these perceptions?

We leverage future time perspective (FTP), a motivation framework, to answer these research questions (Husman & Lens, 1999; Kirn, 2014; Tsugawa, 2019). We use FTP as an interpretive qualitative lens to make sense of how engineering doctoral students' prior motivations, current career goals, and programs influence students' perceptions of graduation and career preparedness.

2.4. Theoretical Framework

Future Time Perspective (FTP) is a theoretical framework of motivation used to understand how individuals' future career goals are incorporated into the present and influence the actions taken to complete present tasks and objectives (Hilpert et al., 2012; Husman & Lens, 1999; Kirn & Benson, 2018; McGough Spence et al., 2022; Nelson et al., 2015). In this work we define future career goals as a career role that students can envision having after getting their doctoral degree. Students' FTPs influence their intentions to persist, problem-solving approaches, and learning strategies used in engineering (Faber et al., 2014; Hilpert et al., 2012; Kirn & Benson, 2018; McGough Spence et al., 2022; Nelson et al., 2015; Perkins et al., 2019; Tsugawa, 2019). These results show the importance of creating educational environments where students can develop and leverage FTPs are more likely to use approaches that promote learning and deep understanding.

Previous research working to extend FTP to doctoral engineering students has highlighted the importance of the relationships between past experiences, future goals, task difficulty, and identity for persistence and valuing of graduate education (Perkins et al., 2019; Tsugawa, 2019). Tsugawa merged these ideas together into the identity-based motivation conceptual framework (IBMCF) to understand how past experiences and future-oriented goals integrate to understand graduate students' motivation and identities (Tsugawa, 2019). This work validated the following FTP constructs with graduate students: *career connectedness, perceived instrumentality, near-future goal attainment, multiple futures,* and *future possible selves*. Definitions of these constructs are articulated in Table 2.1 Description of FTP constructs used in graduate education contexts.. These constructs help us to examine how students conceptualize the future (i.e., near-future job attainment, multiple futures) and how these conceptualizations influence actions taken in the present (i.e., career connectedness, perceived instrumentality).

Table 2.1 Description of FTP constructs used in graduate education contexts.

Construct	Description
Career connectedness	How closely related students’ experiences and tasks in graduate school are to their desired future careers.
Near-future job attainment	How confident students are that they can get a job after graduation.
Multiple futures	The variety of future careers that students talk about or are planning towards.
Perceived Instrumentality	The importance given to completing a task that will help them reach their desired future career goal.

2.5. Current Study

To address the gap in understanding students' experiences, a multiphase mixed methods research project was conducted where students were asked about their motivation, identity, and general experiences while in graduate school. This larger project helps to shape and guide this analysis. During this multiphase project, we first collected and analyzed focus group data to examine the transferability of existing theoretical models of FTP, identity, and experience to doctoral engineering students (Tsugawa, 2019). The interview protocols for each of these areas was collaboratively developed by a team of engineering education researchers and social psychologist, with at least one member of the team having significant experience with one of the theories utilized (Cass et al., 2018). At the time of the protocol development, virtually no research was conducted to understand graduate engineering student motivation and identity development. As such, the development of the interview protocol for these focus groups relied on leveraging protocols and survey items from undergraduate engineering role identity and future time perspective research (e.g., citations) and reflecting on our own past graduate experiences in engineering. We rephrased undergraduate survey items as open-ended questions and altered the wording from other interview protocols to relate to graduate contexts (e.g., research experiences, coursework, teaching). The protocol was then piloted with a focus group of engineering graduate students to see how they perceived the questions and revisions were made for clarity and flow. The developed protocols were then used to conduct interpretative phenomenological analysis for both interviews and focus groups which resulted in themes and an initial codebook. One of the research team members refined the codebook through a directed content analysis on more interviews with engineering graduate students related to their professional identity development and perceptions of the future (detailed in their dissertation work, citation). Additional details about the developmental processes can be found in (Tsugawa, 2019).

Results of the qualitative analyses were compared with existing theory and survey instruments to develop the GRADS survey (Cass et al., 2018). The survey was disseminated to a nationally-representative sample of engineering doctoral students. Results from the approximately 2300 survey respondents were analyzed using latent profiles analysis to determine the different motivation profiles of engineering doctoral students. Latent profile analysis is a person-centered methodology that uses mixture modeling to identify latent or previously undetected groups within a sample (Godwin et al., 2021; Spurk et al., 2020). Once descriptively referred to as “the art of unscrambling eggs” (Oberski, 2016, p. 1), latent profile analysis has been used in educational research to uncover meaningful sub-groups within samples. For instance, Grunschel et al. (2013) identified four groups of academic delayers (including a group of students who delayed tasks because they were worried or anxious and another group of successful students who delayed in order to create pressure and motivation). This analysis allowed for increasing recognition of the heterogeneity among academic delayers, and thus provided for better tailoring of procrastination interventions. Snodgrass Rangel et al. (2020) examined a nationally representative sample of students’ science and math motivational beliefs (e.g., science/math interest, competence, utility, etc.) and identified four groups, ranging from a high-all group (24%) to a low-all group (15%). A follow-up analysis demonstrated that first-generation college students were overrepresented in the low-all group, demonstrating how latent profile analysis can be used in tandem with other analyses to examine patterns that might otherwise be masked in linear, non-person-centered methodologies.

The latent profile analysis from the GRADS project shed new light on how doctoral students think about their future, suggesting notable differences from undergraduate students. Instead of centering on the temporal distance (2-15 years) and perception of time as was the case with undergraduates, the five motivational profiles suggest that doctoral students instead focus on the types of futures available, the value of their tasks, and alignment with any desired future careers (Perkins, Tsugawa, et al., 2019). These five latent profiles, described in Table 2.2 Latent motivation profiles with definitions., are: 1) *low future time perspective*, 2) *low career connectedness*, 3) *intermediate future time perspective*, 4) *high commitment*, and 5) *high perceived instrumentality* (Perkins et al., 2019). While these profiles predict perceptions of degree progress and persistence, the explanatory causes behind these connections were not thoroughly examined in the analyses of survey data. We utilized the conceptualization of FTP outlined above and the profiles established in previous work to address our research questions and connect students' FTPs to their lived experiences in their doctoral programs.

Table 2.2 Latent motivation profiles with definitions.

Profile	**Definition**
Low Future Time	Students who scored low across all measures, did not connect current

Profile	Definition
Perspective	experiences to their future, and found little to no value in the tasks they were doing while in graduate school.
Low Career Connectedness	Students did not connect what they were doing in graduate school to their future goals.
Intermediate Future Time Perspective	Students who scored neither high nor low in any construct and consisted of nearly half of the students surveyed.
High Perceived Instrumentality	Students who found a lot of value in the tasks and experiences that they had as part of their doctoral program.
High Commitment	Students who scored low on multiple futures, and therefore were focused on one or two closely related careers.

2.6. Methods

2.6.1. Positionality

We present a group positionality statement to articulate the ways our individual experiences came together to shape the choices made in this paper (Secules et al., 2021). Five of the authors are trained in engineering education, while two are trained as social psychologists. At the time of the study, the last two authors were engineering education faculty at land-grant institutions, with the remaining authors being graduate students in their respective disciplines. All members of the author team were motivated to explore and improve engineering graduate student experiences due to direct or vicarious instances of significant negative graduate experiences. Specifically, the engineering education authors had seriously considered leaving their programs due to these experiences. All authors had experience exploring students' future-oriented motivations and leveraged this lens to explore how students interpreted their lived experiences. This choice also influenced how we analyzed the qualitative data (described in section 6.3). All interviews were conducted by the first three authors, who were doctoral students in an engineering education program. This choice was made to avoid power dynamics and to have researchers who could directly connect to the students' lived experiences during the interview. We also sought to leverage students' perceptions and lived experiences rather than connecting to transcript, programmatic, or faculty data as these data often are designed with implicit and explicit norms that mask key features of graduate experiences (Berdanier et al., 2020).

2.6.2. Data Collection

2.6.2.1. Participants

The participants and data utilized in this project were part of a larger mixed-methods study working to examine the ways engineering graduate students' motivations and identities were shaped by their lived experiences (Cass et al., 2018). Previous work described above generated latent profiles of doctoral student motivation (Perkins et al., 2019). These profiles serve as a method of categorizing motivational attitudes. Guided by these categorization profiles we recruited participants from the five motivation profiles found within engineering doctoral education. Of the 1,122 participants in the quantitative analysis representing 118 institutions, we invited 25 engineering doctoral students (five randomly selected participants from each profile) from various institutions to participate in interviews about their FTPs and doctoral program experiences. Participants were emailed three times; if there was no response or a decline to participate after these emails, another random participant from the respective profile was selected. While we worked to have five participants per profile, lack of responses and data corruption from some of the profiles limited having a balanced sample and resulted in a final sample of 15 participants from various institutions. Of the 15 participants 10 of them identified as men, while 5 identified as women. Ten participants did not hold traditionally underrepresented identities (e.g., white or Asian) while five participants held traditionally underrepresented identities (e.g., Hispanic, Multiracial). The pseudonym, gender, race/ethnicity, year in their program, major, and profile membership of each participant are shown below in Table 2.3. Participant membership in FTP profiles.

Table 2.3. Participant membership in FTP profiles.

Pseudonym	Gender	Race/Ethnicity	Year	Engineering Major	Profile
Steve	Man	White	5	Material Science	Low FTP
Jim	Man	Asian	6	Mechanical	
Jacob	Man	Multi-Racial	6	Material Science	
Alice	Woman	Hispanic	5	Nuclear	
Fred	Man	White	5	Environmental	Low Career Connectedness
Tim	Man	White	4	Civil	
John	Man	White	3	Chemical	
Mark	Man	Middle Eastern	5	Electrical	Intermediate FTP
Sean	Man	Asian	5	Electrical	
Olivia	Woman	White	2	Material Science	
Carey	Woman	Multi-Racial	4	Nuclear	
Alex	Woman	Asian	5	Chemical	High Commitment
Arthur	Man	Hispanic	5	Industrial	
Amelia	Woman	White	4	Biomedical	High Perceived Instrumentality
Carl	Man	White	3	Material Science	

2.6.2.2. Interviews

Prior to conducting the interviews analyzed in this paper, the researchers piloted the newly developed interview protocol by interviewing each other and then reflecting on their own answers to recognize their positionality going into interviews. Interviews with participants were conducted virtually using video chat by three doctoral engineering education students who met weekly with the full research team to discuss the data collection process. The goal of the interviews was to collect data focused on students' future career goals and doctoral experiences. Guided by the previous latent profile analysis, we interviewed fifteen engineering doctoral students from institutions across the nation to understand their motivations for entering and persisting in doctoral education. Prior to the interview, participants completed a short demographic survey shown in the supplemental materials (S1. Intake Survey). Interviews with participants ranged from 30 to 45 minutes in length, followed a semi-structured format, and were guided by previous multi-institution surveys and focus group data (Cass et al., 2018) in Appendix A. Sample questions from the protocol include:

- How far into the future do you see yourself professionally? Personally?;
- What research tasks, assignments, activities do you find useful toward your future?;
- Is your degree program preparing you for the future?

A full copy of the interview protocol can be found in Appendix B. Memos were generated to note the researchers' feelings and positionalities and embed any thoughts that would otherwise be lost in the interview. These memos were completed directly after the interview concluded to maintain accuracy. Research participants were compensated for their time with a $20 electronic gift card. The interviews were recorded and transcribed verbatim by a third-party service. The research team reviewed each participant's audio and transcription data concurrently to increase the process reliability by reviewing the accuracy of the transcript and grounding the analysis in participant narratives. During iterative passes through the data, ethical validation was prioritized by having the lead researcher continue to listen to the audio files alongside the transcripts to ensure that participants' voices were preserved throughout the process.

Trustworthiness and quality in collecting the data were guided by Walther et al. (2017). The research team met throughout the data collection process to debrief and discuss initial conceptualizations of the participants' experiences. This initial examination of knowledge co-construction between the interviewers and interviewees was essential for establishing clear communication of the findings across the research team and prioritizing our communicative validation throughout the study. Additionally, interviewers comparing interview techniques and responses helped establish process reliability across participants to mitigate random influences. These meetings also supported the research team in understanding how students were talking about their future to co-construct the participants' shared experiences.

2.6.3. Data Analysis

The data analysis process was guided by thematic analysis (Braun & Clarke, 2006). This method allowed the research team to utilize an existing codebook, shown in Table 2.4., which was developed previously in the larger project (Table 3.3; Tsugawa et al., 2017) while providing the flexibility to incorporate emergent codes (Nowell et al., 2017). We present this analysis in a linear fashion; however, the path for this analysis was cyclical and reflective throughout the identification, analysis, organization, description, and reporting of themes (Braun & Clarke, 2006). The main steps in this project following data collection involved three passes through the interviews. During these analytic steps, we ensured the process reliability, ethical validation, and theoretical validation as recommended by Walther et al. (2017).

Table 2.4. Condensed Codebook taken from Tsugawa (2019).

Code	Description
Career - Avoid	Discussion of what they do not want to be in the future
Career - Ideal	Discussion of what they do want to be in the future
Career - Realistic	Discussion of what they can realistically do in the future
Connectedness - Career	Student describes how their future career goals influence their present actions
Future - General	A broad goal for the future that does not necessarily relate to anything
Future - Career	The student describes attributes or characteristics of their future career.
Future - Personal	A personal goal for the future such as starting a family or losing weight
Multiple Futures	Participant describes having multiple divergent future goals
Near Future Job Attainment	Participant described the certainty with which they believe they can get a job post-graduation.
Perceived Instrumentality	The student describes how relevant they view certain tasks as related to their future identity
Task - Avoid	A task a participant perceives as not relevant to their future goals such as avoiding teaching assistantships because they want to be a researcher at a national lab
Task - Useful	A task a participant perceives as useful toward their future career and identity and necessary for achieving their future goal such as doing teaching with a lecturer position in mind
Task - Useless	A task a participant perceives as useless toward their future career and not necessary for achieving future goal or identity such as filing paperwork

Code	Description
Useful Experiences	Experience or opportunity that provided knowledge or skills that students felt they can utilize in the future.

The first step was familiarization with the data, wherein we listened to the interviews alongside the transcripts to center the participant voices in our analysis from the beginning. The first two authors, engineering doctoral students, listened individually to each interview before meeting to discuss what they heard in the data. While discussing the interviews, the first two authors also discussed the existing codebook with the third author, who led its development (Tsugawa et al., 2017). By discussing the coding structure, definitions, and ways of coding, the authors could better align their analysis plans to mitigate random influences, thereby increasing the process reliability (Walther et al., 2017).

With agreement on the existing codebook, the first author conducted the first pass through the data using sentence-level coding. During this first pass, the goal was to understand the prominence and ways students talked about their future goals related to their future time perspective. During this analysis stage, we coded the data at the descriptive level focusing on the topics discussed by the participants. Using the descriptive coding and data from the demographic survey, the first two authors worked together to generate participant summaries with the compiled themes to examine similarities and differences within and across profiles. These participant summaries allowed for comparisons between each student and the available literature. The summaries also maintained individual voices, thus supporting the theoretical and ethical validation (Walther et al., 2017). After descriptive coding, the full team met to discuss additional emergent themes and patterns in the summary. Common themes arose that did not fit the existing coding structure, which prompted another analytic pass with this emergent coding structure.

In the second pass, we iterated on the interview data using descriptive, linguistic, and thematic lenses and developed emergent themes not previously examined in the existing codebook (Smith, JA, Flowers, P., & Larkin, M, 2009). These iterations involved sentence-level coding where overlap was allowed if multiple themes were present in the same sentence. The topics that students discussed during this analysis stage included their mental health, their motivation for going to graduate school, their plans for their future goals, how they were or were not being prepared for their future, interactions with faculty, their personal future goals (e.g., having a family), and their intentions to persist. A list of the emergent themes and their definitions can be found below in Table 2.5. Codebook of emergent themes in this study Similar to the previous analysis, the first two authors discussed their findings and the updated participant summaries before meeting with the entire research team. This process also allowed for continual auditing of the research process by the research team and opportunities for reflection by the entire research team on the post-interview memos, further ensuring validity.

Table 2.5. Codebook of emergent themes in this study

Code	Description
Mental Health	Student discussed their mental health while in graduate school.

Code	Description
Motivation or Purpose	The student describes their reason for going to graduate school or persisting.
Planning	The student describes a series of steps or paths needed to reach a distant future goal.
Preparation for Future	Student perceptions of how prepared they are for their future beyond graduation.
Support	Student talks about the support they do or do not receive from peers, advisors, faculty, and their graduate program.

A third and final pass of the data involved examining the themes across participants and profiles. While there was variation in the emergent themes across students' narratives, students consistently highlighted the source of their goals, future career goals, plans for those career goals, and support from faculty and doctoral programs as important to their perceptions of the future. These four overarching themes and supporting evidence are presented below to show commonality within and variation across profiles.

2.6.4. Limitations

The work presented in this paper provides evidence-based on students' perceptions of their lived experiences. While we have taken the approach that students' perceptions shape their lived experiences, this work does not triangulate these perceptions with students' graduation rates or career preparedness through other data. The data presented in this study also comes from students who were enrolled in the earlier portions of the larger mixed-methods study, which raises two other limitations. The participants here were all still enrolled in doctoral programs. We were not able to recruit any students who had left their doctoral program. Having data on students' experiences of leaving would have helped triangulate this work's findings and support how students' attrition decisions were influenced by their perceptions and environments, however no students who left their program agreed to participate. Additionally, while we connected students to their original profiles, there was a lag of a year between survey dissemination and student interviews. Students may have shifted profiles during this time. To counteract this limitation, we present a summary of the cross-cutting themes but have also presented students within each profile to help connect these findings to larger work within engineering education.

Two additional limitations arose in the data collected for this project. First, the sample in this study is heavily white and male and missing members with other identities; thus, the transferability of this work is limited to populations included in our sample and may not fully represent the experiences of traditionally underserved students. Second is that in some of the profiles on two participants agreed to participate in our study. This smaller sample size does reduce our ability to provide a comprehensive understanding of the range of experiences of these students but does not prevent us from presenting insight into some of the ways in which students in these profiles navigate doctoral education and prepare for their future careers.

2.7. Results

From the analysis of interviews with fifteen engineering doctoral students about how they describe their future goals and experiences in graduate school, four themes, described in Table 2.6. Definitions of the four emergent themes and supporting quotes for each theme.., emerged. We present the variation in the themes through the different motivation profiles used as a preliminary categorizing mechanism. In the presentation of these themes, we provide insight into existing knowledge on students who do not have goals (Gibbs & Griffin, 2013) and the importance of faculty in students' development (McGee, 2019). The first three themes, presented in sections 2.7.1-2.7.3, provide evidence for how engineering doctoral students describe their goals, and future oriented perceptions (RQ1). The fourth theme, presented in sections 2.7.4-2.7.5 showcases how students' program-oriented experiences shape their future-oriented perceptions (RQ2). The first theme, *self-derived goal*, reflects on how students talked about the source of their goals(e.g., personally set, or the counter example of at the recommendations of others). When these students had goals, they talked about the foundations of their goals in three distinct ways: a desire for different career opportunities, needing an advanced degree for continued career advancement, or as a counter-point to being self-derived, at the recommendations of faculty or family. The second theme, *future career goal,* focused on how students expressed if they have career goals beyond the completion of their doctoral degree. When talking about their future career goals, students described them in the following ways: not having a future career goal, future career goals they did not want, having multiple divergent future career goals, or having one to two well-defined future career goals they were working towards. The third theme, *plan for career goal,* highlights how students discussed their plans, or lack thereof, for setting themselves up to be prepared for their post-graduation careers. Students talked about their plans in three ways: that they did not have a plan, that they had divergent paths in mind but were hesitant to commit to anything, or that they had a few convergent and well-articulated ways to reach their goal. The final theme of *program and faculty support* focused on how students described aspects of their program, such as advisor feedback and professional development seminars, that aligned with their post-graduation careers. The support mentioned by students ranged from neglect and sexism (counter-points to support), industry support, advisor support, and program support in the form of professional development.

Table 2.6. Definitions of the four emergent themes and supporting quotes for each theme.

Theme	Definition	Key Examples
Self-Derived Goal	Discussion on driving factors for going to graduate school	*"I didn't know what else to do and didn't want to move back home." (Steve)* *"So all the goals I have, I need a PhD and it isn't one of those things where I'm getting it just so I can get the promotion although it doesn't hurt. I chose a lab where I would get a skill set that was more helpful rather than just getting a piece of paper." (Amelia)*
Future Career Goal	Description of the number and certainty of future career goals	*"I'm kind of exploring everything right now to see what comes up… The main goal is just like, get a job." (Steve)* *"Why did I want to go to grad school? Because I wanted to be a professor." (Alex)*
Plan for Career Goal	Ways in which students talked about how they would achieve their career goals	"*I do have future plans, but ... The way you work towards a plan should be flexible, because you know, call it the things, start with the change at some point, a different plan for the next five or ten years, or twenty years*." *(Mark)* *"Well, there is some visa immigration stuff on my end that I have to solve. That is the only concerning problem...I am very confident that with that out of the picture I will probably get a promotion in 3.5 years. Then after that it sounds like three more, so in 7 years we are thinking that with all the immigration stuff out of the way, I am very confident I will be on a tenure*

Theme	Definition	Key Examples
		track, with tenure completed." (Arthur)
Program and Faculty Support	How program and faculty provide resources and feedback aligned with students' career goals	*"There are certain types of students that he [my advisor] is looking to graduate… They [other students] know what they want, and they themselves will probably be successful professors in the future." (Jim)* *So [my advisor] recommended early on that if I'm going to go for policy track that I need to be involved with something more than just lab work. He's the one who in my first year told me, you know, find a physics group, find someone where you can do something. Because it's going to be that experience more than the actual science you do in my group I think that's going to get you, that's going to make you stand out." (Carl)*

Note: Example quotes are included with more context below.

As highlighted in Figure 2.1, while students' goals can build on each other, this development is far from static as students gain more experience and explore potential career paths. Additionally, regardless of students' individual goals, a need exists for program and faculty support throughout if we want students to leave feeling prepared for their desired futures. In addition to showing the relationships between the four themes, Figure 2.1 also highlights where each FTP profile falls in this model. The themes presented represent the four major checks of career preparation, relating to goals, goal planning, and program and faculty support. This support, which is embedded throughout the process, relates not only to students' goals, but also can include intellectual and emotional support. Students with no self-derived goal, Profile 1, often left without a degree and struggled to receive support from their programs and faculty. Profiles 2, 3, and 4, while having self-derived goals, struggled with planning for their futures and found their faculty and programs to be sources that could undermine their preparation.

Finally, Profile 5 represents what happens when each of the themes found in our analysis comes together in positive ways for students. They perceive they can graduate and are prepared for their futures. We unpack specific examples and provide supporting evidence for these claims in the following subsections.

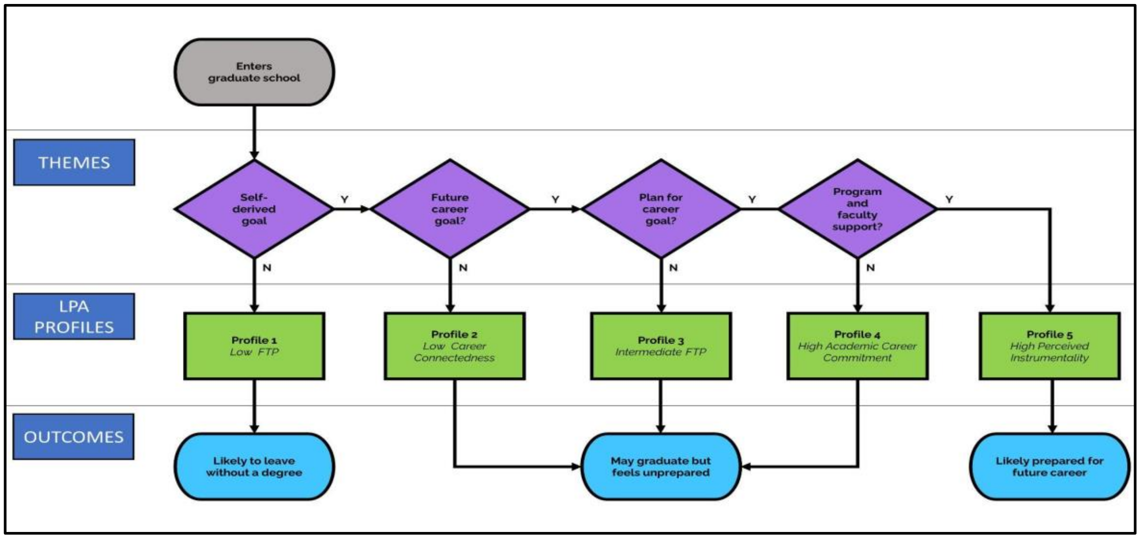

Figure 2.1 A conceptual model linking the qualitative themes (purple diamonds), latent profiles (green squares), and potential student outcomes (blue ovals).

2.7.1. Lack of Personal Goals and Limited Experiences of Program Support in Profile 1

Aligned with research question 1, the ways in which students in profile 1 described their future-oriented goals centered on a lack of personal goals and negative experiences from faculty and staff. Because of these experiences these students did not think about their future and instead focused on surviving graduate school.

> *"Having that realization in the second year like, 'What am I doing here? Why am I doing this? Like why, this sucks! I don't need to keep doing this." (Steve)*

As highlighted by Steve's quote above, all four participants in this profile lacked personal goals. Additionally, these participants were not supported by their program or faculty. The lack of support for these students was often experiences as neglect and sexist comments, further causing students to focus on surviving graduate school rather than thriving. While some students persisted through multiple negative graduate school experiences (e.g., advisors neglecting student needs, sexist faculty interactions), the lack of self-derived goals and support led them to either strongly consider or act upon leaving their doctoral program for other opportunities. Those who persisted perceived that they were highly unprepared for their future careers.

When discussing the goals that led them to enter graduate school, these students described reasons that were not their own. As was the case with Jim, he was encouraged to go by his future advisor and had *"never planned on going to grad school"*. Meanwhile, Steve described how he *"didn't know what else to do and didn't want to move back home"*, leading him to continue his education despite not having goals aligned with needing the doctoral degree. In all cases, external factors pushed students through graduate school instead of personal goals.

The lack of self-derived goals for these students went beyond personal goals to not having career goals or plans for future careers. The problem with only having external motivators is that when students encounter difficulties, they question their reasons for being in graduate school in the first place: *"I almost dropped out in my second year. But then I switched groups" (Steve).* These periods of questioning undercut students' motivation and often negatively impacted their mental health.

Graduate school is touted as difficult and demanding under the best circumstances; however, the neglect and exclusion experienced by students in this profile further undercut their motivation. Jim mentions this specifically when talking about how his advisor left for a start-up and only met with him twice a year. Jim goes on to say that his professor told him that:

> *"There are certain types of students that he is looking to graduate… they know what they want, and they themselves will probably be successful professors in the future." (Jim)*

For Jim, a student not interested in being a professor, this neglect from his advisor shows the ways academics perpetuates educational models focused on preparing students for academia.

However, while neglect and ignorance are one problem, faculty also actively exclude students through discriminatory practices, like in the case of Alice:

> *"The qualifying exam experience was pretty difficult. I did experience some sexist comments during the middle of my exam and also in the preparation from faculty." (Alice)*

Experiences like Alice's above, where students were subject to discrimination or neglect, resulted in half of the students interviewed deciding to leave their program. Those who remained continued to feel unsupported and were subject to further negative experiences during their time in graduate school.

Despite entering graduate school without self-set goals, dealing with adverse circumstances, and in some cases leaving their doctoral program due to negative experiences, students in this profile described reaching “turning points” where they began to believe they could reach graduation. Jacob describes how looking over his data he saw a clear path to graduation stating he finally *“saw clearly all the necessary steps I have to do to finish the degree.”* However, when these students finally reached graduation or felt they could graduate, they realized they had given no thought to what they would do with that degree. When thinking about their careers after graduation, Steve said *“I’m kind of exploring everything right now to see what comes up… The main goal is just like, get a job.”* With their time in graduate school so focused on survival, they did not stop to think about their future goals or how to prepare for them, leaving them no better prepared than when they started.

2.7.2. Uncertain Future Career Goals and Experiences of High Transition in Profile 2

Further exploring research question 1, when discussing their future-oriented goals, students in profile 2 described having multiple future careers they were considering but expressed uncertainty around their commitment to these futures. This uncertainty was influenced by the fact that their decisions to pursue graduate school were guided by their unhappiness with their previous careers, leading them all to enter new fields of study.

> *“I wasn’t coming from an engineering background, so it was essential for me to get a broader understanding of the field outside of the very narrow scope that I’ve*

> *researched…. My possibilities with my bachelor's degree were basically analytical [chemistry], as like a field technician or something like that, so I was looking for something a little more skilled." (Tim)*

Low career connectedness students' self-derived goals manifested as self-set career goals in new fields of study. These career goals served to create an ideal future career goal; however, that goal is not connected to tasks and opportunities in the present. The lack of a plan or personal development was further spurred by the feeling that their advisors were only focused on their completion of research tasks rather than their development. The students' lack of experience and knowledge in a new field, coupled with the demands of their advisors, meant that they could not determine what knowledge, skills, and abilities to develop and refine while in graduate school to prepare for their future career goals.

These students described their self-derived goal as gaining different career opportunities than those available with their original degrees. However, when trying to create new career opportunities, these participants had to move away from their areas of expertise to explore new degree programs. Even Fred, whose change in fields was within civil and environmental engineering, said, *"I'm coming from applied physics to chemistry, [which to me are] totally unrelated fields."* By expressing the disconnect these students perceive between their new field of research and previous knowledge, these participants convey their struggle to connect what they are learning to what they already know. Their struggles are further compounded by the rigor of their program, leaving them unable to think beyond graduate school tasks: "*In graduate school, I have to admit, the blinders have been on. The most I have been able to think ahead is maybe two years"*

(Tim). Participants struggled to organize and integrate what they are learning without a reference point to connect the new knowledge.

For these students, their future career goals were guided by their previous discontent with their career, leading students to have not one but several future career goals. For example, when asked about his future careers, Fred stated *"I could sit down and I could write out five or 10 unique career paths that I could envision myself doing, but I think it comes down to getting my feet wet*." The myriad of divergent career goal paths meant that while students had potential goals, there was no way they could create plans for all the different paths before them and only loosely connected their current tasks to their future plans.

The support from programs and faculty for these students was not described as adequate for these students either. When thinking about the futures before them, students mentioned feeling unprepared because of a lack of opportunities, such as teaching assistantships, and not knowing if there were any professional development opportunities due to the rigor of their studies. When talking about their advisors, students mentioned being left to struggle.

> *"At the beginning, there were a lot of struggles where I didn't know what I was doing… That's kind of what being a Ph.D. student is about [though], is your struggle, and your advisor kind of watches you fail sometimes, because it's for your own good." (Fred)*

For Fred, it is an ingrained belief that isolation and hardship are for your own good, and this highlights the problematic nature that faculty expect students to be prepared even when entering a system that is meant to train and prepare them.

Students in this profile described coming in with strong self-derived goals to create new career opportunities; however, their lack of practical knowledge about the new field and a lack of guided experiences from programs and advisors undercut their preparation. This left them in a state of exploring multiple divergent career paths. While their past experiences motivate them to finish their degree, the demands of their program and lack of practical knowledge mean they will likely feel unprepared for their future career upon graduation.

2.7.3. Previous Career Experience but Limited Experiences of Program Support in Profile 3

To further address research question 1, students in profile 3 described having previous careers in industry before returning to college for advanced degrees. Because they had worked in industry these students described knowing how to obtain and navigate careers outside of academia. However, when describing their future-oriented goals they did not experience support from their advisor aligned with their needs.

> *"Before I entered graduate school, I had four years of professional experience as a research engineer… While I was working, I was working with my coworkers and my colleagues, and as we were doing this teamwork, we're discussing, and getting some feedback. I think that helped me become more independent,*

> *especially in my situation where my advisor is not there following me all the time." (Mark)*

Like profile 2, possessing self-derived goals allowed the participants to persist through difficult tasks and experiences to help them reach graduation. Further, their future career goals were concrete, with clearly identified careers they were working towards. However, when these students discussed how they planned to reach their career goals, they described the few years after graduation as flexible and dependent on available opportunities. For these students, their lack of a concrete plans coupled with advisors who were not involved at the University reduced their capacity to connect the opportunities in graduate school to the necessary knowledge, skills, and abilities for the next steps in their career pathways. The evidence below unpacks the nuances that emerged through the analysis of this profile.

Unlike the profile 2, where students' goals for graduate school were disconnected from their previous careers, these students wanted more opportunities related to their current careers. For example, Sean stated, "*I wanted to move to a research job. I was working in a more engineering kind of job, not that I wasn't happy but I just wanted a little bit more.*" *(Sean)*. For those participants who partnered with industry while in graduate school, they described how, for example,

> *"If I got my PhD I would always have the option if I wanted to be a consultant and have the credential, build up the network, have the knowledge base to do that and basically run my own business in my specific research field that I was interested in." (Carey)*

The motivation to get more opportunities, partnered with the experiences working in industry positions, meant that these students could better ascribe value to their graduate school experiences for distant future goals.

When talking about their future goals, the students in this profile talked specifically about the type of career and goals they have for graduation.

> *"Idealistically, I would really like to make a nuclear rocket go into space. So, whatever way I need to get there, I'll figure out how to get there. And if the right opportunity is there, I'll go do it… The reality is to work at NASA, optimize nuclear fuel for a rocket, and test it. [But] I need a team to actually make an engineering product. There's a lot more steps that go in it, but it is just one step in the staircase. Its all mapped out. Everything shifts, everything changes. You have to be willing to do the dance." (Carey)*

In this quote, Carey talks about her idealistic goal and outlines the major points she envisions on how to reach that goal, and while she expects things to shift or change, she is willing to do whatever it takes to make it happen.

The certainty of these students' self-derived career goals serves to motivate them through hardship and obstacles; however, in contrast to the certainty of their goals, these students plans for how they would reach that goal were not well described. When talking about his plans, Mark noted,

> "*I do have future plans, but ... The way you work towards a plan should be flexible, because you know, call it the things, start with the change at some point, a different plan for the next five or ten years, or twenty years*." *(Mark)*

A distinction in this flexibility from the previous profile is that Mark is not being flexible in what his long-term goals are and is instead being flexible to changes in his plan to reach that future. This distinction is key as it gives students a goal to work towards in the face of difficulty and obstacles.

While these students are thinking far into their futures, they are not receiving support from their program or advisors to plan their futures. This is not to say they cannot leverage their resources to find the pathways to reach their future career aspirations, but they do not receive the same level of mentoring and information about opportunities as some of their peers.

> *"I think I ended up with a lot of extra things that I could've avoided if my advisor would've been more [involved]... Because he's not really part of the faculty in the department, I think sometimes he's a bit out of the loop… My peers told me that I shouldn't do extra stuff, but I didn't really know what to do when my advisor was telling me to do all these extra things. So, I feel like there could've been some more communication, maybe that would've helped me to not add extra things onto my plate." (Olivia)*

These additional requirements and the lack of communication between her and her advisor, and her advisor and the institution meant that Olivia was not thinking about the next steps in her future, only about getting through graduate school so she could reach her future goals.

While these students have future goals and are progressing towards graduation, they are still likely to feel unprepared for their future careers at graduation. Their experiences give them the skills needed to craft distant future goals but not the support and knowledge of how to prepare for the various career paths they want to take. These students are potentially on a path to graduate feeling unprepared and are likely not receiving the full benefits of their time in graduate school to prepare for future careers beyond graduation.

2.7.4. Program Experiences Shape Career Goal Changes in Profile 4

Aligned with research question 2, the experiences discussed by students in profile 4 showcased the dynamic nature of goals, and the influence that their time in academia had on their perceptions of their future and perceived preparedness for a future career. In the interviews, participants discussed wanting to be a professor, *"Why did I want to go to grad school? Because I wanted to be a professor." (Alex).* Because the students had thoroughly explored academia while being doctoral students, they knew the steps that needed to be taken and had well-developed plans for their next steps after graduation. However, students in this profile noted that their advisors only focused on having the students complete research tasks regardless of the students' needs. This research at all costs perspective offered limited support for students' development of their future career goal of being a professor. The narratives in this profile also serve as a cautionary tale if students are only trained for a single career type. Alex, who was initially academia-focused, decided she did not want to go into academia after gaining experience on what being a professor is like. The singular focus meant that when Alex reevaluated her career pathway, she realized she had no idea what skills, knowledge, or abilities she had that supported other career paths.

Reflecting on why they went to graduate school, the participants in this profile expressed desires to become professors due to a passion for teaching and working with students. Alex said,

> "*I wanted to be a professor because I loved my undergrad professor so much. I loved what she got to do and I loved how she was able to mentor her students and build them up and make them feel empowered." (Alex)*

These aspirations to be a professor required students to get a PhD and develop the many skills and pursue opportunities required for being a professor. Despite coming into graduate school focused on being a professor, these students used their time in graduate school to reflect on if being a professor aligned with their expectations and interests.

When thinking about their goals and plans and by exploring their future careers they could determine if they would navigate that career path. Alex, upon reflecting on her goal, expressed that she was no longer pursuing academia and instead wanted to join a small company. When asked why Alex said, "*I ended up not wanting to go into academia [from] seeing so many examples where the research is so far removed from anything that could be made of use, within the time scale of our lives."* Conversely

Arthur who mentioned having a position lined up for the following semester, articulated a well-developed plan for his immediate future:

> *"Well, there is some visa immigration stuff on my end that I have to solve. That is the only concerning problem...I am very confident that with that out of the picture I will probably get a promotion in 3.5 years. Then after that it sounds like three more, so in 7 years we are thinking that with all the immigration stuff out of the way, I am very confident I will be on a tenure track, with tenure completed." (Arthur)*

The confidence Arthur has for his future is related to is experience in the academic environment and working with individuals in the type of career he wants. This highlights the importance of exploring and gaining experience in the field you want to pursue a career in to support your career aspirations.

In talking about their program and advisor support neither of these students felt well supported or prepared. Arthur mentions the focus on publishing and demands put on him and his peers saying:

> *My advisor wants his students... or measures the success of his students by the amount of publications. I guess at the beginning it was definitely hard for me to learn how to make that happen very frequently, basically publishing a lot of papers. But I saw throughout my program that other students never managed to get the hang of it and they were not in the lab anymore. It is not like the department or my advisor would give you like the right tools to learn. You have to*

> *learn yourself and have to become good at it as soon as you can. If you take too long then that is too long for us. (Arthur)*

In this quote we can see that Arthur perceives himself as one of the few who could navigate the rapid publishing demands embedded in his program. Arthur also noted the lack of support in the form of mentorship, resources, and tools to help keep up with the 'publish or perish' culture. While Arthur was able to persist and maintain an 'acceptable' publishing rate, the lack of support and tools can be seen in other areas, particularly in that Arthur feels unprepared due to a lack of teaching experience. When asked why he mentioned never having a teaching assistantship and subsequently said "*I was not taught how to teach."* This was a major concern, particularly because part of his upcoming position involved teaching.

In this profile, students' career planning was far from static, with experiences and opportunities influencing and challenging students' career interests. For the students in this profile, despite coming into graduate school highly committed to careers as professors, these participants' future goals were challenged by a "publish or perish" culture or desires to see the impact of their work. Additionally, despite being academia-focused and having experienced faculty, the participants noted that they felt unprepared for futures in academia. This highlights the need for mentorship and collaboration between faculty and students to find or create opportunities to support students' future career interests.

2.7.5. Experiences of Goal Aligned Support in Profile 5

Further addressing research question 2, when talking about their time in graduate school, the students in profile 5 described not only having goals but also having faculty who provided and encouraged experiences where students could explore their desired future careers while completing their dissertation. These individualized opportunities influenced students future planning.

> *"So my PI, the way he runs the lab is based on what our goals are. He kind of like makes our own individual training program. So he decides what conferences would be important based on what we want to do." (Amelia)*

Students in this profile see their time in graduate school as useful for refining their future career plans and future goals by leveraging resources that help prepare them for their future careers. Their reason for getting a PhD was to move beyond credential-based ceilings in their current careers and to have control over their futures. Each student described well-developed plans for reaching their future goals with milestones starting right after graduation and including distant future goals. In addition to having self-derived goals, future goals, and a plan to reach their future goals, they discussed the ways that their program and advisor supported their development towards their futures. A common narrative was the discussion of their advisors' recommendations of other sources of knowledge and mentorship to help refine their future goals and plans to align with their future career goals.

When these students talked about transitioning into their doctoral program, they discussed self-derived and future goals concurrently, with a specific focus on future careers that require a doctoral degree. Amelia noted,

> *"So all the goals I have, I need a PhD and it isn't one of those things where I'm getting it just so I can get the promotion although it doesn't hurt. I chose a lab where I would get a skill set that was more helpful rather than just getting a piece of paper."* (Amelia)

Amelia's desire to find opportunities that are useful for her future are further supported by her advisor. She said her advisor let her "*do a lot of different projects and he's very open minded. So if I field something by him most of the time he's like 'yup go and get it'".* This support of autonomy and letting students seek out their own projects is one of the many ways that her advisor allowed her to find value in her doctoral program.

When talking about their time in graduate school, the students' ability to develop plans alongside their advisor made a big difference in their ability to think about their future careers. Amelia mentioned how she talked with her advisor about "*what kind of postdocs would be helpful for the kind of career I ultimately want,"* leading her to be able to plan for her career *"like five or seven years into the future".*

For students who are taking nontraditional paths, like Carl who was in an engineering program and getting a certificate in policy, this guidance was pivotal. When asked about his experience Carl said *"It's been interesting, trying to navigate a nontraditional career option. Like my department doesn't really know how to handle that.*

But I have an advisor who's really supportive." He went on to talk about how his advisor encouraged him to seek out other mentors that knew the career area that Carl was interested in and how it made all the difference in his ability to make plans for his future.

> *"So I only decided on policy, not long after I got into grad school actually because I didn't know that you could really mix science and policy.… So [my advisor] recommended early on that if I'm going to go for the policy track that I need to be involved with something more than just lab work. He's the one who in my first year told me, you know, find a physics group, find someone where you can do something. Because it's going to be that experience more than the actual science you do in my group, I think that's going to get you, that's going to make you stand out." (Carl)*

For these students, the investment by their advisor made their time in graduate school more valuable to them by allowing them to move beyond the common goal of getting a degree, and to strive to be prepared for their futures.

Across this profile, we can see advisors' guidance supporting these students while providing the autonomy to allow students to explore and find the path they want beyond graduate school. Without the guidance and opportunities from their program and advisors, these students would be trapped in negative experiences and likely underutilize their time in graduate school. These students present the value of student-centered advising that can improve students' motivation and perceptions of preparedness and graduation.

2.8. Discussion

The results generated from students' lived experiences highlight the ways the individual (i.e., motivations for the future) and systematic (i.e., program and faculty support) factors interact and shape engineering doctoral students' perceptions of reaching graduation and being prepared for their future careers. This work highlights that while students' motivations can undermine these perceptions, as shown by the low FTP profile's lack of self-derived goals, a lack of program and faculty support undermines students' perceptions of graduation and preparedness regardless of the motivations they have for the future. This trend occurred despite the fact that the overwhelming majority of students have goals for the future (i.e., Profiles 2-5). While graduate engineering students being motivated by a future in engineering (Bahnson et al., 2019; Berdanier et al., 2020; Kajfez & Matusovich, 2017; Tsugawa et al., 2017) and faculty as agents who can undermine students' pathways to achieving their goals (Artiles & Matusovich, 2020; Boulder, 2010; Burt et al., 2019, 2018; McGee et al., 2016) are not surprising findings, the results from our work show that the myth of the unmotivated graduate student is given too much weight (M. Nerad et al., 2006). Instead, the story of faculty and programs as active agents that support or undermine students' motivations must replace this myth to create meaningful change.

To create meaningful change in faculty and programmatic practice, faculty should understand that students have a range of motivations regardless of their time in their program (Table 2). Participants in this study were sorted into different profiles in prior work, but their narratives supported a limited number of ways motivations for the future drove their perceptions (Gelles, 2019). This finding aligns with work showing that engineering students' attitudes are not a monolith and that to reach the goal of producing more skilled engineers, we should work to support the broad range of attitudes that exist in engineering (Bahnson et al., 2019; Perkins et al., 2019; Perkins et al., 2021; Rohde et al., 2020; Tsugawa et al., 2017).

Further, our results show that engineering doctoral students' motivations are not static. As highlighted most clearly by Alex in Profile 4, who showed a significant shift in her future-oriented motivations, the lived experiences of students can shift their goals and the pathways they wish to pursue. This finding aligns with findings across motivation frameworks, showing that students' motivations are socially constructed and responsive to context (Choe & Borrego, 2019; Kirn & Benson, 2018; Major et al., 2020; Perez et al., 2014; Saddler & Creamer, 2020). Further, work within engineering graduate education has shown that students' goals, particularly those for academic careers, can shift based on changes in their lives (e.g., having a child) or seeing how faculty have to operate to be successful (e.g., the pressures of applying for grants) (Berdanier et al., 2020; Burt, 2019; Mosyjowski et al., 2017; Peters & Daly, 2013; Tsugawa, 2019).

Finally, the three themes (i.e., self-derived goal, future career goal, and plan for career goal) that emerged on the student level point to important motivational features that need to be considered by all involved in the graduate education ecosystem. While the ways the past shapes student motivations has been discussed for engineering doctoral students (Tsugawa et al., 2017), our results extend this conversation to show how without a self-derived goal students may stumble or be guided into graduate school without fully processing why they are there (e.g., Profile 1). Without internalizing their goals, students are less likely to persist through difficult tasks or work to retain key information (Husman & Lens, 1999; Kirn & Benson, 2018; Satterfield et al., 2019). The themes of *future career goal* and *plan for career goal*, show that even students who have a clear idea of what they want to do are unsure of how they will reach their goals or what skills are needed for these goals (e.g., Profiles 2 - 4). Previous work has shown that students who can craft goal paths, a series of interconnected goals, are more likely to perceive the future as attainable and reduce feelings of being overwhelmed by unclear goals (Husman & Lens, 1999; Raynor, 1969). Only when these three themes come together alongside faculty and programmatic support, do students perceive they will graduate and be prepared for future careers after the PhD (i.e., Profile 5). Students who are confident that they can apply the skills gained during their graduate programs, like those in Profile 5, are more likely to utilize these skills in their future careers (Artiles & Matusovich, 2020; Eccles & Wigfield, 2002), thus more directly transferring graduate-level skills into other contexts.

2.9. Implications

The results of this work highlight two practical implications. On the student level, supporting students' development and exploration of their motivations through conversations with advanced peers, industry mentors, and other partners could help foster and refine their motivations for the future (E. Crede & Borrego, 2012; Puruhito et al., 2011). Having more refined motivations for the future can help students focus on the skills they need to develop in the present to reach these goals and to begin to understand the interconnected nature of graduate-level tasks for achieving these goals (Kirn & Benson, 2018). A simple starting point is having doctoral students and faculty co-utilize individualized development plans (IDP) to articulate and reanalyze future goals (Clifford et al., 2013; Tsugawa, 2019). Despite recommendations for widespread use of these plans by leading governmental and societal bodies, doctoral programs have been slow to use these evidence-based tools (NASEM, 2018). Additionally, motivational interventions have been developed for undergraduate contexts and have improved students' motivations (Chatterjee et al., 2021; Puruhito et al., 2011). Implementing modified versions of these interventions and testing their efficacy in doctoral education contexts could provide specific tools that students can use to refine their future and extend beyond the questions and models outlined in current individualized development plan models.

Given the central role of faculty and programmatic support in influencing students' perceptions of graduation and preparedness for future careers, faculty should be trained to understand and foster students' motivations. Given that the influence of faculty has long been documented in graduate education and that the same problems continue to propagate across the engineering ecosystem (Artiles et al., 2018; Matthew Bahnson et al., 2021; Burt et al., 2019, 2018; McGee & Martin, 2011), diffusion models of good mentoring practices, while important, are not sufficient (Henderson et al., 2011). Specific, intentional, and evaluated training results are needed to create meaningful change. The engineering disciplines and educational societies could work together to generate specific policies and training to help faculty understand the role they have in undermining and supporting student motivations. Additionally, faculty workloads and burdens continue to increase along with the long-term impacts of societal issues like racism and Covid-19. As such, programs should explore support models and resources that can foster doctoral student success at the departmental and program levels in addition to those at the university level. These support models will likely need resources to foster sustainability and long-term impact.

For researchers, this work highlights the need to consider doctoral education as an ecosystem and look at multiple variables or experiences simultaneously. While additional depth can be gained by examining specific variables in engineering doctoral programs, this work points to the need to consider the ways variables at different levels interact to influence engineering students' experiences. While work has begun to utilize this approach (Bahnson et al., 2019; Berdanier et al., 2020; E. Crede & Borrego, 2012; Erin Crede & Borrego, 2012), additional work exploring the complexity of engineering doctoral programs could guide the changes necessary to address persistent issues.

2.10. Future Work

The results of this paper show that students being unmotivated is far from the problem, and rather students are not provided with the resources and experiences that align with the needs of large groups of the doctoral student population. Future work guided by this research should test interventions that change the doctoral education system to support students' exploration of career paths, plans, and sub-goals. In addition to the development of goals, research should develop data-driven interventions on programs and faculty to help with the development, maintenance, and growth of students' goals. As shown, students are motivated; however, students' goals are not static and without the proper support, amotivation for doctoral education can occur, leading to consequences for students and

2.11. Conclusions

This study provides evidence across the motivational landscape of engineering doctoral education to explore the lack of career preparation for engineering doctoral students. How students described their futures varied significantly across the four themes presented in this paper. Their stories chronicle the experiences that students have in taking the next steps toward their future careers. The findings in this paper show various influences present at the individual (i.e., self-derived goals, future career goals, and plans for future career goal) and systematic (i.e., program and faculty support) levels. These influences effect students' development as professionals as they navigate doctoral education and prepare for their future careers and their significance should be explored further.

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3. Development and Initial Validation of a Survey of Career-Oriented Preparation for Engineering Doctoral Students (SCOPEDS)

3.1. Introduction

Engineering doctoral students have specialized interests, skillsets, and research opportunities that push the boundaries of existing knowledge. Researchers have emphasized the societal value and need for people with these degrees (Holloway et al., 2022), however, the support structures for doctoral students are often missing or inadequate (Bahnson, Perkins, et al., 2021; Satterfield et al., 2022). As a result of inadequate support structures, students who complete their doctoral programs are often unprepared (e.g., lack leadership competencies, communication skills) to meet the requirements of their future career interests (National Academy of Science, Engineering, and Medicine, 2018). The intersection of these inadequate support structures and lack of career preparation indicate a need to explore the efficacy of graduate education as it relates to doctoral student professional development and goal setting.

To support an examination of students' professional development this work is guided by previous research with STEM graduate students highlighting the importance of socialization and teaching experiences to support student development (Gardner et al., 2014; Kajfez & McNair, 2020), however, this research has focused predominantly on preparations for a career in academia (e.g., tenure track faculty, lecturer, etc.). According to the National Center for Science and Engineering Statistics in 2021, 71.6% of students were pursuing non-academic careers (National Center for Science and Engineering Statistics, Survey of Earned Doctorates, 2022). With the majority of students not interested in academic careers and students' professional development not aligned with industry careers, there is a misalignment between graduate education and the needs of the majority of its students (National Academy of Science, Engineering, and Medicine, 2018). To address this misalignment, I seek to develop a predictive model of students' perceptions of career preparation and perceptions of program persistence. In the following sections I will unpack existing research on career planning and preparation, present the research questions guiding this analysis, and finally, describe the theoretical frameworks leveraged as part of the model.

3.2. Career Planning and Preparation

Engineering doctoral students are expected to balance multiple roles while developing as early career researchers and professionals (Kajfez & McNair, 2014; Miller et al., 2017). Sources of professional development and mentorship include faculty advisors (Allum et al., 2014; Barnes, 2009; Noy & Ray, 2012), peers (Crede & Borrego, 2012; Golde, 2005; Holloway et al., 2022), industry professionals (Holloway et al., 2022), and professional development events hosted by graduate programs (Louis et al., 2007). Across these multiple sources of mentorship and information students are expected to build a professional network with which they can enter their future careers. Due to the variety of careers that students can be interested in (Choe & Borrego, 2019), providing every student with the information they need can be difficult for smaller research groups and graduate programs (Crede & Borrego, 2012). Furthermore, evaluating whether students have the knowledge and resources for their future careers is exceedingly difficult for a few reasons.

The predominant reason for this difficulty in evaluating students' knowledge and resources is that students often do not know or have the space to find out what they need for their future careers, assuming they are in an environment that encourages thinking about a future career (CHAPTER 2). Another reason is that there are no existing measures to examine engineering doctoral student's ability to conceptualize and plan for their future careers at a domain-specific level, here engineering. Without measures to assess students' ability to conceptualize and plan for their future careers, the ability to evaluate and make data-driven changes in engineering graduate education is uncertain.

As a first step to develop measures related to the ways students conceptualize and think about their future careers, I began by examining existing data on graduate experiences and the ways students talk about their future career goals and how their program is or is not preparing them (CHAPTER 2). During this analysis, I found that FTP captured the ways they talk about future career goals and their influence on present tasks, but did not capture how they talked about support structures and career planning. These concepts aligned with goal-setting (Satterfield et al., 2022). Guided by this analysis I seek to integrate future time perspective and goal-setting and examine the predictiveness of a model of students' perceptions of career preparation and perceptions of program persistence.

3.3. Research Questions

To examine the ways future time perspective and goal setting can be used to develop a predictive model of students' perceptions of career preparation and perceptions of program persistence I sought to answer the following research questions.

1. What is the factor structure for future time perspective and goal-setting items for engineering doctoral students?
2. How do students' future time perspective and goal setting predict perceptions of career preparation and program persistence?

3.4. Theory

To examine future-oriented career goals and systemic support structures we leveraged future time perspective (FTP) and goal-setting theory. FTP is a future-oriented motivation framework examining internal motivation that has been used in engineering education to conceptualize how students think about and relate their future goals to current tasks and experiences (Husman & Lens, 1999; Kirn & Benson, 2018). Previous work recontextualized existing FTP measures from undergraduate contexts to engineering graduate student contexts (Tsugawa et al., 2019). In this work, we continued this refinement process by leveraging the constructs of *career connectedness, near-future job attainment, multiple futures,* and *perceived instrumentality* (Markus & Nurius, 1986; Perkins et al., 2019; Tsugawa, 2019) to make sense of students' future goals, and their relation to current tasks. These constructs are defined below in Table 3.1.

Further, we extended previous framings of FTP to include goal setting based on previous qualitative interviews with engineering doctoral students (Satterfield et al., 2022). Because the application of goal-setting theory has predominantly been conducted in organizational and occupational research, these interviews served to guide the refining of these items for the context of doctoral education. Through these interviews, I found four themes that were not captured in existing FTP theory. These themes were how students articulated their goal planning, goal commitment, and the support structures within graduate education (Satterfield et al., 2022). In the context of this paper, goal-setting is leveraged as a theoretical framework to extend FTP. Goal setting broadly examines external supports by examining the relationship between demands (i.e., prescribed goals) and performance, with intermediate factors mediating or modifying the relationship to the outcome variable, satisfaction. The constructs, refined and piloted through cognitive interviews specifically measure *career strategy, goal commitment, faculty and supervisor support, and organizational support.* These constructs and their definitions are found in Table 3.1.

Table 3.1 Description of FTP and goal-setting constructs used in graduate education contexts (Satterfield et al., 2022).

Theoretical Framework	Construct	Description
Future Time Perspective	Future Possible Selves	A future version of oneself that they can see themself becoming in the future.
Future Time Perspective	Career connectedness	How closely related students’ experiences and tasks in graduate school are to their desired future careers.
Future Time Perspective	Near-future job attainment	How confident students are that they can get a job after graduation.
Future Time Perspective	Multiple futures	The variety of future careers that students talk about or are planning towards.
Future Time Perspective	Perceived instrumentality	The importance given to completing a task that will help them reach their desired future goal.
Goal setting	Career strategy	The plan that an individual has to achieve their desired career.

Theoretical Framework	Construct	Description
Goal Setting	Faculty and supervisor support	The support an individual receives from a faculty advisor or mentor, examples include but are not limited to planning meetings, interest in a future career, and sharing opportunities.
Goal Setting	Goal commitment	The ways in which students talk about their desire to see the career described achieved.
Goal Setting	Organizational support	The support that an individual receives from their program or department such as professional development and internship opportunities.

3.5. Methods

In this paper I present the results of an exploratory structural equation model (ESEM) that seeks to conceptualize the relationships between engineering doctoral student motivation, future-oriented plans, and the outcomes of perceived graduate program persistence and career preparation. Before showcasing this model, I outline the data collection, compilation and refinement of survey items, and statistical analysis supporting this model.

3.5.1. Positionality

Author 1: I am a white man from a nuclear family who has a technical background in chemical engineering. My experiences pursuing two graduate degrees simultaneously with two different advisors inform my approach to understanding graduate students' experiences and the ways they are motivated by their own goals and goals encouraged by others. I apply a pragmatic approach to my research and apply the tools and methods that align best with the design of my research. For this chapter my positionality as a pragmatist and someone interested in the experiences of engineering doctoral students led me to follow where the data led me, and consider exploratory structural equation modeling in place of traditional structural equation modeling due to better representing non-simulated or real world data.

3.5.2. Data Collection

The selection process for this work involved leveraging the data from the National Science Foundation Survey of Earned Doctorates for the years 2018-2020 to generate a population of engineering graduate programs that would be used to determine representation across four criteria. A three-year span was used to ensure that smaller and developing programs were included in the sampling structure. The compilation of this dataset resulted in 256 institutions with 1401 engineering graduate programs in the sample frame. The four criteria used in generating a nationally representative sample of engineering doctoral students were 1) state, 2) engineering discipline, 3) program size, and 4) institution size. The program and institution size criteria were determined by calculating the number of graduates between 2018-2020 and classifying them to create three classifications. For program size, these classifications were small (1-7), medium (8-21), or large (22-246). For institution size, the classifications were small (1-28), medium (29-117), or large (118-941).

Engineering graduate programs were randomly selected using a random number generator initially, and programs were systematically removed to reduce oversampled criteria (e.g., with too many large material science engineering departments at a medium institution in a given geographic region, I would filter to only meet those criteria and remove one at random). To meet any areas of underrepresentation across the four criteria, programs were purposively sampled. The result was that no criteria were allowed to be overrepresented or underrepresented by more than one program. Once the final list of programs was determined, e-mail addresses for program leadership were pulled from institutional websites and used as contact points where I asked the program leadership to share the survey with their doctoral students. After reaching out to 263 programs and 463 individuals from previous research, we obtained 241 survey responses. After accounting for incomplete responses where participants did not complete all of the FTP, goal setting, and outcome items, the population included 191 participants from 159 institutions, their geographic location and time in program are represented below in Figure 3.1. The time in program for these participants is presented in Figure 3.2.

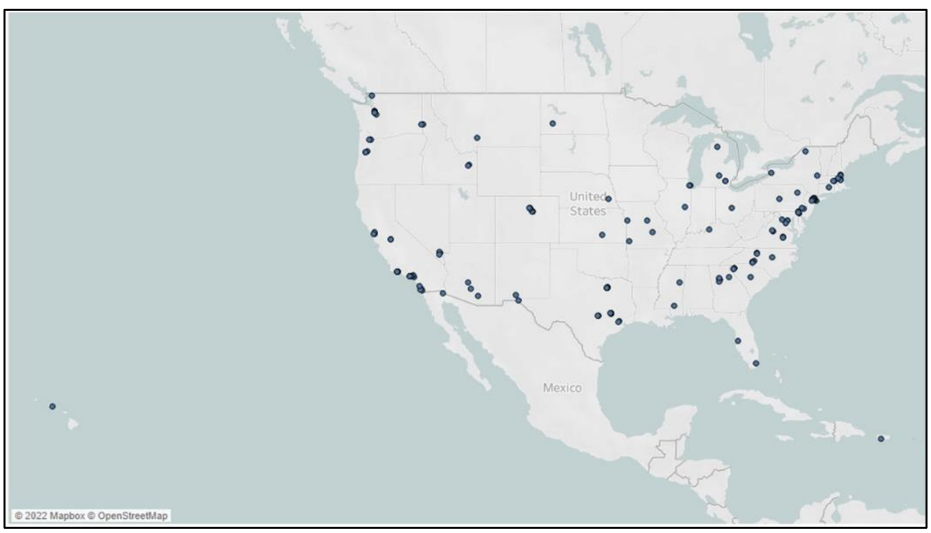

Figure 3.1 Map depicting where students were enrolled for their doctoral degree.

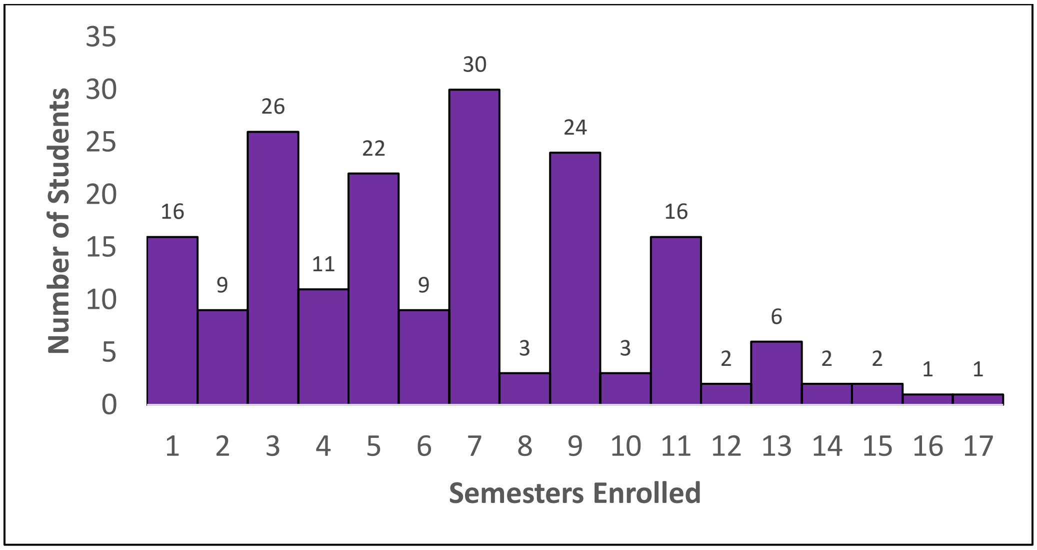

Figure 3.2 Time in program by semester for the participants in this analysis.

3.5.3. Survey Validation

3.5.3.1. Cognitive Interviews

Prior to distributing the survey, I conducted five cognitive interviews with engineering doctoral students separate from the sample described above to measure the face validity of the survey items and make any necessary changes (Willis, 2004). These interviews lasted 30-60-minutes where participants considered each question and rated them on a five-point scale one being “Very Unclear” and five being “Very Clear”. Any items that were rated as three or less were discussed. As the interviewer I also asked if there were any questions that they wanted to talk about or that required significant thought when answering. Throughout the cognitive interviews participants were given the opportunity to make suggestions on how to change questions based on what I described as the question trying to measure. During the fourth and fifth interview no new suggestions were made that changed the survey, indicating that the questions were sufficiently clear and through discussion had strong face validity.

3.5.3.2. *Initial Scale Item and Development*

To validate the scale items I tested for normality, internal consistency, measuring sample adequacy, and whether the variables are orthogonal (i.e. not correlated) to determine how reliable the items are and how suited the data is for factor analysis and exploratory structural equation modeling using R (R Core Team, 2021).

Cronbach alpha is a measure of internal consistency, a measure of reliability. The alpha value represents the extent to which a subset of items measures the same thing. The acceptable cutoff values for Cronbach alpha coefficients are 0.7-0.9 (Hair, 1998), where a higher number represents more internal consistency.

Skew and kurtosis are a measure of how closely related the distribution is to the normal distribution and guide whether or not parametric or non-parametric statistical tests are required. In their relation to the normal distribution, skewness is related to how symmetric the distribution of the data is, while kurtosis is related to how closely the outliers of the data follow a normal distribution (i.e., 66% of the data is within 2 standard deviations of the mean value). Cutoff values for skew and kurtosis are |2| and |7| respectively (Curran et al., 1996).

The Kaiser-Meyer-Olkin test is used to evaluate how suitable your data is for factor analysis by providing the measuring sampling adequacy for each item and the complete model. Measuring sample adequacy is related to the proportion of the variance that is not shared by all items. The reference values for measuring sample adequacy are unacceptable (<0.50), miserable (0.50-0.59), mediocre (0.60-0.69), middling (0.70-0.79), meritorious (0.80-0.89), and marvelous (0.90-1.00) (Kaiser, 1974). The closer the measuring sample adequacy is to 0 the more widespread the correlations for the item or model, making factor analysis insignificant.

Bartlett's test of sphericity tests whether the variables are orthogonal by comparing the correlation to the identity matrix (i.e., a matrix where variables are only correlated with themselves) (Bartlett, 1954). A significant result from the approximated chi-square value and p-value indicates that the data is not an identity matrix and is well-suited for factor analysis.

3.5.4. Quantitative Survey

Our survey included 70 items, with 42 items focusing on students' motivations and their perceptions of graduating and being prepared for a future career. The remaining 28 items collected their demographic information. Anchored numeric on a scale of 5, where only the endpoints of 1 and 5 have descriptors, was used to support the assumption of equal distance between response values. In this section, I present the survey items followed by the measures of reliability and validity for these items. The full survey can be found in Appendix C.

3.5.4.1. Future Time Perspective Items

Participants responded to 16 items measuring their future time perspective (Tsugawa, 2019). Example items include, "My future career influences what I want to learn in my graduate program.", "I can see myself in my ideal career in the future.", and "I will use the information I learn in my graduate program in the future." Participants rated each item on a Likert scale from *strongly disagree* (1) to *strongly agree* (5). The mean of these items represents how students' future-oriented goals influence decision-making in the present. The items demonstrated good internal reliability (α=0.75).

3.5.4.2. Goal Setting Items

Participants responded to 18 newly developed items measuring their goal-setting attitudes. Example items include, “My advisor updates me regularly concerning my progress.”, “My graduate program treats all graduate students equitably.”, and “I have a strategy for attaining my career goal(s).” Participants rated each item on a Likert scale from *strongly disagree* (1) to *strongly agree* (5). The mean of these items represents students' strategies and support structures that are a product of their graduate program. The items demonstrated very good internal reliability (α=0.87).

3.5.4.3. Perceptions of Career Preparation and Persistence Items

Participants responded to 8 novel items developed as part of this work that measured students' perceptions of preparedness for their future careers and perceptions of task and degree persistence. Example items include, “My time in this doctoral program is preparing me for my future career.”, “In my graduate program, I keep trying even when things are not going well.”, and “I will graduate from my program with a doctoral degree.”. Participants rated each item on a scale from *strongly disagree* (1) to *strongly agree* (5). The mean of these items represents how students perceive they are being prepared for their future careers and will persist in their program. One item was removed (Persist_3; In my graduate program, I work harder after failure.) due to low internal consistency. The final subset of 7 items demonstrated very good internal reliability (α=0.81).

3.5.4.4. Demographic Items

Participants indicated gender identity by selecting one or more of eight options, with a write-in option available (woman, man, genderqueer/agender). Participants indicated their race or ethnicity by selecting one or more of nine categories with a write-in option (American Indian or Alaska Native, Asian, Black or African American, Hispanic, Latino/Latina/Latinx, or Spanish origin, Middle Eastern or North African, Native Hawaiian or Other Pacific Islander, White, another race or ethnicity not listed above). The demographics of participants are presented below in Table 3.2. Another demographic characteristic included in our sample was: living with a disability (n = 42).

Table 3.2 Participant demographics for race/ethnicity and gender

	No Response	Genderqueer/Agender	Man	Woman	Prefer not to say
No Response	3	0	2	0	0
Multiracial	0	0	8	6	0
American Indian or Alaska Native	0	1	0	1	0
Asian	0	2	33	23	2
Black or African American	0	0	2	3	0
Hispanic, Latin, or Spanish Origin	0	0	5	4	0
Middle Eastern or North African	0	0	3	1	0
Other Not Listed	0	0	1	1	0
White	0	4	33	50	3

3.5.5. Limitations

The work presented in this chapter had two main limitations. Despite efforts to recruit a large sample of doctoral students, as has occurred in previous work, I was not able to obtain a large enough sample for granular analyses. Therefore, a more traditional exploratory and confirmatory factor analysis design could not be conducted due to the small sample size. We address this limitation by leveraging ESEM to handle the smaller response rate and more closely mirror the larger variance present in social science data. The second limitation generated by the smaller sample size is the inability to meaningfully conduct measurement invariance to understand how the models fit for various intersectional identities and programmatic structures. Future work will involve semi-structured interviews to explore the relationships presented in the ESEM.

3.6. Data Analysis and Results

Using R (R Core Team, 2021) an ESEM was conducted to examine the relationships between 42 items that measured students' motivation, goal setting, and perceptions of their future. The full R code used for cleaning and analysis can be found in Appendix D. The process involved conducting an EFA to create the initial factor structure. The goal of the EFA is to understand which survey items measure a shared phenomenon without any *a priori* assumptions (RQ1). After validating a three-factor model, I next conducted ESEM to determine the relationships between the factors and the outcome variables (i.e., perceived career preparation and perceived program persistence) (RQ2).

Before unpacking the results, I note that ESEM differs from structural equation modeling in a few distinct ways. In ESEM, instead of fixing most or all cross-loadings (i.e., items correlation to multiple factors) to zero based on a specified factor structure, ESEM minimizes cross-loadings based on an expected number of factors (Asparouhov & Muthén, 2009). This allows for more tolerance of cross-loadings and is more closely related to real-world data. Further, I used the principal axis factor and oblique (Promax) rotation to identify the factor structure and a maximum likelihood estimation to examine the relationships between factors. Promax was chosen in this work because of its ability to handle highly correlated items and the high multicollinearity present in this data (Finch, 2006). A description of the survey validation and exploratory factor analysis is presented to answer research question 1 followed by the results of the exploratory structural equation model to address research question 2.

3.6.1. Exploratory Factor Analysis

With the 191 participant responses, I examined the descriptive statistics for all scale items, including means, standard deviations, ranges, skew and kurtosis, and bivariate correlations. All variables were normally distributed with skewness from -1.84 to 0.09 and kurtosis from 1.94 to 6.35. The bivariate correlations generally demonstrated moderate to small positive relationships. Three faculty and supervisor support items were removed for multicollinearity (FSS_4, "I get regular feedback concerning how I am performing in my program."; FSS_8, "My advisor helps me find the information necessary to perform well in my future career."; FSS_9, "My advisor is supportive when I face obstacles in my program."). One additional faculty and supervisor support item was removed for low measuring sampling adequacy (FSS_3, "I am told the negative aspects of my performance by my advisor.”), and one perception of program persistence item was removed for low internal consistency (Persist_3, “In my graduate program, I work harder after failure.”). The removed items are reported in Appendix E. The remaining items in the ESEM met criteria for the Kaiser-Meyer-Olkin and Bartlett’s Sphericity. Kaiser criterion and parallel analysis were used to identify the factor structure. Items with a factor loading of less than 0.40 or multicollinearity greater than 0.32 were eliminated. With an overall KMO statistic of 0.87, and Bartletts' test for sphericity (χ^2=3157.227, df=528, $p < 0.001$) rejection of the null hypothesis, suggests that the data is well-suited for factor analysis. Theory and scree plots, included below as Figure 3.3 suggested three factors. Interpreting the scree plot below there is a clear change in the slope at three factors. These factors are *career certainty*, *feedback and support,* and *interest in multiple futures.* Addressing research question 1, the existing FTP and goal-setting items grouped to form factors focused on students’ motivation derived from their certainty of a future career, the external motivation to the student provided by feedback and support, and the number of futures the student is considering.

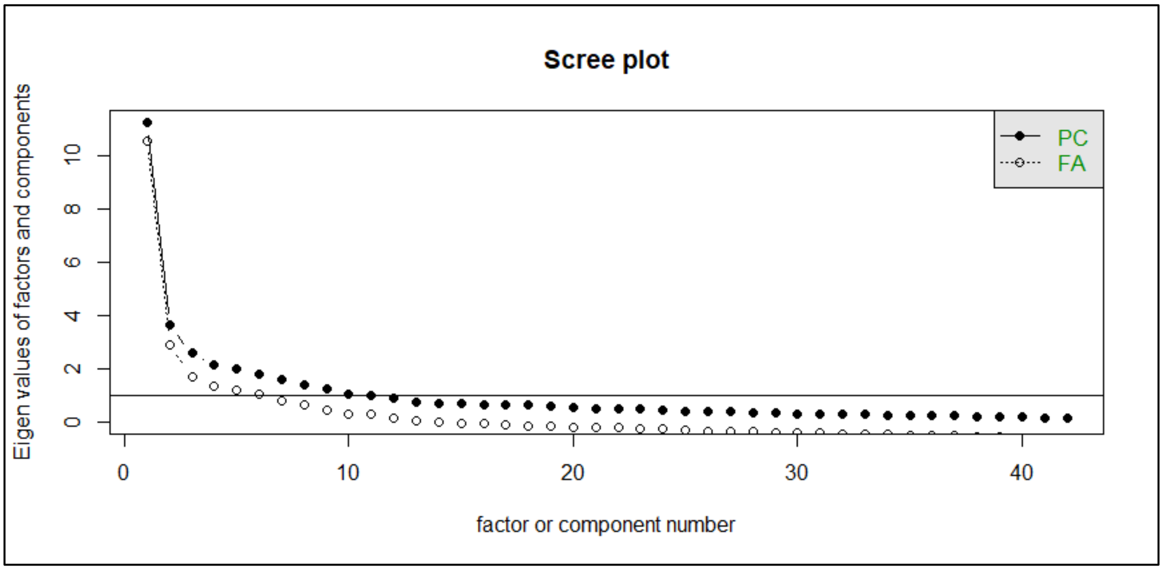

Figure 3.3 Scree plot of FTP and Goal Setting items

3.6.2. Exploratory Structural Equation Modeling

I fit the ESEM model to the outcome variables using minimum likelihood estimation and Promax rotation. The structural equation model leveraged the three input factors, *career certainty* (X1), *feedback and support* (X2), and *interest in multiple futures* (X3) as previously described above. The factor loadings and communalities (h^2), reported on a scale of 0 to 1, of these input factors are presented below in Table 3.3. Factor loadings represent the strength of the correlation between the item and the derived factor, where a 1 means they are highly correlated. Communality represents the amount of variance for an item that is explained by other items. An example would be if we measure participant confidence in getting a job upon graduation and note high communality for the item, the variance in this item could be mostly explained by another item asking students if they already have a job offer.

Table 3.3 Factor loadings (λ) and communalities (h^2) of the *Career Certainty, Feedback and Support, and Multiple Futures factors.*

Factor Name	**Items**	**Item Label**	λ_{X1}	λ_{X2}	λ_{X3}	h^2
Career Certainty	The career path I would find most rewarding is not realistic. (R)	FPS_1	0.45			0.27
Career Certainty	I can see myself in my ideal career in the future.	FPS_3	0.72			0.48
Career Certainty	I can get a job upon graduation.	NF_1	0.45			0.28
Career Certainty	I can get the job I desire upon graduation.	NF_3	0.59			0.42
Career Certainty	I think about my future career to determine which tasks to prioritize in my graduate program.	CC_1	0.62			0.38
Career Certainty	My future career influences what I want to learn in my graduate program.	CC_2	0.52			0.28
Career Certainty	My future career is an important consideration in how I decide to approach my dissertation project.	CC_3	0.42			0.18
Career Certainty	My future career goal(s) are important to me.	GC_1	0.68			0.44
Career Certainty	I do not care if I achieve my career goal(s). (R)	GC_2	0.44			0.18
Career Certainty	I am strongly committed to pursuing my career goal(s).	GC_3	0.73			0.49
Career Certainty	My graduate program will help me reach my future career goal(s).	OS_1	0.41			0.55
Career Certainty	I have a strategy for attaining my career goal(s).	Strat_1	0.71			0.47
Career Certainty	I reflect on the most suitable strategy to follow before taking action towards my career goal(s).	Strat_2	0.70			0.40

Factor Name	**Items**	**Item Label**	λ_{X1}	λ_{X2}	λ_{X3}	h^2
Career Certainty	I usually feel that I have an effective action plan for reaching my career goal(s).	Strat_3	0.66			0.43
Feedback and Support	My advisor updates me regularly concerning my progress.	FSS_1		0.62		0.51
Feedback and Support	I am told the positive aspects of my performance by my advisor.	FSS_2		0.83		0.60
Feedback and Support	In one-on-one meetings with my advisor, problem-solving is the focus.	FSS_5		0.84		0.65
Feedback and Support	My advisor encourages me to reach my future career goal(s).	FSS_7		0.77		0.61
Feedback and Support	My graduate program provides sufficient resources to help me prepare for my future career.	OS_2		0.48		0.41
Feedback and Support	My graduate program treats all graduate students equitably.	OS_3		0.46		0.41
Interest in multiple futures	I am interested in three or more future careers after graduating.	MF_1			0.70	0.49
Interest in multiple futures	There are multiple future careers I am interested in after graduating.	MF_2			0.78	0.59
Interest in multiple futures	I am only interested in one future career after graduating. (R)	MF_3			0.62	0.42
Interest in multiple futures	I imagine many career paths I can take depending on available opportunities when I graduate.	MF_4			0.62	0.41

FPS = Future Possible Self; NF = Near Future Job Attainment; CC = Career Commitment; PI = Perceived Instrumentality; GC = Goal Commitment; FSS = Faculty and Supervisor Support; OS = Organizational Support; Strat = Strategy; MF = Multiple Futures
(R)=Reverse coded

The input factors were then related to the outcome factors of *perceptions of career preparation* (Y1) and *perceptions of program persistence* (Y2). The factor loadings and communalities for these outcome factors are presented below in Table 3.4 to highlight the strength of the correlation to the derived factor and the amount of variance that could be explained by other items. Items not reported below in Tables 3.3 and 3.4 were removed due to not meeting the minimum required factor loading cutoff of 0.4, and are included in Appendix E.

Table 3.4 Loadings and communalities (h^2) of the *Perceptions of Career Preparation* and *Perceptions of Program Persistence.*

Factor name	**Items**	**Item Label**	λ_{Y1}	λ_{Y2}	h^2
Perceptions of Career Preparation	I will be prepared for the career I want when I complete my doctoral degree.	CP_1	0.68		0.44
Perceptions of Career Preparation	I will be able to effectively complete the tasks required for my future career.	CP_2	0.78		0.56
Perceptions of Career Preparation	I am taking steps to prepare for the career I want in the future.	CP_3	0.63		0.52
Perceptions of Career Preparation	My time in this doctoral program is preparing me for my future career.	CP_4	0.72		0.63
Perceptions of Program Persistence	I strive to achieve my goal(s) in my program even when I'm faced with obstacles.	Persist_1		0.75	0.59
Perceptions of Program Persistence	In my graduate program, I keep trying even when things are not going well.	Persist_2		0.76	0.50

CP = Perceptions of Career Preparation; Persist = Perceptions of Program Persistence

The full structural equation model, Figure 3.4., shows the relationships between these five factors. Addressing research question 2 the model indicates that *career certainty* was strongly related to *perceived career preparation* and weakly related to perceived program persistence. *feedback and support* was weakly related to the outcome of perceived career preparation, and not related to perceived program persistence. *Interest in multiple futures* was not related to either of the outcome factors. There was additionally significant multicollinearity between the input factors of *career certainty* and *feedback and support.*

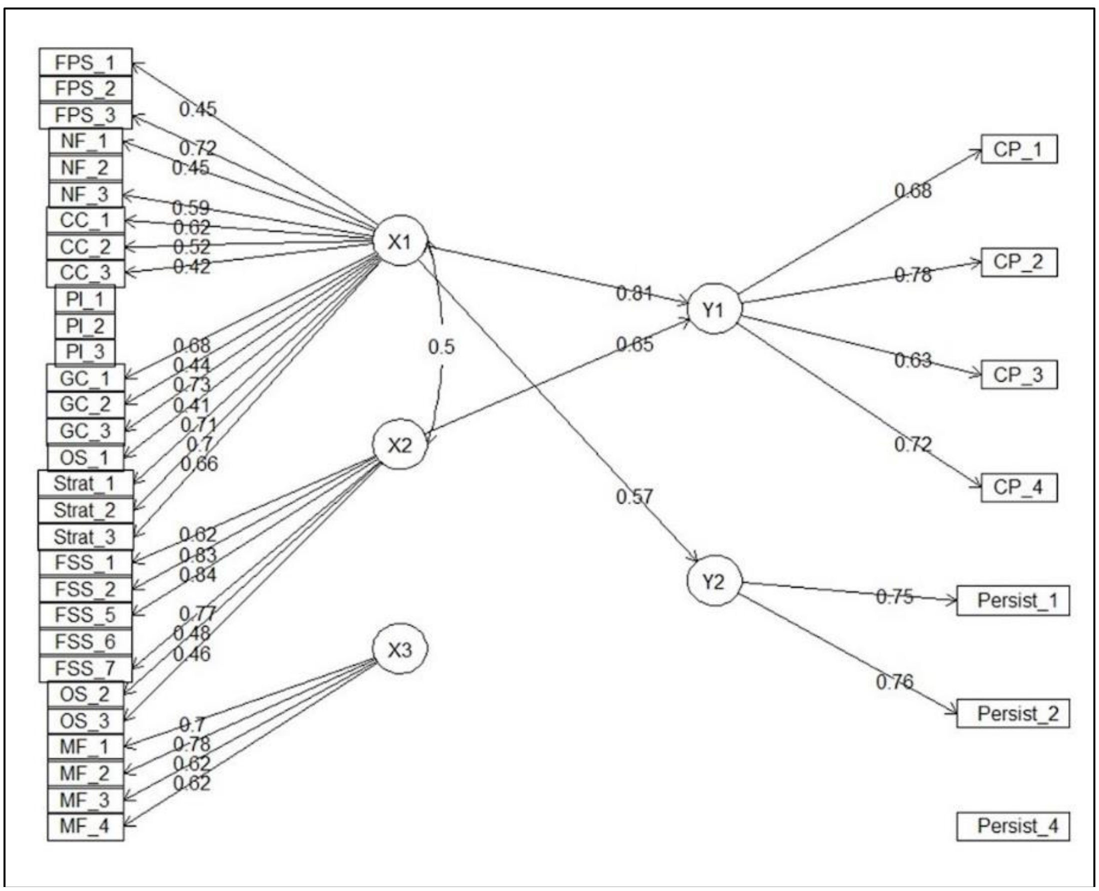

Figure 3.4 Exploratory structural equation model with career certainty (X1), feedback and support (X2), and interest in multiple futures (X3) relating to outcome factors of perceptions of career preparation (Y1) and perceptions of program persistence (Y2).

FPS = Future Possible Self; NF = Near Future Job Attainment; CC = Career Commitment; PI = Perceived Instrumentality; GC = Goal Commitment; FSS = Faculty and Supervisor Support; OS = Organizational Support; Strat = Strategy; MF = Multiple Futures; CP = Perceptions of Career Preparation; Persist = Perceptions of Program Persistence

3.7. Discussion

The splitting of individual and programmatic factors when integrating FTP and goal setting indicates that a gap did exist in using FTP alone to examine external career motivation. Since students are a product of their educational environment, particularly due to the apprenticeship model applied in graduate education (Newstetter, 2005), a factor that examines their environment can help expand our understanding of doctoral student development. Guided by previous research on doctoral student experiences the ability to examine both levels simultaneously is important for students with underrepresented identities (Bahnson et al., 2021; Bahnson, Hope, et al., 2022; Burt et al., 2019, 2020).

When considering the relationships between students' future time perspective, goal setting, and perceptions of the future the existing constructs blended into individual and organizational level factors. These factors are supported by existing research examining the individual (Burt, 2020; Kajfez & Matusovich, 2017; Kirn & Benson, 2018; McGee et al., 2019; H. L. Perkins et al., 2018; Perkins & Tsugawa, 2017; Tsugawa et al., 2017) and program level (Allum et al., 2014; Bahnson, Satterfield, et al., 2022; Crede & Borrego, 2012; Noy & Ray, 2012) influences on students experiences. Aligned with previous research on engineering doctoral students' future time perspective (Tsugawa, 2019), the weak relationships between the perceived instrumentality items and the career certainty factor is expected. This is due to the career certainty factor focusing on the domain-specific level of an engineering career, rather than the task-specific level of how the utility of tasks in the present relates to their future career (Husman & Lens, 1999; Shell & Husman, 2001). At the program level, the focus on advisor feedback was to be expected based on existing research (Allum et al., 2014; Bahnson et al., 2021; Burt et al., 2018; McGee et al., 2022), however, the lack of a relationship between feedback and support and the outcome factor of perceived program persistence was unexpected.

How engineering doctoral students think about their future and are motivated by their future goals has been previously explored as it relates to student experiences in existing research and CHAPTER 2 (Artiles & Matusovich, 2020; Kajfez & Matusovich, 2017; H. L. Perkins et al., 2018), however, *career certainty* also includes their commitment to and plans to reach their future goals. Further, the *career certainty* factor's relationship to perceived program persistence aligns with attrition and completion work at the undergraduate level showing that students who are motivated and have future goals are more likely to persist (Tsugawa, 2019; Kirn & Benson, 2013; Kirn & Benson, 2018). The strength of the relationship between students' future goals and their persistence supports that degree completion is a complex and multifaceted process, and indicates that other aspects, such as intersectional identities are key in making sense of this process (Bahnson et al., 2023).

The lack of a relationship between feedback and support and perceived program persistence can be attributed to the skew in response to “I will complete my doctoral degree” (Persist_4). While this single-item measure has proven sufficient in prior research on underrepresented students at high risk of leaving (Bahnson, Hope, et al., 2022); in this study, there was a skew towards students reporting they will complete their degree. I attribute this, in part, to the cultural stigma of failure on the part of students who do not think that they will persist (Berdanier et al., 2020; Zerbe et al., 2023). With 87% of participants agreeing (n=131 strongly agree; n=36 agree) they will complete their degree, the efficacy of this question was reduced. Without this question, the factor of perceived program persistence was very individual-focused for the remaining items. These results provide further evidence for research to look beyond faculty advisor feedback and support for students' completion intentions. For example, there are other people such as peers, family, and external professional mentors (e.g., internship supervisors) that contribute to student persistence (Crede & Borrego, 2012; Golde, 2005; Holloway et al., 2022; Louis et al., 2007). Further, this work supports research on students' experiences, how they see themselves, how other people see them, and the general graduate student environment as they relate to student completion intentions (Bahnson et al., 2023). Because while this work focuses on career preparation, the development and preparation for a future career facilitated in a graduate program are potentially less relevant if students do not complete their degree.

Focusing on areas of the survey that dropped out of the model, negatively worded Factor and Supervisor Support (FSS) and Interest in Multiple Futures (MF) items were not significant in this model. The negatively worded Faculty and Supervisor Support (“FSS_3: I am told the negative aspects of my performance by my advisor.” and “FSS_6: In one-on-one meetings with my advisor, criticism is the focus.”) are hypothesized to have not been correlated with any other items due to the lack of regular one on one meetings for students who have strong negative advisor relationships. The Interest in

Multiple Futures (MF) set of questions not being related to the outcomes measures was likely due to that the number of goals students have does not reduce their perceived career preparation or confidence in completing their degree. In previous work students with multiple career interests more readily noted feeling prepared for a future career than those with fewer career interests (CHAPTER 2)

Overall, the results of this model show that students' specific goals and the advice they receive are crucial to feeling prepared for a future career. Furthermore as shown in CHAPTER 2, when students are not provided with adequate information, resources, and feedback (Allum et al., 2014; Satterfield et al., 2022) their ability to prepare for their future is additionally undercut. With the strong relationships feedback and support and perceptions of career preparation; students' preparation for their future careers is subject to decisions by students and faculty advisors.

3.8. Implications

Engineering doctoral students have been shown to struggle to make plans beyond graduation and often do not plan for their future career goals beyond applying a name to the career they want to pursue (e.g., research scientist) (Satterfield et al., 2023). When students are uncertain about the pathway to achieving their future goals it becomes exceedingly difficult to take actionable steps toward their career and remain motivated while in graduate school (CHAPTER 2). Supporting the variety of roles and expectations students is important for development while in graduate school (Kajfez & McNair, 2014) and now it is clear that fostering students' development of goals and examining the feedback and support that students receive are key to influencing students' perceived career preparation throughout their graduate program.

As students enter graduate school there are many decisions to be made, however, the results of this work further show the importance of selecting an appropriate advisor and support system (e.g., peers) (Artiles et al., 2023; Artiles & Matusovich, 2020). Previously the focus has been on how different types of advising impact students' navigation of graduate school (Bahnson et al., 2021, 2023; Berdanier et al., 2020; Burt et al., 2019), and now there is also evidence that this decision has ramifications beyond graduation as students prepare for the next phase of their career path. This paper makes a data-driven argument for students to have opportunities to explore their future careers while in graduate school and to seek out appropriate advising that aligns with their future career interests. Seeking out opportunities to rotate through research labs to interact with faculty advisors and future research peers is important for students as this decision will have a significant influence on their future career-aligned development.

Shifting to faculty advisors and graduate programs, the results that students' career certainty influences perceived persistence and career preparation do guide areas for intervention. The finding that students' career preparation has a stronger relationship to career outcomes than programmatic further problematizes bad advising relationships beyond the impact on student mental health and development of identity (Artiles & Matusovich, 2020; Kajfez & Matusovich, 2017). When faculty advisors are neglectful or discriminatory toward their students, affects not only the students' time in the program (Bahnson et al., 2021; Burt et al., 2019) but the pedigree of the institution from the perspective of employers. For institutions that are invested in industry endowments and research partnerships, this has the potential to sour future relations.

3.9. Conclusion

The results of this work show that students' certainty about their future careers was related to their perceptions of career preparation and perceptions of program persistence. Meanwhile, positive feedback from their faculty advisor was shown to be related to students perceiving themselves as prepared for a future career. While students' relationship with their advisors is shown to be related to students' intentions to complete their degree, this work indicates that feedback on progress and support with facing obstacles are ways in which faculty advisors can support their students' professional development. The next steps in this research will involve qualitatively exploring how faculty advisor feedback, support, and provision of information are related to students' perceptions of career preparation.

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4. Examining the relationship between feedback and support from various sources and perceived career preparation for engineering doctoral students

4.1. Introduction

Engineering doctoral students are often given feedback and training that aligns with academic careers, despite evidence supporting that nearly three out of four (71.6%) students are primarily interested in careers outside of academia (National Center for Science and Engineering Statistics, Survey of Earned Doctorates., 2022). Existing research has examined students' experiences in graduate education related to intentions to complete their degree (Bahnson, Satterfield, et al. 2022; Bahnson, Wyer, et al. 2021), the interest of students in various career paths (Choe & Borrego, 2019; Main 2018), and motivation from tasks and experiences that align with academia careers (Kajfez and McNair 2014; Tsugawa et al. 2017); a gap exists at the intersection of the feedback and support students receive related to their desired future careers. Guided by previous results indicating a relationship between feedback and support and perceptions of career preparation (CHAPTER 3), I aim to connect existing research on general experiences within graduate education (Zerbe, Sallai, and Berdanier 2023; Sallai et al. 2022; Bahnson, Satterfield, et al. 2022; Tsugawa et al. 2017; Kajfez and McNair 2014; Main 2018; Artiles and Matusovich 2020; Bahnson, Perkins, et al. 2021) and negative advising experiences (Sowell, Allum, and Okahana 2015; Barnes 2009; Noy and Ray 2012; Bahnson, Wyer, et al. 2021) to students professional development. Through students' narratives I will specifically examine how feedback and support internal and external to engineering doctoral programs influences how students think about and feel prepared for their future careers.

4.2. Advisor Relationship and Support Structures

In previous qualitative work, engineering doctoral students articulated that they often struggled to make plans for what they wanted to do for a career after graduating with their advanced degree. Students mentioned not having future career interests, plans for those career paths or support towards preparing for that career (CHAPTER 2). Further analysis of how students thought about, made plans, and were supported in their career goals using exploratory structural equation modeling indicated that faculty advisor feedback and support for engineering doctoral students is predictive of students feeling prepared for the future career they want to pursue (CHAPTER 3). While the primary focus of the sources of feedback and support will be on faculty advisors, existing research supports examining peers, professional contacts, and other members of their social network (Crede and Borrego 2012; Golde 2005; Holloway et al. 2022; Louis et al. 2007)

The examination of faculty advisors is supported by existing research of varying paradigms supports the centrality of faculty advisors on students' progress, experiences, and development of a social network (Berdanier et al. 2020; Crede and Borrego 2012; Barnes 2009; Gardner 2008; Main 2018; Bahnson et al. 2023; Artiles and Matusovich 2020). One key example within graduate education is the Graduate Attrition Decision (GrAD) model which indicated how central advisor relationships can be to most students' experiences. Additionally similar findings have qualitatively shown that students’ main source of professional development was their faculty advisor or informal mentors (Barnes

2009; Bahnson et al. 2023; Burt 2020; Noy and Ray 2012; Allum, Kent, and McCarthy 2014). However, due to many faculty's experiences and social networks residing within academia (Allum, Kent, and McCarthy 2014), the prevalence of discrimination from faculty advisors (16% of students) (Bahnson, Wyer, et al. 2021), and the struggle for underrepresented students to find role models (Burt, Williams, and Palmer 2019; Burt 2020; Noy and Ray 2012), other sources of mentorship and support have been found to be important.

Looking beyond their faculty advisor, other people that students in existing research point to as sources of professional development are their peers (Crede and Borrego 2012; Golde 2005; Holloway et al. 2022), professionals in their field (Holloway et al. 2022), and program-based professional development events (e.g., guest speakers, career fair) (Louis et al. 2007). While peer support has traditionally been connected to persistence to a degree (Gardner 2010), it has also been shown to support students' professional development (Crede and Borrego 2012). Peers are particularly important in larger research groups and labs where more senior students or postdocs take on the role of primary advisor for feedback and training (Crede and Borrego 2012) or where peers have previously held positions that are tangential to the students desired future career.

Considering the centrality of faculty advisors on students' experiences, and influence of affinity groups, peers, and professional contacts; the predictive relationship of feedback and support from various sources on students' perceived future career preparation has the potential to provide data-driven change related to students' ability to find career-aligned feedback and support. To explore the predictive relationship, we use a phenomenological approach to understand how students perceive different groups or individuals as preparing them for their desired future careers.

4.3. Research Questions

Making sense of how the feedback and support that engineering doctoral students receive in their graduate program allows them to not only persist but to leave their graduate program feeling prepared for their future careers is key to realigning graduate education for non-academic careers. Thus, to examine the ways students' feedback from their advisor influences their perceptions of career preparation, I seek to answer the following research questions.

1. In what ways does faculty advisor feedback and support influence students' perceptions of career preparation?

4.4. Theory

Goal setting is a theoretical framework that was inductively developed in 1990 by Locke and Latham and has been used by researchers to examine the relationship between demands (i.e., prescribed goals) and performance, with several mediators and moderators of the relationship leading to the outcome variable, satisfaction (Locke and Latham 1990; Locke et al. 2015). Recently, I recontextualized the existing theory to be applicable to engineering doctoral student populations (Satterfield et al. 2022). The constructs, refined and piloted through cognitive interviews specifically measure *career strategy, goal commitment, faculty and supervisor support, and organizational support* within graduate education. These constructs and their definitions are found in Table 4.1.

Table 4.1 Theoretical constructs and definitions which guide this work (Satterfield et al. 2022).

Theoretical Framework	Construct	Description
Goal setting	Career strategy	The plan that an individual has to achieve their desired career.
Goal Setting	Faculty and supervisor support	The support an individual receives from a faculty advisor or mentor, examples include but are not limited to planning meetings, interest in a future career, and sharing opportunities.
Goal Setting	Goal commitment	The ways in which students talk about their desire to see the career described achieved.
Goal Setting	Organizational support	The support that an individual receives from their program or department such as professional development and internship opportunities.

The goal-setting constructs described above were integrated alongside existing future-oriented motivation theory, future time perspective (FTP) (Satterfield et al., 2022). FTP examines how future goals, in this context careers, motivate individuals to complete current tasks and intermediate goals (Hilpert et al., 2012; Husman & Lens, 1999; Kirn & Benson, 2018; McGough Spence et al., 2022; Nelson et al., 2015, Puruhito, 2018). Previous research on students FTP has shown that as students' ability to conceptualize their goals, and perceptions of how tasks relate to their future career increase, they were more likely to persist on tasks (Kirn & Benson, 2018; Tsugawa, 2019).

Using the integrated goal setting and FTP measures I explored their relationship to students' perceived persistence and career preparation within an exploratory structural equation model (CHAPTER 3). One of the relationships that arose from this model was that faculty and supervisor support was predictive of how prepared for future careers students perceive they are. I choose to explore this specific relationship in more detail because despite students' career certainty also being predictive as shown in CHAPTER 3, the graduate education system can influence and modify the feedback and support systems for students more readily than students career interests.

4.5. Methods

4.5.1. Positionality

Author 1: I am a white man from a nuclear family who has a technical background in chemical engineering. My experiences pursuing two graduate degrees simultaneously with two different advisors inform my approach to understanding graduate students' experiences and the ways they are motivated by their own goals and goals encouraged by others. I apply a pragmatic approach to my research and apply the tools and methods that align best with the design of my research. For this chapter my positionality as a pragmatist using interpretive frameworks required me to consider my own advising, and professional development beliefs throughout the process. Further, as an engineering doctoral student whose own career plans were undergoing change and was actively applying for jobs, I used member checking and memoing to reduce my personal influence on engineering doctoral students' considerations of their future. Finally, to reduce my interpretive bias I leverage thematic analysis as a methodology to prioritize participant voice and words to convey their experiences.

4.5.2. Data Collection

Participants were randomly selected from the sample used in generating the exploratory structural equation model presented in CHAPTER 3. Guided by best practices from Braun and Clarke (2006), I collected 12 semi-structured interviews with engineering doctoral students related to their perceptions of career preparation and what contributed to feeling prepared or unprepared for their desired future careers. Process reliability was ensured by having only one researcher coding all the interviews, ensuring that the approach was used across the collection of the data (Walther et al. 2017). Participant details are presented in Table 4.2., where 75% of the sample was female (n = 9), 25% were international students (n = 3), multiple disciplines are represented, and 50% were interested in industry careers (n = 6) as opposed to 25% in academic careers (n=3). The racial and ethnic identities represented include Asian (n = 2), Hispanic, Latino/Latina/LatinE, or Spanish Origin (n = 2), and White (n = 8). Race and ethnicity data are not connected to specific participants to help protect confidentiality. Interviews ranged from 30 to 72 minutes, with the average being 46 minutes. Sample questions include "What career(s) are you interested in after graduation" and "What role had your advisor played in preparing you for [CAREER]?". The full interview protocol can be found in Appendix F.

Table 4.2 Participant major, time in program, primary career interest, and self-reported perceptions of career preparation.

Pseudonym	Major	Gender	Time in Program	Primary Career Interest	Completed Milestone
Ash	Civil Engineering	Woman	2.5 years	Academia	None
Blake	Agricultural Engineering	Woman	3.5 years	Government	Qualifying Exam
Drew	Biomedical Engineering	Woman	4.5 years	Industry	None
Em	Engineering Education	Woman	3.5 years	Industry	Comprehensive Exam
Hayden	Aerospace Engineering	Woman	7 years	Government	Dissertation Defense
Jordan	Engineering Education	Woman	4.5 years	Academia	Qualifying Exam
Riley	Environmental Engineering	Woman	2.5 years	Government	None
Rory	Mechanical Engineering	Man	3 years	Industry	Comprehensive Exam
Sam	Biomedical Engineering	Woman	3.5 years	Industry	None
Spencer	Human Computing Interaction	Man	3.5 years	Industry	Comprehensive Exam
Taylor	Biomedical Engineering	Man	5.5 years	Industry	Comprehensive Exam
Tsubasa	Industrial Engineering	Woman	3.5 years	Academia	Qualifying Exam

4.5.3. Data Analysis

Data analysis consisted of three passes through the data guided by thematic analysis. The six-step process of thematic analysis is to 1) familiarize yourself with the data, 2) generate initial codes, 3) search for themes, 4) review themes, 5) define and name themes, and 6) write-up the results (Braun & Clarke, 2006). The interviews were audio recorded and transcribed using the machine learning software, Otter.ai. The first pass was to remove any transcription errors and become familiar with the data. Due to having an existing codebook I deviated by allowing the codebook to guide my generation of initial codes in the data. The existing codebook is presented in Table 4.3. (Satterfield et al. 2022).

Table 4.3 Qualitative codebook leveraged in thematic analysis and developed in previous work (Satterfield et al. 2022).

Qualitative Code	Definition	Example
Advisor Relationship	Description of how students interact with their advisor and the role advisor has for students (e.g., mentor, friend, adversary, obstacle).	*Yeah, probably like obstacle. At this point. I think he would like it to be further towards friend and it probably even was at some point. Last semester did not go great. But I- my impression of that was he just stopped talking to me. And when I asked came about it in January he-his response was, "That was me not being friends anymore. That was me just being your advisor." To which I was like, "But you didn't do any advising. And so, to me, that was a-you disappeared? You stopped participating." (Taylor)*
Faculty Advisor Support	Ways in which students feel that their advisor is or is not supporting their future career goals and navigation of their graduate program.	*Yeah, she will send, like, if she sees any interesting like fellowships, or anything she'd like, she thinks we might be interested in, she sends them on to us, either via email, or in the slack. She's always, like, will write us a letter of recommendation or look over*

Qualitative Code	Definition	Example
		our application to things? Yeah, and she always makes it clear, like, I'm not saying you have to apply for this fellowship. If that's not what interests you, I just thought, you know, it might interest you. (Riley)
Organizational Support	Support that students receive from their graduate program or institution	*Through the institution, there is like a consultant-like a student-run consulting group… So I think that's like one resource that could have been very helpful because they connect students with local companies, and helps them troubleshoot tasks. (Drew)*
Ideal Support	Support students wish they had from their advisor, graduate program, or institution	*I suppose the ideal advisor would be more aware of us students. And so kind of, ideally, always passing along any kind of relevant information or opportunities for the students. I think maybe another thing is to expand the student network by connecting them with, you know, contacts that could be, you know, very resourceful in, I don't know, I guess, connecting them to that future job. (Drew)*
Other Sources of Support	Individuals or programs who support the student such as peers, family, spouses, or external mentors beyond formal advisors, graduate program, or institution.	*I mean, my family is an insanely big part of that. In that they have helped me a lot with writing and checking and all this kind of stuff, which many people do not have the luxury of that. (Spencer)*
Perceived Career Preparation	The ways in which students feel they are or are not prepared for their future career(s) of interest.	*I think it kind of goes back to how my experience has been kind of like wide open in terms of getting to write grants and develop a project and do hands-on research and modeling research, like kind of building my own case study, that's letting me build the skills in the areas that I think sound like they will be helpful to what I want to do [in the future]. (Blake)*

Following the process outlined by Braun and Clarke (2006) after initial coding I conducted a second pass through the data using line-by-line inductive coding to begin to understand the prevalence and variance in student responses to the questions. After completing the two coding passes, I searched for themes within the coding and gathered all data relevant to those themes. Two themes arose related to the feedback and support students receive related to their future careers delineated by source, *faculty advisor feedback and suppor*t, and *external advisor/peer feedback and support*. A third and final pass was conducted and used deductive line by line coding to understand the prevalence of these themes within and across participants.

Once the coding process was done, I met with a motivation and engineering education expert to discuss the results of the analysis and improve the reliability and presentation of the findings. Discussing the results served to improve the communicative validity as recommended by Walther et al. (2017). After discussing the results, I concluded the analysis by writing up the themes as presented in this chapter and providing necessary context to help readers make sense of the experiences and relation to student's perceptions of career preparation.

4.5.4. Limitations

The results of this work represent only a subset of the engineering population and highlight rich transferable findings for those who all with the participants included in the sample. Within a field that is traditionally white and male, the sample presented is predominantly women. While these results provide important insight into the future-oriented thinking and career preparation process for women in engineering. The results of this work are also limited due to the self-selection bias of students interested in talking about their future goals and does not include students who had no future goals, making the results of this work transferable to students who have future goals.

4.6. Results

In talking about their perceptions of career preparation and what influenced these feelings students discussed the sources of career preparation within two themes. The first theme focused on how students talked about feedback and support provided by their faculty advisors as it related to their preparation for a future career. The subthemes presented related to faculty advisor feedback and support directly answer the research question guiding this work. The large influence that faculty advisors have on their students are to be expected based on the exploratory structural equation model in CHAPTER 3, research on identity alignment between students and advisors (Burt, Williams, and Smith 2018; Bahnson, Satterfield, et al. 2022; Bahnson, Wyer, et al. 2021; McGee, Griffith, and Houston 2019), and the GrAD model of graduate student attrition (Berdanier et al. 2020). Specifically, the GrAD model of attrition depicts how interconnected faculty advisors are in students' experiences and training.

While the initial research question was addressed by students' discussion of how their faculty advisors can support or override students’ career interests, students also described how other members of their social networks and communities provided primary or supplemental career-related support. This second theme was responsive to the first theme, particularly in situations where faculty failed to adequately mentor and support their students. In these cases, peers, secondary mentors, or external groups, such as previous employers or national affinity organizations (e.g., SWE), stepped in to fill the gap to help students. One example of this support was peers who returned to academia or current professionals talking about the role titles and expectations that aligned with the students' future career interests. The evidence presented in the second theme advocates for multiple approaches to support students' professional development toward future career interests.

4.6.1. Theme 1: Faculty advisor influence on students' perceptions of career preparation

Guided by previous work which identified a relationship between perceived career preparation and feedback and support, students were asked about their primary advisor(s) and their subsequent influences with students' perceptions of career preparation. In response, students talked about their advisors in four distinct ways, presented as subthemes. The first subtheme was when students described that their advisor offered substantial support and could direct them about what to expect for future careers that aligned with the students' interests. The second subtheme was related to faculty advisors offering similar levels of support toward students' development as the previous subtheme but due to a lack of previous experience connected the students to experts in that career area. The third subtheme was how students talked about having more than one faculty advisor who directly oversaw their dissertation. They mentioned how while both advisors were supportive, there was some delegation where one advisor served as the dominant source of career knowledge and preparation aligned with their future career interests. Finally, the fourth subtheme was how students mentioned having an advisor who was not supportive, neglectful, or disinterested in students' needs towards career development and persistence, and undermined their career potential.

4.6.1.1. Theme 1a: Faculty advisors can direct students' career preparation by providing relevant feedback, information, and desiderata related to student's career interests.

When discussing the ways their advisor served as a major source of career preparation, one common experience that arose was having a supportive advisor who had previous experience or knowledge of the career path the student was interested in. The knowledge and experience allowed advisors to direct students' development and provide feedback that the student felt was accurate and relevant to their interests. These types of experiences were more common for students interested in academia. One example was mentioned by Ash, a second-year civil engineering PhD student interested in academic careers, her advisor specifically drew from their own experience when advising and ensured that Ash got teaching experience during her assistantship.

> *I've been very verbal that I do want to go into Professor position. So yeah, like I said, we've had long chat about the tenure process. And so he's giving me advice, like, if you want to get tenure, then you know, you should do X, Y, and Z, or this is why it's a good idea to like, keep all your papers and everything you've ever done in any awards, like really organized, because you're going to want all of this for your dossier or. Yeah, help like that has been, it's been good. He has given me some of his opinions on what it means to like recruit grad students or hire them. Or maybe even recruit and hire undergrads. He's given me some of his thought processes and how he does that. (Ash)*

Shared knowledge and direction were important for students whose primary career interests lie outside of academia, which often goes against the norms and training within graduate education.

Another important consideration aspect of advising described by these students was their advisors' mindset and approach to understanding their students' goals. Sam, a third-year biomedical engineering student interested in industry careers, discussed how her advisor believed that the purpose of a Ph.D. program is to provide students with additional training for the career their students want.

> *My advisor has always been very good in terms of like, their perspective is that they want to prepare you for your career. So your Ph.D. is a training preparation for your future career. And so they don't want to keep you behind just to do research for them. It's like it's all about your career. So I think that has been a really helpful perspective and frame to have. (Sam)*

Support of students' career development went beyond having previous experience and believing that the training in a doctoral program should align with student's career interests. Students also mentioned the opportunities and resources that they were provided that helped them to understand what they would need to know and be able to do in the future. Rory, a third-year mechanical engineering PhD student with an interest in industry-based careers, mentioned how understanding his advisor was and how they applied their previous experience to provide detailed feedback on communication within and outside academia.

> *I think, like I said they understand that my goals aren't to stay in this space [academia]. So they, they're able to kind of I guess, almost format, even the way that I present information in the right context. So they'll be able to say, "Okay, well, since this is going to this has been presented faculty, this is what it needs to look like but in the future for you. This is the way that someone you might see in a couple of years would want to see it." (Rory)*

This account from Rory exemplifies advisors who have previous experience with a career in the area students are interested in. Specifically for Rory this meant that his advisor could filter and direct Rory on how to present information to his dissertation committee as well as to supervisors within an industry-based career. This style of advising allows students to see how their academic skillset is directly transferable to other career pathways, and to further foster those skills. Like how Rory talks about his advisor recognizing his goals, the mindset of the advisor was key to directing students in ways that aligned with their career interests.

Communication of knowledge, feedback that aligns with students' interests, and support are important for faculty advisors to embed in their advising and mentoring. By embedding the practices of communicating knowledge and feedback aligned with students' career interest, faculty can help students develop in ways that align with their future careers during and beyond their graduate program. However, faculty cannot be experts in all potential career paths alongside their current responsibilities. Therefore, I next unpack advising approaches where faculty are supportive and instead of directing student developed based on previous experience, they connect students to others who are more knowledgeable about the field or roles that students are primarily interested in.

4.6.1.2. Theme 1b: Faculty advisors can connect students to other individuals who can support their career preparation.

Unlike the experiences expressed above, faculty advisors often have experiences that are misaligned with students' career interests (e.g., faculty had postdoc and tenure track faculty positions while student is interested in industry-based careers). In this subtheme students discussed their experiences being provided resources or connections to professionals with knowledge and experience that aligned with their career interests by their faculty advisor.

Riley, a second year environmental engineering Ph.D., is her advisor's first Ph.D. student and is primarily interested in careers in the government sector. While Riley's advisor has not held the role nor is an expert on government careers, she goes out of her way to support Riley by connecting her to other people and compiling potential career options.

> *[My advisor] puts together this whole booklet of all like, these resources for us and including, like career options. She sent me when I was-told her I was starting to think about Europe, she sent me some of the contacts she has in Europe and like the institutions they work for… And like, even before I like confirmed as a student in her group, I asked about career options, and she, created this list for me of like, you know, people who worked in academia versus policy versus, other areas, so I think she goes above and beyond to do our best to like, make sure we have all the information we need to make decisions. (Riley)*

For many students who are trying to find their footing while in graduate school these resources can be pivotal in feeling prepared and knowledgeable about career paths. Further this support and sharing of opportunities sets the expectation for students that they can explore these careers while in graduate school, which is crucial for developing interest and committing to future goals.

Contrary to the abundance of knowledge given to Riley, Drew, a fourth-year student in a biomedical engineering Ph.D. program with an interest in careers in the industry sector, was supported by having autonomy in exploring careers. Drew also expected, due to previously asking for professional connections from her advisor during an internship, that when the time came her faculty advisor could introduce her to other professionals. These connections could expand Drew’s professional network significantly when she had time to think about careers.

> *With regard to interaction with my advisor, maybe like, you know, I wanted to have a very clear idea of the expectations for when I am more likely to graduate. So, you know, that's something that I brought up during our meeting... And I'm sure that like, if I reached out to them, like asking for, "oh, do you know, any people that I could contact in industry? If they're working on maybe this disease area, or they're doing this, they're using this kind of technique? Do you know anyone that I could reach out to?" And I'm sure that they would, they've done that in the past… I think my advisor would be able to expand my network. That's not something that I have yet asked them. Just because I'm not actively searching for job right*

now. But I think that's definitely something that I will do once I am on the job market. (Drew)

For many students the reassurance that their advisor has the network, and they will have the opportunity later to connect with professionals in the field or roles that they want in the future reduces concerns, allows students to focus on being successful in their program.

Despite some faculty advisors presenting career opportunities, other advisors sometimes take a more neutral but supportive approach, as exemplified by Blake—who is in her third year of an agricultural engineering Ph.D. program with a primary interest in careers in government careers. She mentioned how her advisor is ensuring that she will be ready for academic careers, and also allows Blake to explore her careers of interest.

When I started to go on job visits or submit some application materials like then all of a sudden he's like, sharing a lot more insights and speaking to me a little more about the [tenure] process. The [government role] part... not so much. Yeah, he's not stood in the way but he's not offered any particular wisdom… I think he's been very helpful in like a, you can do whatever you want kind of way. And still being there as a grounding of like, "that does sound cool, but in my opinion that would slow you down too much" or "that's not super related." He is a good voice of reason. But not-does not exactly know the ins and outs of my area or what I want to do. (Blake)

For many students the act of prioritizing finishing their degree with taking advantage of opportunities is an ever-shifting balance. While the quote from Blake seems discouraging of opportunities, there is support in being the “grounding” voice that ensures that students are moving forward in ways that support degree completion and career preparation.

4.6.1.3. Theme 1c: Faculty advisors can distribute the workload of supporting students’ career preparation through co-advising relationships.

Having more than one advisor or chair of a dissertation committee provides the opportunity for students to have support on their progress to degree and perceptions of career preparation. In unpacking the structure and operationalization of co-advising relationships three types of experiences came forward from students. The first type of experience, described by Em, a third-year engineering education PhD student, is one in which the two advisors serve distinct roles. Her primary advisor supports her progress towards graduation and navigating academia, while her co-advisor provides additional mentoring and advice on non-academic future career pathways.

> *I'm grateful to have my co-advisor who's not in engineering education, he's in electrical engineering and, like, a different area completely, who does deal with industry. Like my, engineering education advisor is like, "Yeah, I can't help you [with industry careers]. Like I can help you get your dissertation done. I can help you get published. But I can't help you if you don't want want to go tenure track… [Meanwhile] my co-*advisor has *a lot of partnerships with, like, companies and stuff like that he a lot of his students do internships, a lot of his students, even his PhD students are industry bound... So I feel like with his help, I could navigate the application process, too. So I feel better equipped for like the [industry] position." (Em)*

The goal of many graduate programs is to prepare students to be successful in academia, thus most advisors are very helpful in completing milestones, getting published, and preparing for academic careers, but may not be helpful for industry careers. Meanwhile, having a co-advisor who provides meaningful contributions to the dissertation process, is in a different discipline, and can provide specific mentorship on how to prepare for industry careers is a favorable situation for the student and advisor. The student gets multiple perspectives while the advisors can delegate and support each other is advising as needed.

The second experience, described by Jordan a fourth-year engineering education PhD student interested in academic careers, talked about how her two advisors build on each other with different resources and mentorship.

> *My main advisor helped me become a TA, in different courses. And now, like, kinda like this, or like course, for me to actually collect my own thesis data, but also like, you know, in the process of teaching online. My co-advisor, because he's in engineering education, he is just working through my thesis also helped me to become more aware of how to be a good teacher… So they both adjust their teaching style, based on my level of understanding. So that also helped me realize and become more aware of how to be a better teacher. (Jordan)*

As described in this quote, faculty advisors are often role models, particularly for students who want to be faculty themselves in the future. Having multiple mentors who can not only source opportunities but also model what good teaching, research, and advising looks like helps students to understand what different manifestations of success look like.

In rare cases advisors sometimes must recuse themself due to being too closely involved in students' opportunities. This was the case for Tsubasa with her two co-advisors. She was interested in a tenure track faculty position, however, her primary advisor who often reviewed materials for her was on the search committee. In this case her advisor had to step back from her mentoring due to a conflict of interest.

> *It was kind of weird when I applied for this position, because she's on the search committee. And so she was like, I cannot provide help on writing a cover letter or a CV or anything, she had to recuse herself from all of that…. Um, so he, [my co-advisor], helped with writing the CV and writing the cover letter and getting the application packet and knowing like, what kind of stuff to do. And also with the, he kind of was like, "Okay, well, I can't tell you what they're going to ask in the interview. But like, these are the kinds of questions I've heard they ask, and that kind of thing." Um kind of coaching me like, this is you know, it's an interview, but it's also a professorship interview and like, it's different than necessarily an industry job and that kind of thing. (Tsubasa)*

In cases like this, the importance of having multiple sources of mentorship and support is key to student success when advisors have priorities or responsibilities that prevent them from fulfilling their regular role in supporting students.

4.6.1.4. Theme 1d: Faculty advisors can neglect students' career preparation needs by not prioritizing students or exhibiting exclusionary behaviors.

Faculty wanting to support and acknowledge students' goals is always the hope within academia. However, some faculty are focused more on research progress, their additional obligations, or are simply not interested in mentoring students. In some cases, this results in neglect toward the student. In this section I define neglect as not taking an interest in the student's career interests, intellectual development, or ability to reach graduation. To showcase examples where faculty are disinterested in their students and operate in ways that undermine and destroy student career prospects, I unpack three experiences.

Reflecting on his experience, Spencer, a third-year human computer interaction PhD student interested in industry careers, discusses how he has at times been without funding and was unsupported due to his advisor taking a job outside of academia. When asked about how his advisor has supported him, he said the following.

> *[His mentoring] I think I could summarize it with just negligence. It's likely negligence basically, that's how I feel. Negligence in not giving enough sources or books or knowledge required for doing this? Yeah, I mean, I think that that's, it's a lot, but that's it. (Spencer)*

While some faculty choose to leave in the middle of a student's graduate degree, the lack of a support network, reduced feedback, and resources to help understand the existing research is outright neglect on the part of the faculty. Further for international students during COVID, like Spencer, who have no local support network, the detriment of not having knowledge, resources, or a connection to the institution undermines their progress in many ways. One such way was expressed by Spencer related to his writing skills, he mentioned how his advisor never showed an interest in what Spender wanted to do, and only gave non-descript feedback requiring multiple iterations.

> *He has for sure. taught me basically through trial and error how to write because that's what we have been doing writing and how to do research. But I mean, he-he doesn't know what I'm going to-he has no idea I want [for a career]. That's how I'm going to put it. So it's been insanely difficult to help someone if you don't know what the person wants. (Spencer)*

For students in this situation there are often no other institutional resources to help keep them on track. Spencer mentioned talking to the Ombudsperson at his school who said there was nothing that could be done.

In other cases, when faculty advisors do not provide support or guidance the responsibility shifts to the student themself. One such example is when Taylor talks about how his advisor has not been helpful and does not put the time in to help his students. When asked about how his advisor has supported him, Taylor said the following.

> *[He is] pretty much not involved… In theory, we're starting weekly meetings again, but out of all 40 hours available per week for him to pick a time, the one hour that he picked, well we are on week three, and he has not come to two of them. (Taylor)*

The situation of neglect by not making time for student is one perspective on the problem of ineffective advising that does not support students' growth. However, extending this situation Taylor went on to share that when his advisor does provide information it goes beyond misaligned to flat out wrong.

Sometimes he comments on how like jobs work. And we're like, we have no other evidence that supports that theory of how the industry works. And we have lots of evidence to the contrary. (Taylor)

The undermining of students' future careers by pretending to have expertise where there is none is a problem. The misguided advice by advisors has the opportunity to put students into a position where they are left unemployed for months or forced to take on careers that do not align with their career interests, further obfuscating their career path as they move forward. Without proper guidance on how to prepare for their future career from their advisor students who lack a well-developed professional or support network, are more likely to be unprepared for their future career.

Beyond having advisors that ignore or do not provide resources, there are also advisors who actively work against students' goals and follow their own whims. For example, Hayden described how her advisor was outright discriminatory towards her.

He's made comments about me being like a female and how I'm supposed to work in like R2 or R3 institution in California or Texas or Florida because I'll receive a job immediately just because I'm a Hispanic person in a highly Hispanic-populated area and I'm supposed to bring diversity and empower their students and all this probably could be true but also nonsense coming from a racist guy. (Hayden)

Discrimination is a major problem within academia, and for many students these faculty can destroy or undermine their career prospects by neglecting opportunities that align with student interests and pressuring students into other careers.

> *I've told him, I don't want to go into academia, I wouldn't be opposed to a postdoc. But I would want to do a postdoc in these areas or with these people, if they do show up. And it's not like I'm asking to go to Caltech or something insane, but otherwise, I'm not interested in. He keeps telling me about becoming a teaching professor at some R3 University and the same talk over and over again. And I keep saying no, and he keeps sending me emails about applying to those places and forcing me to apply to them. And he's actually reached out to the department head in like, email team. "Oh, you're needing a teaching professor this girl just defended, she'll be good for it." And he gives the ideas if like, I'm interested in that I've talked to him where we have this sort of communication for him to go do it. But he hasn't spoken to me and the stuff I'm saying he's not listening. And so it's like, yeah. You know, I think it would have been better if he probably would have just ignored me and just been like, "No, I don't see you, you don't exist." (Hayden)*

Because Hayden wants to work in a national lab or other government careers, she mentioned how she wishes that her advisor had pretended she didn't exist rather than constantly undermining her autonomy and being outright racist in his discussion of her goals and where she should be aiming to work in the future. For students who due to limited support systems are reliant on their advisors for many aspects of their development and support, the inability to report or defend against these situations is detrimental to their future success.

4.6.2. Theme 2: External advisors and peers can support students' career preparation in addition to, or in place of, faculty advisors' contributions.

Graduate education is a unique space where engineering doctoral students are working, learning, and fulfilling multiple expectations at any given time. While these various expectations come from multiple stakeholders, each often offers its own support and resources. When faculty advisors are not knowledgeable or perpetuate toxic environments, students are required to find this knowledge and these other stakeholders are often required to bolster and fortify the students. These additional sources include but are not limited to external advisors and peers. To exemplify this phenomenon, I present three situations where students described people other than their advisor who helped them to feel prepared for their future careers.

First, I revisit Blake, a third-year student in an agricultural engineering Ph.D. program who was interested in government careers. She had an advisor who has been helpful in outlining what an academic career as a tenure track faculty looks like, however, due to a strong interest in government careers as her primary interest she said the following when asked who was helped her most to feel prepared.

> *Well through my internship, there's the mentors there. And then by [external] program, there's like we're, we have, another assigned mentor who I have, who is kind of helping me with the kind of more social science side of evaluating my project. And, yeah, there's another like seminar with required club meetings through this traineeship. And there's been some networking and training there that have been different amounts of*

helpful… I think getting to have conversations with the people and the potential job areas was super helpful. (Blake)

This quote exemplifies the situation where a student feels supported by their advisor, but the career knowledge and information is not perceived as helpful because the students' career interests do not align with their advisors experience. For these students the additional mentoring and knowledge adds to the support they perceive from their advisor.

For some students, getting involved outside of their dissertation project is not feasible due to advisor oversight or expectations. However, if there are more senior students, postdocs, or students who have had experiences that align with the person's interest they can help foster perceived career preparation. When talking about where she found the most support towards her future career interests in the industry sector, Drew, a fourth-year student in a biomedical engineering Ph.D. program interested in industry careers, talked about her peers and postdocs in her research group as being the most helpful.

So one, I guess a group of people has been the postdocs within my research group. They've been very great whenever I wanted to find out more about like, if I have to do a postdoc before I can go have a full-time career. So this was something that I had asked them about before. And, you know, they've given me their perspectives, and I've gotten a much clearer idea of what I can do next after I'm done with my degree. So I'll say postdocs have been very helpful. Another group of people is my peers. One of them had previously worked in industry, and so I was very curious to get their perspective on what it was like working there before getting a

> *Ph.D.… So yeah, people who are a little bit more advanced than I am with career progression. (Drew)*

In research groups that are large enough to have multiple students and postdocs there are opportunities for these other people to serve as primary sources of information related to future careers, the types of jobs available, and what skills would be needed to be successful.

Reaching the end of the degree is an important consideration in obtaining the future careers that many of these students want. Up to this point, the focus has been on thinking about the next steps after graduation, however, reaching the end of the program and graduating with a degree is a major obstacle for many students whose career interests require a doctoral degree. To provide context on how these students persisted, particularly with advisors who perpetuate toxic and discriminatory behavior, we revisit Hayden, who had an advisor that was outright racist and sexist to her and undermined her career interests. Reflecting on her experience following a recent dissertation defense she talked about how things got better at a certain point due to another professor she worked with.

> *The reason why I say that it became better after late April 2021, was because a new faculty member was hired to start in August 2021. But my advisor was having communications with that Professor since like, February 2021. And since I wanted to do data-driven model, and that's what the professor worked on, he started to come to our meetings. So since he was in our meetings, [my advisor] wasn't being hostile with me anymore… [my advisor] wasn't being helpful. But he wasn't at least being*

hostile. And so it was interesting, because since then, on all the way until, like, I believe, like, right before I did the internship last year, maybe like close to May 2022, the person who actually came to the meetings and held the advisor role was this other professor. So that professor quickly caught up on that on how the dynamics work, and how every time he would ask a question to the main advisor about like, where do you want to take this to what, what's the goal you're after? For this publication? The person who would answer would be me. But obviously, I would answer saying, like, "Well, this is where I would like to go. I've pitched this to [my advisor]." You know, I know he says it to you, but he wouldn't really say something clearly. One day, [my advisor] would say something. And then the next day, [my advisor] would say something else. And that second Professor got, he got very tired of that. And so he actually stopped meeting with us and just let us work on our own. But I, you know, kind of secretly met with him individually after the fact, and he decided to help me. If it wasn't for him I probably wouldn't be here sitting saying I've defended. (Hayden)

Without the other professor stepping in Hayden's experience would likely have had a very different outcome and shows the potential for other faculty mentors to influence students' experiences.

The environment of graduate education is unforgiving and highly demanding for many students whose experiences are further compounded by negligent or discriminatory advisors. For students in this situation, the connection to external mentorship, other students, and resources is paramount to their success. Further for students whose experiences are less exclusionary, these additional supports serve to improve their perceptions of their future up to and beyond their graduation with an advanced degree while providing faculty with some additional space to support other students and meet the burgeoning requirements of their own positions.

4.7. Discussion

Being successful in graduate education is undoubtedly influenced by many factors internal and external to the student. The external system level factors and student-focused instead of research-focused mentoring mentioned in existing research offer an opportunity to make changes in graduate education related to students' experiences (Bahnson, Perkins, et al. 2021; Burt, Williams, and Palmer 2019; Artiles and Matusovich 2020; Burt et al. 2021). In considering where change can be made, I first describe how my work extends of previous work followed by the implications of this work at each administrative level (i.e., student, faculty, and institutions)

The importance of the advisor relationship for graduate student experiences have been thoroughly explored from many different perspectives, however, only recently has research sought to understand how this relationship influences students' perceptions of career preparation. When students were asked about their experiences, often their relationship with their advisor is discussed in CHAPTER 2. In cases where students' identities did not align with their advisors, negative experiences were more common and echoed existing qualitative research on student experiences (Bahnson, Wyer, et al. 2021; Bahnson, Hope, et al. 2022). Due to the centrality of faculty advisors within students' experiences and models describing their experiences (Berdanier et al. 2020), this is to be expected. However, in cases where faculty work to limit students' involvement in additional activities outside of research, this isolation impedes students' growth and well-being. When students built and maintained external support systems, they were able to help students succeed across the range of experiences presented in this paper.

Existing research has highlighted within STEM graduate education broadly that in larger research groups near peers, senior doctoral students, and postdoctoral scholars all support students development in graduate school (Holloway et al. 2022; Crede and Borrego 2012). The discussion of these engineering doctoral students presents evidence for these other students and scholars either providing additional knowledge and support or serving as the primary source for students with negligent faculty advisors who perpetuate discrimination (Burt, Williams, and Smith 2018; Bahnson, Satterfield, et al. 2022; Bahnson, Wyer, et al. 2021; McGee, Griffith, and Houston 2019). Since engineering doctoral students are unlikely to seek help (Lipson et al. 2016; Hargis et al. 2021), these near-peers and scholars offer a unique opportunity for students to ask for help in ways that align with graduate education culture (Lipson et al. 2016; Bahnson, Satterfield, et al. 2022).

In cases where career knowledge or experience can be difficult to find within a research group, external mentorship can be found in fellowships, national affinity organizations, previous internships, and graduate program-based professional development events (e.g.., guest speakers, career fair) (Holloway et al. 2022; Louis et al. 2007). One solution to increase the impact of these groups is embedding these events, and interactions, such as career fairs, into graduate programs through professional development courses and incentives. An additional solution is through industry partnerships that allow students to explore their career interests, develop valuable professional skills, and expand their professional network.

Engineering doctoral students enter programs with a variety of motivation, career interests, skills, and knowledge that can guide their experience within their doctoral program. However, since they often are interested in new careers, or developing additional skills that align with upward mobility in their current career, ensuring that these students develop as researchers and as professionals is key to the student's success. Advocating for multiple sources of mentorship and support allows students to weather bad faculty advisors and integrate their training as a researcher into who they want to be in the future instead of forcing them into the mold that others set out for them as mentioned in CHAPTER 2.

4.8. Implications

The results of this work have implications for students and faculty advisors. At the student level this work advocates for seeking out multiple perspectives and sources of mentorship toward future career interests. At the faculty level this work presents cases where students can integrate multiple mentors, take part in external professional development and internships, and succeed in supporting research as well as their own development. Implementing and acknowledging the benefits of support systems aligned with students' future goals presents an opportunity to improve students' professional development while also taking pressure off faculty who already have an extensive list of responsibilities, fostering success across the educational landscape.

At the student level this work highlights that there are a variety of advising approaches that significantly influence students' experiences not only during their time in graduate school, but also beyond. For students the selection of an advisor should consider their working style and expectations, how the students interest aligns with the research being conducted, and the professional development opportunities available to them. Developing and maintaining support systems such as family, friends, peers, and domestic partners were beneficial to how students thought about how prepared they were for their desired future career. In cases where faculty are unable or unwilling to direct students on how to prepare for their desired future career, these support systems become very important.

When shifting to consider how this research informs the practices of faculty advisors, several different advising styles on various students have been presented. Reflecting on how each student talked about the intersection of their advisor and perceived career preparation, a key point to consider is that many students benefitted from having multiple people informing their career preparation practices. While some faculty had the expertise and previous experience to direct students' career preparation, the students who were connected to other people talked just as positively about their advisor and expressed similar feelings of career preparation. The take-away being that faculty do not and probably should not be the only source of knowledge and guidance related to future careers. By acknowledging this shift the pressure placed on faculty to be experts on multiple career pathways can be eased without sacrificing supporting student's needs. The dual benefit on students and faculty should be considered to inform research group practices.

4.9. Conclusion

Engineering doctoral students' descriptions of the ways in which they perceive they are or are not being prepared for their future careers show how supportive faculty advisors, even when not experts on that career path, can influence their students' experiences. The damage done by faculty advisors who are not supportive or try to override their students' goals is clear in the ways that some students described their experience. While these advisors are detrimental to students' development, this can be offset by other faculty, external advisors/mentors, or family members. Thus I advocate for student engagement in multiple forms of mentoring, such as national discipline-based affinity groups, institutional graduate associations, and career-aligned internships/fellowships. These other sources serve to support exploration by the students in ways that support their generation of goals that serve to motivate them and increase their professional networks for the benefit of themselves and their peers.

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5. Discussion, Implications, Future Work, and Conclusions

The purpose of this dissertation was to explore and make sense of engineering doctoral student experiences related to their development as early career professionals with a variety of future career interests. Through my research, I found that students' development toward future careers is driven by student-specific (e.g., student future career interests) and programmatic factors (i.e., faculty advisor and graduate programs). In this section, I begin by summarizing the key points of each chapter before unpacking three sections that chronicle how this work extends existing knowledge and informs data-driven change in graduate education. I then discuss the implications of this work and how it informs engineering doctoral student experiences, faculty advisor approach to student career development, and suggestions for embedding career development support into graduate programs.

5.1. Discussion

As part of this research CHAPTER 2 qualitatively examined how students differentially thought about their futures up to and beyond graduation using previously determined latent motivation profiles to examine the variation (Perkins et al., 2019; H. L. Perkins et al., 2018; Satterfield et al., 2022). In examining the various ways students talked about their experiences and future goals, differences arose based on the source of their future goal (i.e., the student, or parents/faculty), whether their future goal was graduation or career-focused, the depth of their planning for their career goals, and how the program (e.g., faculty and department) helped students develop their future career goals. The latent motivation profiles, qualitative interviews from CHAPTER 2 provide nuance to national reports on graduate education indicate that up to 50% of students do not feel prepared for their future careers (NASEM, 2018).

To better understand why students feel unprepared for their future careers, I developed, piloted, and disseminated a survey integrating future time perspective and goal setting (CHAPTER 3). In CHAPTER 3 the results of the exploratory factor analysis indicated that a three-factor model was appropriate. These three factors were career certainty, feedback and support, and multiple futures. These factors were then applied in an exploratory structural equation modeling to predict the outcomes of perceived career preparation and perceived program persistence. As expected, the career certainty factor, which is intrinsically focused, was strongly predictive of both outcome factors. Shifting to the second factor, feedback and support, an externally focused factor, there was a relationship to students' perceptions of career preparation. While research has examined how faculty advisors influence students' time in graduate school (Allum et al., 2014; Bahnson et al., 2021; Bahnson, Hope, et al., 2022; Barnes, 2009; Burt et al., 2018; Burt, 2020; McGee & Martin, 2011; McGee et al., 2022; Noy & Ray, 2012a), this finding indicated that the impact of advisors extends to students’ thinking about spaces beyond graduation. With the evidence that support structures, which graduate programs can influence, provide a potential intervention point, I sought to find specific ways that graduate education can better support perceptions of career preparation.

To inform change in graduate education, a deeper understanding of how feedback and support while students were in their graduate program was required. CHAPTER 4 presented the results of interviews with 12 engineering doctoral students related to their perceived career preparation, advisor relationship, and who or what was helping them to feel prepared for their future careers. Two relevant themes arose related to guiding support structures in graduate education. In the interviews, students talked about a variety of ways that their advisor did or did not help them to feel prepared for their future careers. Common actions mentioned were faculty advisors sharing their relevant experiences during the job application process, providing information about opportunities, or connecting the students with individuals who had relevant experiences aligned with students' career interests. In some cases, students had co-advisors who were able to support the student when one advisor was unavailable. In cases where faculty advisors ignored or were discriminatory toward students, external mentors, other faculty, family, and peers were able to help bridge the gap.

The presentation of these chapters has thus far have built on each other to guide focused examinations of engineering doctoral student motivation and perceptions of career preparation. Through these chapters, this research has described student experiences, connected structural elements to future-oriented motivation, generated a model for predicting perceived career preparation, and unearthed how differential feedback and support relate to students' perceived career preparation. In the following sections, I present cross-cutting themes related to expanding and informing the preliminary model presented in Figure 2.1 and reproduced as Figure 5.1 below.

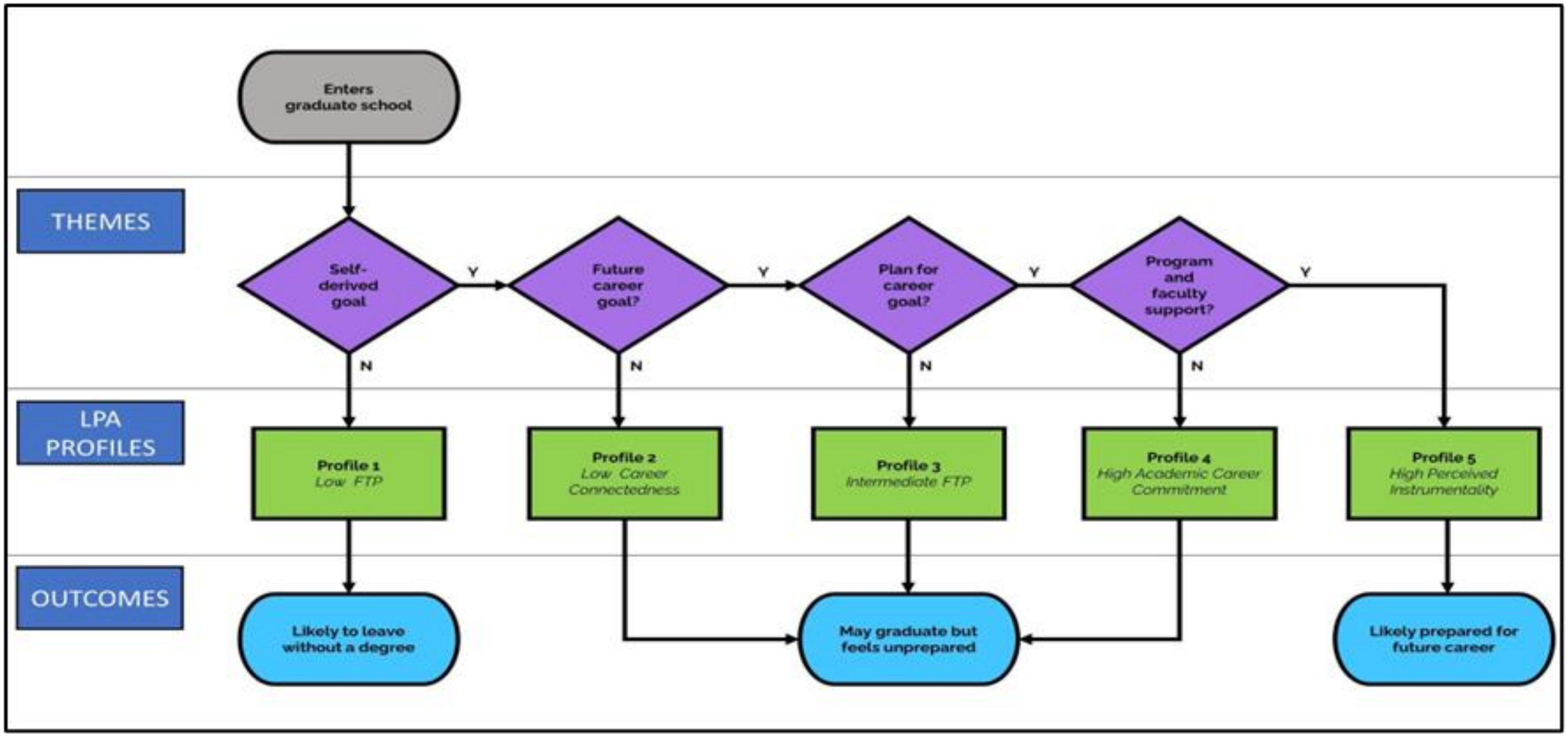

Figure 5.1 A conceptual model linking the qualitative themes (purple diamonds), latent profiles (green squares), and potential student outcomes (blue ovals).

The original model developed within Chapter 2 and reproduced in Figure 5.1 highlights key pieces that influence how students think about and navigate their graduate program. Looking at their completion intentions and perceptions of career preparation we see that the first three diamonds are focused on the individual, aligning with the career certainty factor presented in Chapter 3. The fourth diamond, program and faculty support has been further unpacked through the feedback and support factor (CHAPTER 3) and semi-structured interviews conducted in Chapter 4 related to the sources of and magnitude of support. Based on the compilation of the findings across these chapters, I present an expanded model that integrates this information as Figure 5.2. The importance of this new model is that it presents a boundary around where students personal development and sources of support/professional development intersect. Further by embedding multiple paths within the feedback and support, we can see how students can benefit from or circumvent faculty advisor influence related to their perceptions of career preparation.

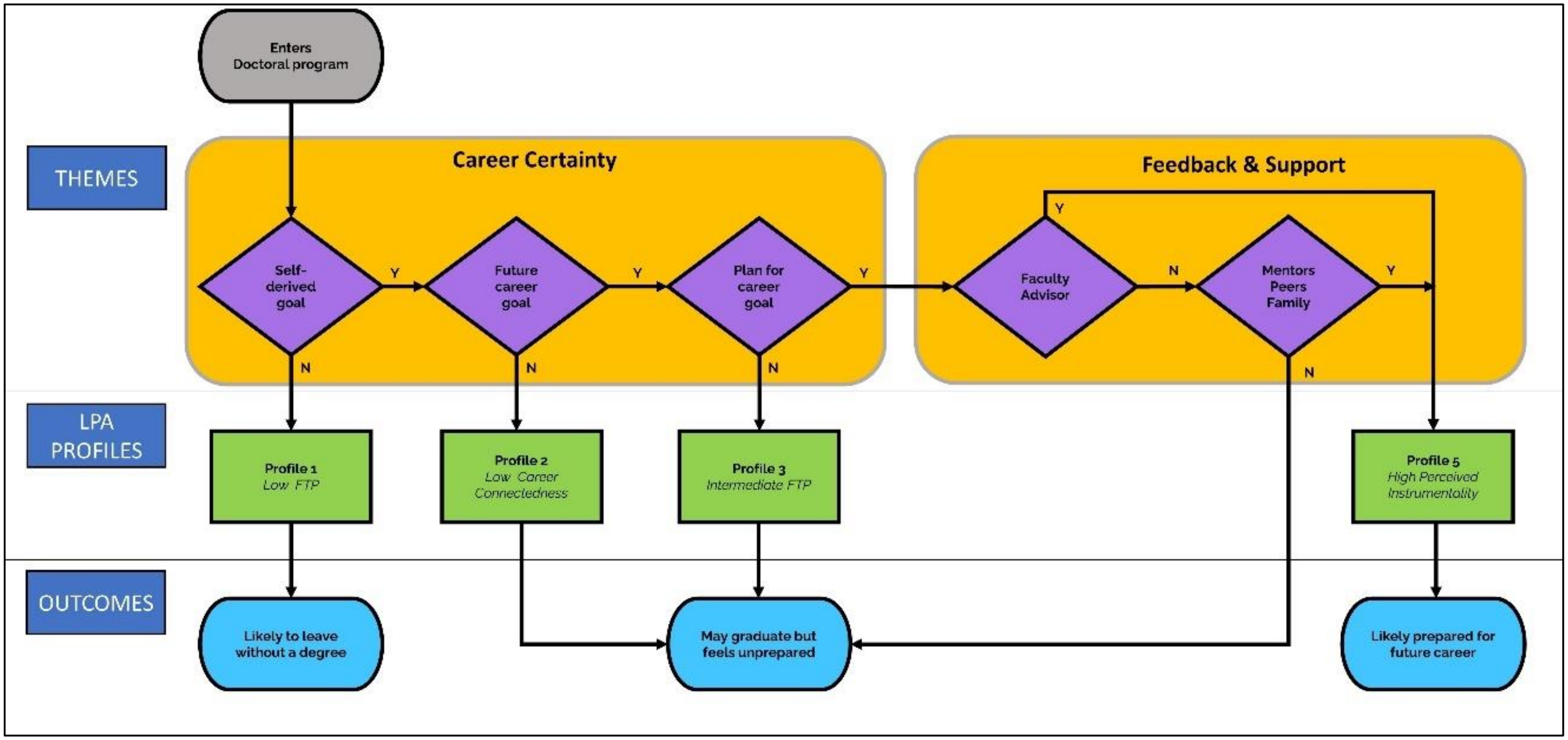

Figure 5.2 A conceptual model linking the qualitative themes (purple diamonds), factor model (yellow squares), latent profiles (green squares), and potential student outcomes (blue ovals).

Within the refined model presented in Figure 5.2, we see that profile 4: High Academic Career Commitment, is removed from the model. The removal of this is based on nuances of the data between the two qualitative strands, particularly that students in profile 4 of CHAPTER 2 represented high commitment to academic careers, while students in CHAPTER 4 represented high commitment to a variety of careers intersecting with different sources of feedback and support. Additionally, those who were committed to academic careers displayed complexity in their stories not well captured by the questions guiding CHAPTER 4. Future directions based on this data is described later in future work.

5.1.1. Motivation researchers should consider the environmental influences on doctoral student motivation

The intersection of engineering graduate student motivation and the individuals or systems available to support students in a variety of ways in graduate education have been examined separately in detail. In examining engineering graduate student motivation, existing work has predominantly focused on how individuals' goals and present tasks influenced their willingness to complete those tasks (Artiles & Matusovich, 2020; Kajfez & Matusovich, 2017; McGee et al., 2016; Mosyjowski et al., 2017; Peters & Daly, 2013; Satterfield et al., 2022; Tsugawa et al., 2017). Important considerations in students being motivated are students' conceptualization of the future (Satterfield et al., 2022; Tsugawa, 2019; Tsugawa et al., 2017; Husman et al. 1999) and engagement in career-aligned opportunities (Kajfez et al., 2016; Kajfez & Matusovich, 2017; Mosyjowski et al., 2017, Kirn et al. 2014).

Extending the conversation on graduate student motivation this works indicates that when students have support systems where they have adequate feedback and support, they are more likely to be more comfortable in developing knowledge and engaging in experiences that increase their perceived persistence and development toward their career interests, as shown in CHAPTER 2 and CHAPTER 4. These findings mirror models within goal setting that highlight the importance of regular feedback on accomplishing goals (Latham et al., 2005) Integrating these findings with existing engineering education research indicates that having peers, such as senior graduate students (Crede & Borrego, 2012, CHAPTER 4), or faculty advisors that share students' identities (Burt, 2020) in their program are additionally helpful in this development. Further extending this conversation are the other program level support sources such as graduate schools providing professional development opportunities (Holloway et al., 2022; Louis et al., 2007), research group socialization (Crede & Borrego, 2012; Gardner, 2010), and graduate department cultural norms (Bahnson, Satterfield, et al., 2022; Zerbe et al., 2023). By creating an overlapping structure of research group and graduate program supports including diverse faculty, varying professional development opportunities aligned with different career paths, and normalized socialization within and across research groups can support student development.

Examining the intersection of student motivation and programmatic structures this work highlights the importance of career-aligned experiences as discussed in CHAPTER 4 and supported by existing motivation research on careers in academia (Kajfez & Matusovich, 2017; Main et al., 2021; Peters & Daly, 2012; Zerbe & Berdanier, 2020). By creating opportunities where students can explore industry and government career-aligned opportunities, students can gain pertinent knowledge, increase their motivation as they see the next steps in their careers, and find value in their graduate program. For students who lack future goals, providing them the opportunity to explore that career and determine some of what is needed can offset feeling overwhelmed by the need to learn everything as students use advanced degrees to change careers. When developing these opportunities to get involved, researchers, faculty advisors, and institutions should consider the cultural norms that engineering doctoral programs are subject to (Bahnson, Satterfield, et al., 2022; Zerbe et al., 2023), and the experiences of underserved students (Artiles & Matusovich, 2020; Bahnson, Hope, et al., 2022; Burt et al., 2018; McGee et al., 2016; O McGee et al., 2019).

Connecting across these research topics discussed in this dissertation I have indicated that when students cannot leverage previous professional experience, having either access to people who are knowledgeable or having the opportunity to engage in exploratory career experiences was helpful in further conceptualizing their future plans (CHAPTER 4). Thus, this work does not support that students are responsible for their degree completion alone, but rather that the cultural norms of graduate education continually undermine students' ability to reflect on their experiences without attributing hardships to something they lack rather than a failure by the graduate education system.

5.1.2. Faculty advisors should be cognizant of how various models of advising interact with the different motivations that students have within doctoral programs

As evidenced in CHAPTER 2 and CHAPTER 4, students' interactions with their advisors have varying degrees of efficacy on their perceived career preparation based on students' career interests and advisors' knowledge of the career pathway that a student is interested in. While research has shown that faculty advisors influence many aspects of students experiences while in graduate school (Artiles et al., 2023; Bahnson, Hope, et al., 2022; Barnes, 2009; Burt, 2020; Burt et al., 2018; Crede & Borrego, 2012), this work extends that knowledge by highlighting how the ability to direct students on how to prepare or connect students to other people who have the knowledge and experiences to guide students were significant in improving how students thought about their ability to effectively transition into their future careers.

CHAPTER 2 and CHAPTER 4 discussed how students with varying motivations talked about their experiences with their advisor, and how different advising approaches influence how students think about their time beyond graduation (i.e., perceived preparation for their postgraduate career). These narratives indicated that how advisors' mentoring and the knowledge they pass on is filtered by the students depending on if it aligns with their career interests. The filtering of importance related to presented information and experience is well documented within the FTP literature as perceived instrumentality (Hilpert et al., 2012; Husman & Lens, 1999; Tsugawa, 2019) and is important for knowledge retention and persistence (Godwin & Kirn, 2020; Kirn & Benson, 2018; Tsugawa et al., 2019). Because of the variety of different career paths that students can take (Choe & Borrego, 2019), faculty advisors should have ongoing discussions with their students about what they want to do in the future to increase the value students find in the information. The importance of these conversations being ongoing is that students' goals are subject to change based on opportunities available, lifestyle changes, and disinterest after exploring the positions (Main et al., 2021; McGee et al., 2019).

The results of this research support that faculty and students should discuss future goals when students start their program, while students may be uncertain or their goals are subject to change as shown in CHAPTER 2, this initial alignment can support students taking a significant interest in the experiences and knowledge faculty share related to future careers as shown in CHAPTER 4. The additional interest expressed by faculty coupled with research showing the importance of identity alignment between students and faculty (Burt, 2020), supports the fostering of stronger advisor-advisee relationships. The development of these strong relationships is crucial for students' development as academics (Kajfez & Matusovich, 2017; Main et al., 2021; Peters & Daly, 2012; Zerbe & Berdanier, 2020), navigation of their graduate program (Bahnson et al., 2019; Bahnson, Satterfield, et al., 2022; Burt et al., 2018; McGee et al., 2019; Zerbe et al., 2023), and as shown in CHAPTER 3 and CHAPTER 4, their future careers (Satterfield et al., 2022).

Relating this back to the model presented in Figure 5.2., the two themes (i.e., purple diamond) encompassed within the yellow square representing *feedback and support* is exemplified throughout CHAPTER 3 and CHAPTER 4. CHAPTER 3 provides quantitative evidence through the predictive relationship between feedback and support, particularly from faculty advisors, and student's perception of career preparation. The evidence of this relationship is further triangulated by the qualitative evidence presented in CHAPTER 4, wherein students' discussion of who or what was helping them feel prepared for their future careers focused heavily on their faculty advisor(s) and other sources of mentorship. While not discussed outside of academic careers, the exploration of future careers and sharing of experiences from faculty advisors, experienced peers, and external program mentors are an area for intervention within graduate education (Kajfez & Matusovich, 2017; Main et al., 2021; Peters & Daly, 2012; Zerbe & Berdanier, 2020).

5.1.3. Implementing multiple sources of feedback, support, and mentorship as institutional interventions to improve students' perceived career preparation

A key topic of this research has focused on feedback and support as a mechanism to increase engineering doctoral students' perceptions of career preparation. Specific experiences or practices that are included in my definition of feedback and support were guided by how participants in CHAPTER 2 and CHAPTER 4. I defined feedback and support as being guided on how to present information to different audiences, faculty advisors allowing students to engage in opportunities that align with their career interests, students being provided targeted feedback on how to improve their writing and talking through the details of career paths. These practices were commonly expressed within the literature as they relate to academic careers (Kajfez & Matusovich, 2017; Main et al., 2021; Peters & Daly, 2012; Zerbe & Berdanier, 2020), but were not mentioned related to government and industry careers. The three career sectors (i.e., academia, government, and industry) are discussed due to their categorical use in existing research (Choe & Borrego, 2019; National Center for Science and Engineering Statistics, 2017)

As shown in CHAPTER 2 and 4, for engineering doctoral students these other sources of knowledge and professional development are particularly effective as they try to plan, prepare, and develop in ways that align with their future career interests. The importance of peers and professional development programs has been shown across multiple studies and disciplines of graduate education (Gardner, 2010; Holloway et al., 2022; Louis et al., 2007). However, the outcome of the previous research has remained focused on students' time within their graduate program. The results of the work presented in this research have showcased how engineering doctoral students perceive the influence of peers, family, and professional development programs on their time beyond graduation. Having multiple perspectives and sources of information can be helpful in triangulating what is needed in many contexts.

In consideration of the perceived long-term effects that peers, family, and professional development have on students, I must also caution that as shown in CHAPTER 4 the deleterious effects that some faculty advisors have on students through neglect and discrimination are not only undermining students' degree progress (Bahnson, Hope, et al., 2022; Bahnson, Satterfield, et al., 2022) but also their perceived future employment opportunities. Unless changes are made to address these instances which disproportionately affect international students (Artiles & Matusovich, 2020; Bahnson et al., 2019; Bahnson, Hope, et al., 2022; Tsugawa, 2019) and evidenced in CHAPTER 4, the efficacy of graduate education on student development will continue to be besmirched.

5.2. Implications

Improving engineering doctoral students' career preparation intentions and how they perceive themselves as prepared or not prepared for their future will impact individuals across engineering graduate education. Creating change in graduate education is not easy, however, with the data presented in this work, there are several ways change can be implemented with data-driven reasoning. These include embedding career planning into graduate programs to help students take ownership of their futures, shifting from faculty being students' only source of career information and guidance for doctoral students, and recognizing the effect that other faculty, peers, family, and friends have on students’ development within a graduate program.

The primary focus of this work was on students who had already decided on future career paths or had considered their future while in a doctoral program. The results of CHAPTER 2 coupled with completion and attrition data indicate that many students enter graduate education without a goal, begin to feel lost, and often leave in the middle of their program (Artiles & Matusovich, 2020; Lott et al., 2009; Sallai et al., 2023; Sowell et al., 2015). While this is only one possible reason within a complex phenomenon, it nonetheless speaks to a need to provide systems that help students in their development of goals. Once students have developed goals, or have career interests, they are less likely to be subject to external pressures from family and faculty advisors to enter particular career paths. As students take ownership of their future, they subsequently can determine the value of particular tasks, opportunities, and knowledge as it relates to their future.

Along with taking ownership of their futures, students should seek out additional sources of mentorship, and career guidance while being provided opportunities to do so. As supported in CHAPTER 4, in the best of cases students have additional information to triangulate and build on their advisor's guidance. In the worst cases when students wish faculty would ignore them, or they are subject to discrimination, these additional sources can serve to protect students from some of the detrimental effects of the advisor. Alongside student efforts institutional research can apply interventions guided by goal-setting theory to examine the environment surrounding students, identify areas of support that align with students' future career interests, and provide mentorship or professional development programs that meet the student's needs.

5.3. Limitations and Future Work

5.3.1. Reexamination of How Students that are Strongly Committed to Single Career Paths are Influenced By Feedback and Support

As described previously the high academic career commitment profile from CHAPTER 2 dropped out of the final model presented in Figure 5.2 due to nuances in the data from CHAPTERS 2 and 4. Because in CHAPTER 2 the students interviewed from the profile were all highly committed to pursuing academic careers, the focus of the profile was on these intentions. However, in CHAPTER 4 when unpacking students' perceptions of how they were being prepared, the two students interested in academic careers were well-supported with two mentors each. The ability to draw conclusions across this data leaves a gap for future work to examine how students who are strongly committed to academic and non-academic careers are influenced by feedback and support from varying source while considering the different systemic pressures attributed to academic and non-academic career interests.

5.3.2. Inclusion of Peers, Family, and External Mentors in Models and Expansion of Perceived Persistence

As presented in CHAPTER 4, the sources of feedback, knowledge, and support go beyond just faculty advisors and is a limitation of the existing survey used in CHAPTER 3. For example, Hayden specifically states in CHAPTER 4 that if not for a professor she met with secretly behind her advisor's back "*I probably wouldn't be here* *sitting saying I've defended" (Hayden).* By expanding the sources of feedback and support beyond just faculty advisors, researchers can better understand how different sources of feedback and support predict perceptions of career preparation and perceptions of persistence. Furthermore, as discussed in CHAPTER 3 the focus of the perceptions of program persistence factor was found to be personally driven (e.g., I will be able to effectively complete the tasks required for my future career), taking the emphasis off the graduate education system. Future work should refine the outcome measure to better align with student persistence could support a relationship between feedback and support and perceptions of program persistence and better examine the student and program's role in students' perceptions that they will complete their degree.

5.3.3. Examination of STEM or Engineering Master's Students Motivation and Perceived Career Preparation

The population of interest for this research has been engineering doctoral students, despite preliminary research examining the experience of masters and doctoral students. A potential direction for future work is to examine how the exploratory structural equation model presented in CHAPTER 3 differs for engineering masters students and STEM doctoral students. Understanding the generalizability of the model for other populations has the potential to drive systemic change across graduate education, rather than within a single discipline-based doctoral program. Some expected outcomes of this future direction include different intrinsic or personal motivations across STEM disciplines, as argued previously.

5.3.4. Embedding Multiple Mentors Within Engineering Doctoral Programs

The culmination of this work has focused on engineering doctoral student career preparation within the current infrastructure. However, I encourage future work to consider a different approach to engineering doctoral student mentorship. The current practice of students relying on a single faculty advisor for the majority of their program leads students whose career interests do not align with their advisor's experiences to struggle to obtain pertinent career information and direction. In opposition to this approach future work should explore how programs with industry partnerships, or external mentors differ to traditional advisor/advisee programs. This evidence could guide change across the graduate system in providing resources and development opportunities to students.

5.4. Conclusions

The purpose of this dissertation was to explore and make sense of engineering doctoral student experiences related to their development as early career professionals with a variety of future career interests. Through qualitative and quantitative analysis, I found that while some students lack future career goals, feedback and support aligned with students' desired future career can significantly improve their perceived career preparation. While there can be many sources, the feedback and support from faculty advisors is crucial as this does not just influence students' degree completion intentions, but also expected success in their future careers.

Cross-cutting through these chapters is that the current system of graduate education would benefit from embedding multiple sources of advising and mentorship aligned with students' career interests into graduate programs. When students are reliant only on their faculty advisor for their development, they are in the best cases prepared for the career their advisor sets out for them. As presented in CHAPTER 4 there are multiple advisory structures, which have the potential to relieve pressure on faculty and improve students' perceived career preparation. Because of this, I advocate that faculty advisors and graduate programs connect students to multiple mentors to distribute the expectations and provide students with multiple perspectives to triangulate what will help them succeed in and beyond their graduate program.

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6. APPENDICES

6.1. Appendix A

Intake Survey

For the following statements, please select your agreement on a range of strongly disagree to strongly agree.

I see myself as a SCIENTIST

My department faculty see me as a SCIENTIST

My peers see me as a SCIENTIST

I have had experiences in which I was recognized as a SCIENTIST

I want to be recognized for my contributions to SCIENCE

My advisor(s) see me as a SCIENTIST

Other scientists see me as a SCIENTIST

I find satisfaction when learning SCIENCE concepts

I am interested in in learning SCIENCE concepts

I enjoy learning SCIENCE

I can overcome setbacks when learning SCIENCE

I am confident that I can understand SCIENCE in class.

I am confident that I can understand SCIENCE outside of class

I can perform well when my SCIENCE knowledge is tested (for instance, in exams or defenses)

I understand concepts I have studied in SCIENCE

I see myself as an ENGINEER

My department faculty see me as an ENGINEER

I have had experiences in which I was recognized as an ENGINEER

Others ask me for help with ENGINEERING

I want to be recognized for my contributions to ENGINEERING

My advisor(s) see me as an ENGINEER

Other engineers see me as an ENGINEER

I find satisfaction when doing ENGINEERING

I enjoy learning ENGINEERING

I am confident that I can understand ENGINEERING in class.

I am confident that I can understand ENGINEERING outside of class

I can perform well when my ENGINEERING knowledge is tested (for instance, in exams or defenses)

I understand concepts I have studied in ENGINEERING

I am confident that I can apply ENGINEERING to solve problems

I see myself as a RESEARCHER

My department faculty see me as a RESEARCHER

My peers see me as a RESEARCHER

I have had experiences in which I was recognized as a RESEARCHER

I want to be recognized for my contributions to RESEARCH

My advisor(s) see me as a RESEARCHER

Other researchers see me as a RESEARCHER

I find satisfaction when learning about my RESEARCH topic

I am interested in in learning more about how to do RESEARCH

I enjoy conducting RESEARCH

I find satisfaction when doing RESEARCH

I can publish RESEARCH results in my field

I can present RESEARCH related topics to relevant audiences

I am confident that I can network with other RESEARCHERS

I understand the concepts needed to analyze and interpret data

I am confident that I can design a RESEARCH study

I find it difficult to evaluate my degree progress

I intend to complete my graduate degree

My advisor…

… has clearly stated his or her expectations for satisfactory participation in my program

… is easy to approach

… is knowledgeable about my research

… encourages and supports my research

… values my work

… provides advice in a timely manner

… is also my mentor

… and I have a positive relationship

Please fill in the following open-ended questions

Did you change advisors within the last year?

What academic rank does your advisor hold?

If any, what administrative positions does your advisor hold?

How often do you have regularly scheduled individual meetings with your advisor?

Do you have a dissertation/thesis project?

Do you have a research assistantship? (i.e., you are paid to work on professor's project)

Are you a member of a lab or research group with other graduate students?

Did you have research experience before starting your graduate program?

What degree are you pursuing?

What is your major?

What is your specialization within your major?

What Ph.D. milestones have you completed?

Did you transfer institutions within the last year?

What is your email address?

6.2. Appendix B

GRADS Phase 3 Interview Protocol

General Questions for All Interviews

1. Tell me about your graduate school experience to date.
2. Tell me how the last year has gone.
3. Describe to me your future goals, this can be as soon or as far into the future as you like.
    a. In this future, what is your career goal(s)?

Future Time Perspective Questions

1. How far into the future do you see yourself...
    a. Professionally?
    b. Personally?
2. Describe your future after graduating…
    a. Do you imagine multiple futures?
    b. What type of career(s) do you want to enter?
    c. What careers are...
        i. Realistic?
        ii. Idealistic?
    d. Is there a career you want to avoid?
3. What research tasks, assignments, activities, etc. do you find useful toward your future?
4. What experiences (e.g., teaching) do you find useful toward your future?
5. Is your degree program preparing you for your future? Why or why not?
6. Why did you decide to enter your graduate program? Did your future goals influence going into your program?

6.3. Appendix C

Career Planning and Preparation - Dissertation

Start of Block: Cover Page

Q1.1 Information Regarding Participation

Thank you for your interest in our Engineering Doctoral Student Experiences survey. We greatly appreciate your time. By thoughtfully completing this survey, you will help us find ways to improve engineering graduate education for future students. Please make your best estimate for each item and answer as many questions as possible. There are no right or wrong answers. Some questions will not apply to your experiences and can be left blank.

Please note:

- You must be 18 years or older to participate.
- You must be enrolled in an engineering doctoral program.
- The survey will take approximately 15 minutes to complete.
- Participation is voluntary.
- You may withdraw at any time.
- Participation will NOT impact your graduate status in any way.
- The information you share will be kept completely confidential.
- You may be compensated with a $10 Amazon gift card for your participation.

We will never share your individual responses with your department or advisor, although we may share group-level information with your department (e.g., 50% of students felt that __________). If you have any questions or concerns, please contact study Principal Investigators Derrick Satterfield (dsatterfield@unr.edu) or Adam Kirn (akirn@unr.edu). You may contact the University of Nevada, Reno Institutional Review Board (IRB) at 775-327-2368 if you have any questions regarding your rights as a research participant.

OPTIONAL: We may want to contact you to ask follow-up questions about your graduate-related experiences. All communications will be kept in the strictest confidence and your email will NOT be disclosed to any third party, including administrators at your university and in your department. By clicking 'Agree' and proceeding with the survey below, you confirm that you are 18 years or older and currently enrolled in an engineering doctoral program.

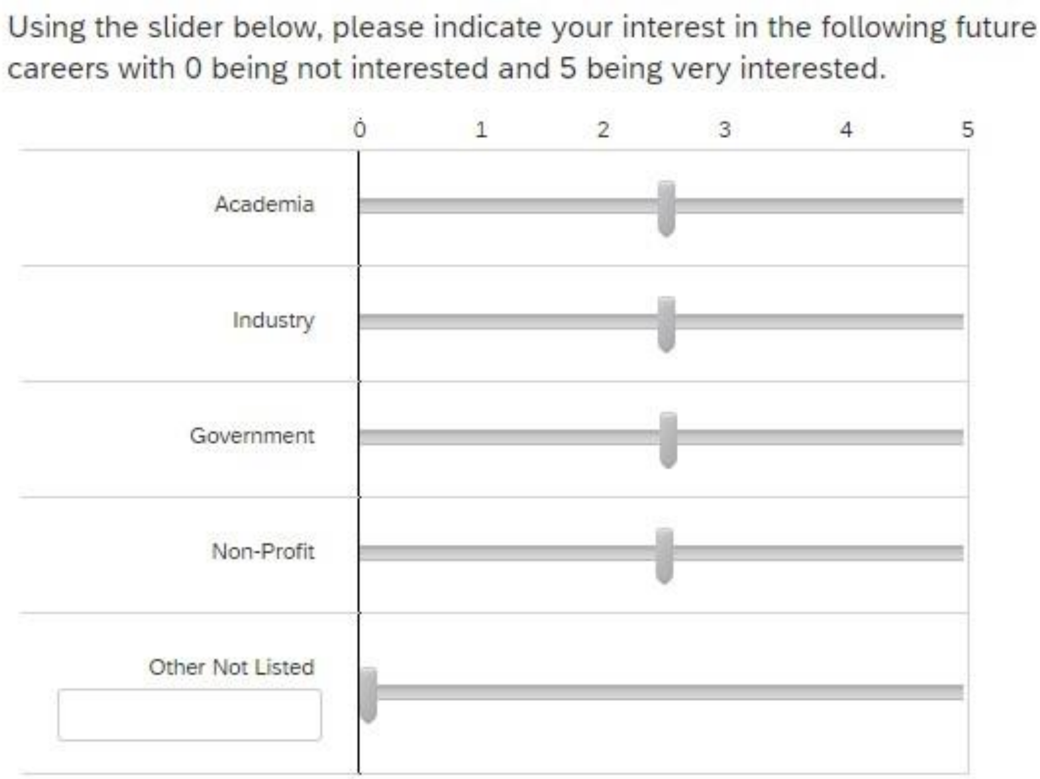
○ Agree

○ Disagree

End of Block: Cover Page

Start of Block: Future Career Goals

1.2



End of Block: Future Career Goals

Start of Block: Goal Setting

Q3.1 To what extent do you disagree or agree with the following statements?

	Strongly Disagree				Strongly Agree
My future career goal(s) are important to me.	○	○	○	○	○

I do not care if I achieve my career goal(s).	○	○	○	○	○
I am strongly committed to pursuing my career goal(s).	○	○	○	○	○
I have a strategy for attaining my career goal(s).	○	○	○	○	○
I reflect on the most suitable strategy to follow before taking action towards my career goal(s).	○	○	○	○	○
I usually feel that I have an effective action plan for reaching my career goal(s).	○	○	○	○	○

Q3.2 To what extent do you disagree or agree with the following statements?

	Strongly				Strongly

	Disagree				Agree
My advisor updates me regularly concerning my progress.	○	○	○	○	○
I am told the positive aspects of my performance by my advisor.	○	○	○	○	○
I am told the negative aspects of my performance by my advisor.	○	○	○	○	○
I get regular feedback concerning how I am performing in my program.	○	○	○	○	○
In one-on-one meetings with my advisor, problem-solving is the focus.	○	○	○	○	○
In one-on-one meetings with my advisor, criticism is the focus.	○	○	○	○	○

My advisor encourages me to reach my future career goal(s).	○	○	○	○	○
My advisor helps me find the information necessary to perform well in my future career.	○	○	○	○	○
My advisor is supportive when I face obstacles in my program.	○	○	○	○	○

Page Break

Q3.3 To what extent do you disagree or agree with the following statements?

	Strongly Disagree				Strongly Agree
My graduate program will help me reach my future career goal(s).	○	○	○	○	○

My graduate program provides sufficient resources to help me prepare for my future career.

My graduate program treats all graduate students equitably.

I strive to achieve my goal(s) in my program even when I'm faced with obstacles.

In my graduate program, I keep trying even when things are not going well.

In my graduate program, I work harder after failure.

I will graduate from my program with a doctoral degree.	○	○	○	○	○

End of Block: Goal Setting

Start of Block: FTP

Q2.1 To what extent do you disagree or agree with the following statements?

	Strongly Disagree				Strongly Agree
I am interested in three or more future careers after graduating.	○	○	○	○	○
There are multiple future careers I am interested in after graduating.	○	○	○	○	○
I am only interested in one future career after graduating.	○	○	○	○	○

I imagine many career paths I can take depending on available opportunities when I graduate.	○	○	○	○	○
The career path I would find most rewarding is not realistic.	○	○	○	○	○
My ideal career is different than one I think I can get.	○	○	○	○	○
I can see myself in my ideal career in the future.	○	○	○	○	○

Page Break

Q2.2 To what extent do you disagree or agree with the following statements?

	Strongly Disagree				Strongly Agree

I can get a job upon graduation.	○	○	○	○	○
I will be satisfied with the career I obtain immediately after graduation.	○	○	○	○	○
I can get the job I desire upon graduation.	○	○	○	○	○
I think about my future career to determine which tasks to prioritize in my graduate program.	○	○	○	○	○
My future career influences what I want to learn in my graduate program.	○	○	○	○	○

My future career is an important consideration in how I decide to approach my dissertation project.	○	○	○	○	○

End of Block: FTP

Start of Block: Career Preparation

Q4.1 To what extent do you disagree or agree with the following statements?

	Strongly Disagree				Strongly Agree
What I learn in my graduate program will be important for success in my future career.	○	○	○	○	○
I will use the information I learn in my graduate program in the future.	○	○	○	○	○

I will use the research skills I am developing in my future career.	○	○	○	○	○
I will be prepared for the career I want when I complete my doctoral degree.	○	○	○	○	○
I will be able to effectively complete the tasks required for my future career.	○	○	○	○	○
I am taking steps to prepare for the career I want in the future.	○	○	○	○	○
My time in this doctoral program is preparing me for my future career.	○	○	○	○	○

End of Block: Career Preparation

Start of Block: Program

Q5 What degree(s) are you pursuing?

☐ Doctorate Degree

☐ Masters Degree

☐ Other ____

Q6 Please enter the two-digit month and the four-digit year you started your engineering graduate degree.

○ Month (MM) ____

○ Year (YYYY) ____

Q7 How do you describe your disability status? We are interested in this identification regardless of whether you typically request accommodations for this disability.

Select all that apply.

☐ A sensory impairment (vision or hearing)

- [ ] A learning disability (e.g., ADHD, dyslexia)
- [ ] A long-term illness (e.g., epilepsy, cystic fibrosis)
- [ ] A mobility impairment
- [ ] A mental health disorder
- [ ] A temporary impairment due to illness or injury (e.g., broken ankle, surgery)
- [ ] A disability or impairment not listed above

____

- [ ] I do not identify with a disability or impairment

Q8 What is your Major?

Example: Chemical Engineering

____

Q9 What is your specialization within your major?

Example: Fluid mechanics, tissue engineering, etc.

____

Q10 What Ph.D. milestones have you completed?

Select all that apply.

▢ Comprehensive or Preliminary Exam (Written or Oral)

▢ Qualifying Exam

▢ Dissertation Proposal

▢ Dissertation Defense

▢ Not Applicable

Q11 Did you transfer institutions within the last year?

○ No

○ Yes

Q12 Did you transfer institutions with your advisor?

○ No

○ Yes

End of Block: Program

Start of Block: Demographics

Q13 What is your gender identity?

☐ Agender

☐ Gender Fluid

☐ Gender Non-conforming

☐ Genderqueer

- [ ] Man
- [ ] Non-binary
- [ ] Questioning
- [ ] Woman
- [ ] Prefer not to say
- [ ] Specify another option

Q14 What is your sexual orientation?

- [ ] Asexual
- [ ] Bisexual

- ☐ Gay
- ☐ Lesbian
- ☐ Pansexual
- ☐ Queer
- ☐ Questioning
- ☐ Straight
- ☐ Prefer not to say
- ☐ Specify another option

Q15 With which racial and ethnic group(s) do you identify?

(Select all that apply)

- [ ] American Indian or Alaska Native
- [ ] Asian
- [ ] Black or African American
- [ ] Hispanic, Latino/Latina/LatinE, or Spanish origin
- [ ] Middle Eastern or North African
- [ ] Native Hawaiian or Other Pacific Islander
- [ ] White

☐ Another race or ethnicity not listed above

____

Q16 Please print your specific ethnicities in the space below.

Example: German, Korean, Midwesterner (American), Mexican American, Navajo Nation, Samoan, Puerto Rican, Southerner (American), Chinese, etc. Note, you may report more than one group.

____

Q17 What is your country of origin?

____

End of Block: Demographics

Start of Block: Email and University and Future Contact

Q18 We understand providing your university name may be concerning. It is completely optional.

We use university name to help us analyze the data by looking for variations and patterns based on university. By knowing your university, we can compare your experiences to other people at the same university as well as compare your university's average to the average at other universities.

OPTIONAL: If you are comfortable, please enter your full university name below. For example, do not enter USC; do enter: University of State - City or Jefferson University

____

Q19 OPTIONAL: We may want to contact you to ask follow-up questions about your graduate-related experiences. All communications will be kept in the strictest confidence and your email will NOT be disclosed to any third party, including administrators at your university and in your department. Your responses to this survey will be stored seperately from your email in a password protected file with only a participant identification number to connect them. Only principal investigators will have access to the password protected email list. To register for additional engineering education research please provide your email below.

____

Q20 Thank you for your participation! Once again, if you have any questions about the survey, please contact Derrick Satterfield (dsatterfield@unr.edu) or Adam Kirn (akirn@unr.edu). If you have any questions regarding your rights as a research participant, please contact the University of Nevada, Reno Institutional Review Board (IRB) at 775-327-2368.

End of Block: Email and University and Future Contact

6.4. Appendix D

```
#Satterfield Dissertation Code
#Written to
  #Clean the data
  #Collect Descriptive Statistics
  #Conduct Factor Analysis
  #Conduct Structural Equation Modeling

# Package Installation ---------------------------------------------------
# install.packages("lavaan")
# install.packages("lavaanPlot")
# install.packages("car")
# install.packages("stats")
# install.packages("psych")
# install.packages("nFactors")
# install.packages("Hmisc")
# install.packages("cluster")
# install.packages("fpc")
# install.packages("moments")
# install.packages("psy")
# install.packages("plyr")
# install.packages("stringr")
# install.packages("corrplot")
# install.packages("GPArotation")
# install.packages("reshape2")

# Library Loading --------------------------------------------------------

library(lavaan)
library(lavaanPlot)
library(car)
library(stats)
library(psych)
library(nFactors)
library(Hmisc)
library(cluster)
library(fpc)
library(moments)
library(psy)
library(plyr)
library(stringr)
library(corrplot)
library(GPArotation)
```

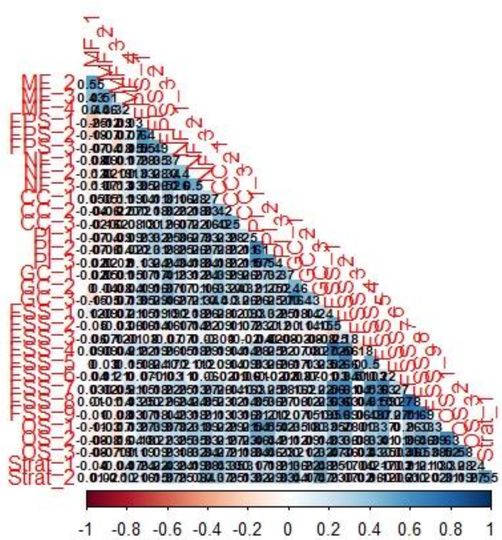
```
library(reshape2)

# Data Loading and Cleaning ---------------------------------------------
#Dataset Loading
rm(list = ls())
Full.Data <-read.csv("Dissertation_Data_10232022.csv")
Full.Data<-Full.Data[Full.Data$Progress == 100,]
Full.Data <- Full.Data[Full.Data$Q5 != 2,]
Other.Careers <-Full.Data[3:nrow(Full.Data),24]
CData<-Full.Data[-c(1:2),-c(1:18,24,67:87)]
CData$X1.2_5[is.na(CData$X1.2_5)] = 0
Data\\Survey Data\\R\\Dissertation_Data_10232022_CLEAN.csv", row.names =
FALSE)

rm(list = ls())
CData <-read.csv("Dissertation_Data_10232022_CLEAN.csv")
DescData <-read.csv("Dissertation_Data_10232022_Desc.csv")
###Data Cleaning###

#Assign ID to participants
ID<-c(1:nrow(CData))
ID<-as.character(ID)
CData<-as.data.frame(sapply(CData, as.numeric))
QData<-cbind(ID,CData)

#Correct reverse coded items (e.g., 5 becomes 1, and 1 becomes 5)
QData$Q2.1_3 <- 6-QData$Q2.1_3
QData$Q2.1_5 <- 6-QData$Q2.1_5
QData$Q2.1_6 <- 6-QData$Q2.1_6
QData$Q3.1_2 <- 6-QData$Q3.1_2
QData$Q3.2_3 <- 6-QData$Q3.2_3
QData$Q3.2_6 <- 6-QData$Q3.2_6


#Full Working Data Theoretical Grouping
WData <-as.data.frame(cbind("ID"=as.character(QData$ID),
                    "MF_1"=QData$Q2.1_1,"MF_2"=QData$Q2.1_2,"MF_3"=QData$Q2.1
_3,"MF_4"=QData$Q2.1_4,
                    "FPS_1"=QData$Q2.1_5,"FPS_2"=QData$Q2.1_6,"FPS_3"=QData$Q2.
1_7,
                    "NF_1"=QData$Q2.2_1, "NF_2"=QData$Q2.2_2,
"NF_3"=QData$Q2.2_3,
                    "CC_1"=QData$Q2.2_4,"CC_2"=QData$Q2.2_5,"CC_3"=QData$Q2.2_
6,
                    "PI_1"=QData$Q4.1_1,"PI_2"=QData$Q4.1_2,"PI_3"=QData$Q4.1_3,
```

```
                    "GC_1"=QData$Q3.1_1, "GC_2"=QData$Q3.1_2,
"GC_3"=QData$Q3.1_3,
                    "FSS_1"=QData$Q3.2_1,"FSS_2"=QData$Q3.2_2,"FSS_3"=QData$Q3.
2_3,"FSS_4"=QData$Q3.2_4,"FSS_5"=QData$Q3.2_5,"FSS_6"=QData$Q3.2_6,"FSS_7
"=QData$Q3.2_7,"FSS_8"=QData$Q3.2_8,"FSS_9"=QData$Q3.2_9,
                    "OS_1"=QData$Q3.3_1,
"OS_2"=QData$Q3.3_2,"OS_3"=QData$Q3.3_3,
                    "Strat_1"=QData$Q3.1_4,
"Strat_2"=QData$Q3.1_5,"Strat_3"=QData$Q3.1_6,
                    "CP_1"=QData$Q4.1_4, "CP_2"=QData$Q4.1_5,
"CP_3"=QData$Q4.1_6, "CP_4"=QData$Q4.1_7,
                    "Persist_1"=QData$Q3.3_4, "Persist_2"=QData$Q3.3_5,
"Persist_3"=QData$Q3.3_6, "Persist_4"=QData$Q3.3_7)
               ,stringsAsFactors=FALSE)
WData[2:43]<-as.data.frame(sapply(WData[2:43], as.numeric))

WData[WData==""]<-NA
WData <- WData[complete.cases(WData),]

#Future Time Perspective Theoretical Grouping
FTP <-as.data.frame(cbind("ID"=as.character(QData$ID),
                    "MF_1"=QData$Q2.1_1,"MF_2"=QData$Q2.1_2,"MF_3"=QData$Q2.1
_3,"MF_4"=QData$Q2.1_4,
                    "FPS_1"=QData$Q2.1_5,"FPS_2"=QData$Q2.1_6,"FPS_3"=QData$Q2.
1_7,
                    "NF_1"=QData$Q2.2_1, "NF_2"=QData$Q2.2_2,
"NF_3"=QData$Q2.2_3,
                    "CC_1"=QData$Q2.2_4,"CC_2"=QData$Q2.2_5,"CC_3"=QData$Q2.2_
6,
                    "PI_1"=QData$Q4.1_1,"PI_2"=QData$Q4.1_2,"PI_3"=QData$Q4.1_3)
                    ,stringsAsFactors=FALSE)
FTP[2:17]<-as.data.frame(sapply(FTP[2:17], as.numeric))

FTP[FTP==""]<-NA
FTP <- FTP[complete.cases(FTP),]

#Goal Setting Theoretical Grouping
GS <- as.data.frame(cbind("ID"=as.character(QData$ID),
                    "GC_1"=QData$Q3.1_1, "GC_2"=QData$Q3.1_2,
"GC_3"=QData$Q3.1_3,
                    "FSS_1"=QData$Q3.2_1,"FSS_2"=QData$Q3.2_2,"FSS_3"=QData$Q3.
2_3,"FSS_4"=QData$Q3.2_4,"FSS_5"=QData$Q3.2_5,"FSS_6"=QData$Q3.2_6,"FSS_7
"=QData$Q3.2_7,"FSS_8"=QData$Q3.2_8,"FSS_9"=QData$Q3.2_9,
                    "OS_1"=QData$Q3.3_1,
"OS_2"=QData$Q3.3_2,"OS_3"=QData$Q3.3_3,
```

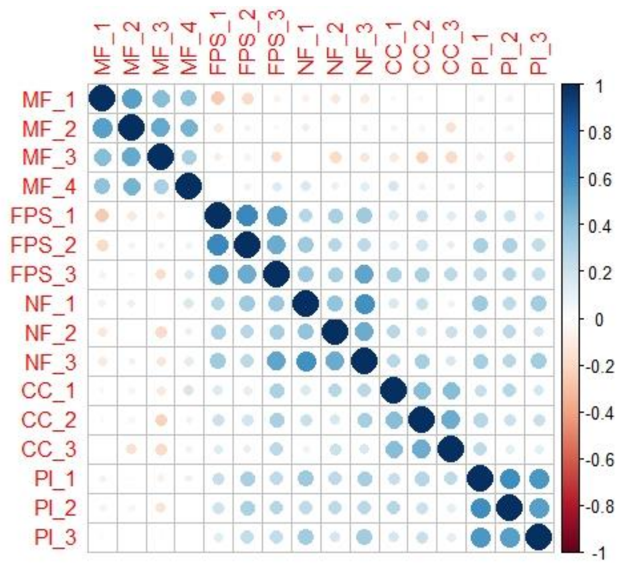
```
                      "Strat_1"=QData$Q3.1_4,
"Strat_2"=QData$Q3.1_5,"Strat_3"=QData$Q3.1_6)
                      ,stringsAsFactors=FALSE)
GS[2:19]<-as.data.frame(sapply(GS[2:19], as.numeric))

GS[GS==""]<-NA
GS <- GS[complete.cases(GS),]


#Outcome Predictor Theoretical Grouping
OP <- as.data.frame(cbind("ID"=as.character(QData$ID),
                      "CP_1"=QData$Q4.1_4, "CP_2"=QData$Q4.1_5,
"CP_3"=QData$Q4.1_6, "CP_4"=QData$Q4.1_7,
                      "Persist_1"=QData$Q3.3_4, "Persist_2"=QData$Q3.3_5,
"Persist_3"=QData$Q3.3_6, "Persist_4"=QData$Q3.3_7)
                      ,stringsAsFactors = FALSE)
OP[2:9]<-as.data.frame(sapply(OP[2:9], as.numeric))

OP[OP==""]<-NA
OP <- OP[complete.cases(OP),]

# Descriptive Statistics -----------------------------------------------
DescData<-Full.Data[WData$ID,]
DescData <-read.csv("Dissertation_Data_10232022_Desc.csv")
table(DescData$Q5)
#No Response=3
#PHD = 183
#MS/PHD = 5
table(DescData$Q6_2)
table(DescData$Q7)
#No Disability = 144
#Disability = 42
#No Response = 5
table(DescData$Q8)
DescData$Q10[DescData$Q10==1] <- "Comprehensive or Preliminary Exam"
DescData$Q10[DescData$Q10=="1,5"] <- "Comprehensive or Preliminary Exam"
DescData$Q10[DescData$Q10==2] <- "Qualifying Exam"
DescData$Q10[DescData$Q10=="1,2"] <- "Qualifying Exam"
DescData$Q10[DescData$Q10=="1,5,2"] <- "Qualifying Exam"
DescData$Q10[DescData$Q10=="5,2"] <- "Qualifying Exam"
DescData$Q10[DescData$Q10==3] <- "Dissertation Proposal"
DescData$Q10[DescData$Q10=="1,3"] <- "Dissertation Proposal"
DescData$Q10[DescData$Q10=="1,5,2,3"] <- "Dissertation Proposal"
DescData$Q10[DescData$Q10=="2,3"] <- "Dissertation Proposal"
DescData$Q10[DescData$Q10=="5,2,3"] <- "Dissertation Proposal"
```

```
DescData$Q10[DescData$Q10==4] <- "Dissertation Defense"
DescData$Q10[DescData$Q10==5] <- "Not Applicable"
table(DescData$Q10)
#Comps/Prelims Not Completed = 39
#Comps/Prelims Completed = 46
#Qualifying Exam Complete = 45
#Dissertation Proposal Complete = 18
#Did Not Respond = 43
table(DescData$Q11)
#No Response = 4
#Transferred Institutions = 12
#Did not Transfer = 175
table(DescData$Q12)
#Transferred with Advisor = 2
#Transferred without Advisor = 10
table(DescData$Q13)
#Women = 89
#Men = 87
#Agender = 1
#Gender Fluid = 1
#Gender Non-Conforming = 2
#Genderqueer = 1
#Non-Binary = 1
#Prefer Not to Say = 5
#ONE PERSON SELECTED WOMEN+AGENDER
Full.Data$Q15[Full.Data$Q15==1] <- "American Indian or Alaska Native"
Full.Data$Q15[Full.Data$Q15==2] <- "Asian"
Full.Data$Q15[Full.Data$Q15==3] <- "Black or African American"
Full.Data$Q15[Full.Data$Q15==4] <- "Hispanic, Latin, or Spanish Origin"
Full.Data$Q15[Full.Data$Q15==5] <- "Middle Eastern or North African"
Full.Data$Q15[Full.Data$Q15==6] <- "Native Hawaiian or Other Pacific Islander"
Full.Data$Q15[Full.Data$Q15==7] <- "White"
Full.Data$Q15[Full.Data$Q15==8] <- "Other Not Listed"
table(DescData$Q15)
#No response = 5
#Other not Listed = 2
#American Indian or Alaska Native = 2
#Asian = 60
#Black or African American = 5
#Hispanic, Latin, or Spanish Origin = 9
#Middle Eastern or North African = 4
#Native Hawaiian or Other Pacific Islander = 0
#Multiracial = 14
#White = 93
table(tolower(DescData$Q18))
```

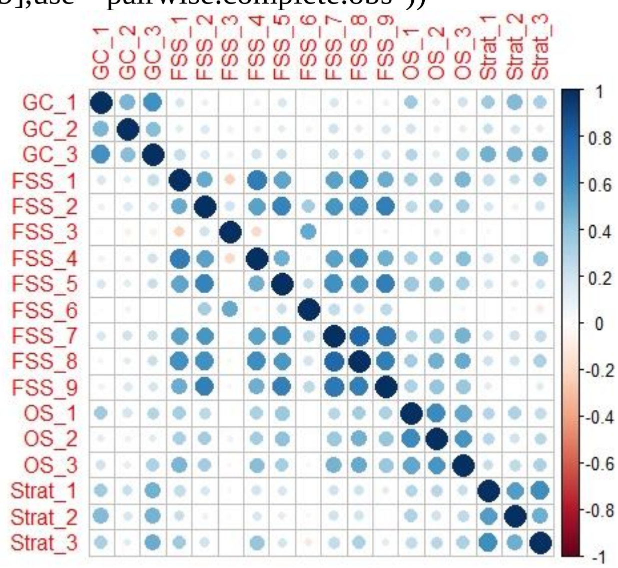
```
# Exploratory Factor Analysis -------------------------------------------
WData[2:43]<-as.data.frame(sapply(WData[2:43], as.numeric))

#Check Missingness
describe(WData)

#Cronbach Alpha
cronbach(FTP[2:5]) #Multiple Futures
cronbach(FTP[6:8]) #Future Possible Selves
cronbach(FTP[9:11]) #Near Future Job Attainment
cronbach(FTP[12:14]) #Career Connectedness
cronbach(FTP[15:17]) #Perceived Instrumentality
cronbach(FTP[2:17]) #Full FTP

cronbach(GS[2:4]) #Goal Commitment
cronbach(GS[5:13]) #Faculty Support
cronbach(GS[14:16]) #Organizational Support
cronbach(GS[17:19]) #Strategy
cronbach(GS[2:19]) #Full Goal Setting

cronbach(OP[2:5]) # Career Preparation
cronbach(OP[,c(6,7,9)]) #Persistence #NOTE removed persist_3 due to low internal
consistency
cronbach(OP[,c(2:5,6,7,9)]) #Full Outcome


#View Correlation Plots
corrplot(cor(WData[2:34],use="pairwise.complete.obs"), method = "color",addCoef.col =
"black",number.cex=0.6, number.digits =2,diag = FALSE,type="lower")
```



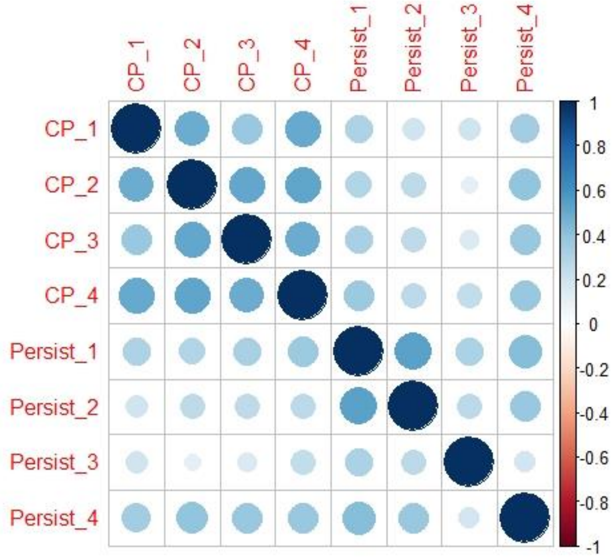

```
corrplot(cor(FTP[2:17],use="pairwise.complete.obs"))
```



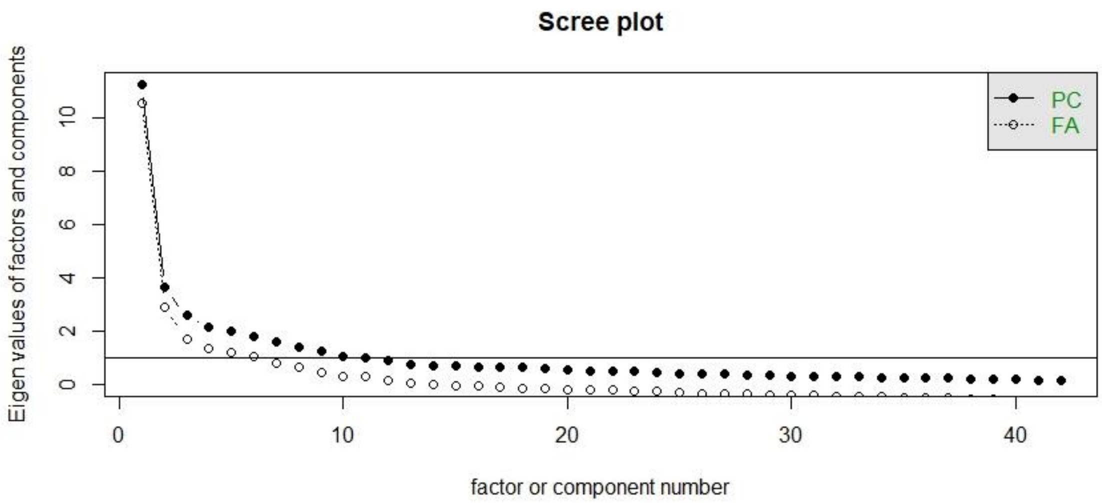
corrplot(cor(GS[2:19],use="pairwise.complete.obs"))



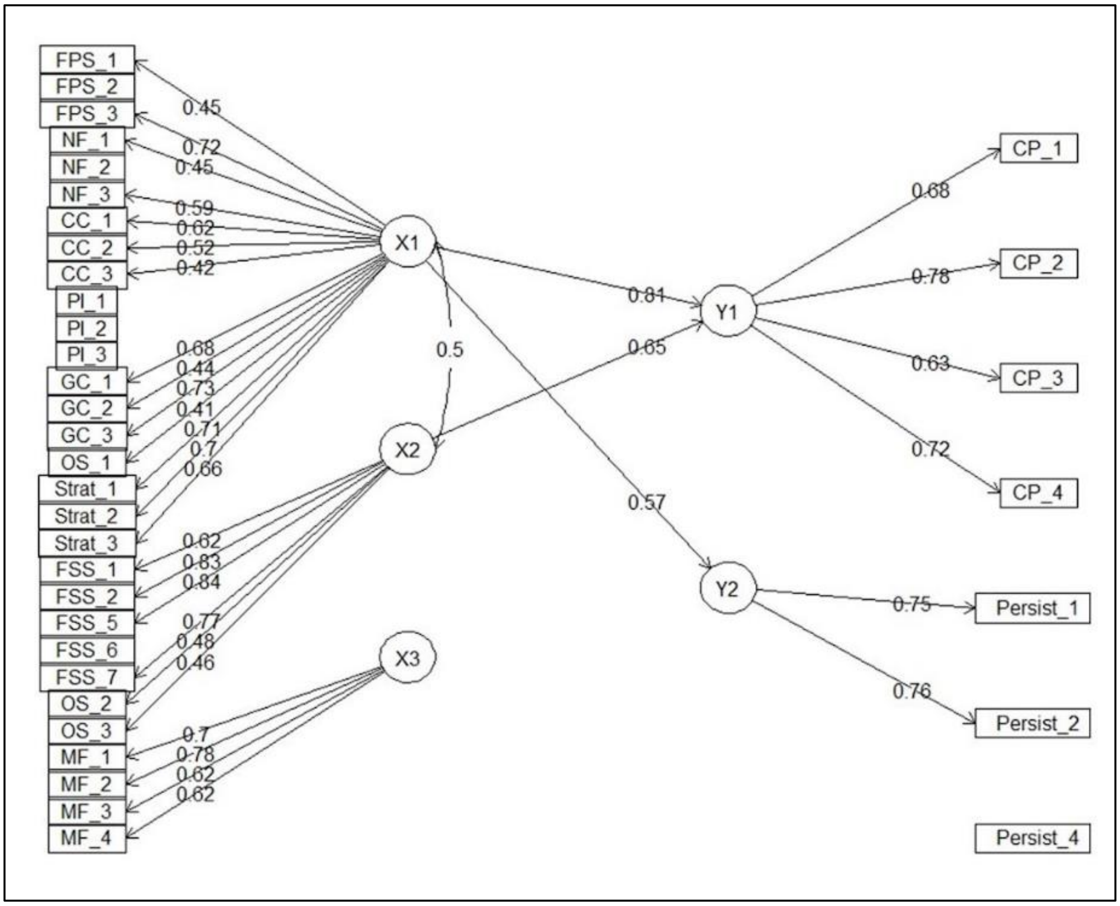
corrplot(cor(OP[2:9],use="pairwise.complete.obs"))




```
#Calculate Normality
skew(WData[2:43])
kurtosis(WData[2:43])

#All variables pass normality test for skew (<2) and kurtosis (<7)

cortest.bartlett(cor(WData[2:34],use="pairwise.complete.obs"), n=191)
KMO(WData[2:43])

#KMO overall passes with MSA = 0.87,
#One item is below the cutoff of 0.6, FSS_3 = 0.45

ev <- eigen(cor(WData[2:43])) # get eigenvalues
ev$values

#Plot the Scree Plot to determine number of factors
scree(WData[2:43], factors = TRUE)
```




```
#The scree plot has an elbow at 3 (change in slope) signifying 3 input factors

Nfacs <- 3
fit <- factanal(WData[2:23,],Nfacs,rotation="promax")
print(fit, digits=2, cutoff=0.4, sort= TRUE)

#promax rotation used due to its ability to have the items be highly correlated
#and computational advantage for large datasets

# ESEM V2 ----------------------------------------------------------------
kappa(WData[2:34])

#Matrix condition number is 31.01
#With this matrix condition number we conclude there is high multicollinearity
#Matrix is not well-conditioned therefore we use "mle" factoring method

#REMOVED COLUMNS 22:23 and 27:28. These are FSS 3,4,8,9. FSS_3 had low MSA,
FSS_4,8,9 had high multicollinearity.
ESEM <-esem(cor(WData[2:43],use="pairwise.complete.obs"), varsX =
c(1:21,24:26,29:34), varsY = c(35:40,42), fm= "mle", rotate = "promax", nfX = 3, nfY =
2,n.obs=191,plot=FALSE)
esem.diagram(esem = ESEM, cut = 0.40 , adj = 1, digits = 2)
```


FPS_1
FPS_2
FPS_3
NF_1
NF_2
NF_3
CC_1
CC_2
CC_3
PI_1
PI_2
PI_3
GC_1
GC_2
GC_3
OS_1
Strat_1
Strat_2
Strat_3
FSS_1
FSS_2
FSS_5
FSS_6
FSS_7
OS_2
OS_3
MF_1
MF_2
MF_3
MF_4
X1
X2
X3
Y1
Y2
CP_1
CP_2
CP_3
CP_4
Persist_1
Persist_2
Persist_4
0.45
0.72
0.45
0.59
0.62
0.52
0.42
0.68
0.44
0.73
0.41
0.71
0.7
0.66
0.62
0.83
0.84
0.77
0.48
0.46
0.7
0.78
0.62
0.62
0.5
0.81
0.65
0.57
0.68
0.78
0.63
0.72
0.75
0.76

6.5. Appendix E

Item Removed	Reasoning
FPS_2: My ideal career is different than one I think I can get. (R)	Low factor loading in ESEM that was below cutoff value of 0.40.
NF_2: I will be satisfied with the career I obtain immediately after graduation.	Low factor loading in ESEM that was below cutoff value of 0.40.
PI_1: What I learn in my graduate program will be important for success in my future career.	Low factor loading in ESEM that was below cutoff value of 0.40.
PI_2: I will use the information I learn in my graduate program in the future.	Low factor loading in ESEM that was below cutoff value of 0.40.
PI_3: I will use the research skills I am developing in my future career.	Low factor loading in ESEM that was below cutoff value of 0.40.
FSS_3: I am told the negative aspects of my performance by my advisor. (R)	Low measuring sample adequacy in Kaiser-Meyer-Olkin test.
FSS_4: I get regular feedback concerning how I am performing in my program.	Had high multicollinearity with other items that recommended removal from model.
FSS_6: In one-on-one meetings with my advisor, criticism is the focus. (R)	Low factor loading in ESEM that was below cutoff value of 0.40.

FSS_8: My advisor helps me find the information necessary to perform well in my future career.	Had high multicollinearity with other items that recommended removal from model.
FSS_9: My advisor is supportive when I face obstacles in my program.	Had high multicollinearity with other items that recommended removal from model.
Persist_3: In my graduate program, I work harder after failure.	Low internal consistency reported by Cronbach alpha coefficient.
Persist_4: I will graduate from my program with a doctoral degree.	Low factor loading in ESEM that was below cutoff value of 0.40.

(R) = reverse coded item

6.6. Appendix F

Faculty Advisor Support Interview Protocol

Hi <<name>>. Thank you for agreeing to participate in this interview.

First, let me introduce myself. My name is (NAME) and I am a (Research Assistant/Professor) at (Institution). I am interested in how students experience graduate education and how those experiences influence the way they think about their postgraduate plans. My interest came from (REASON)

I am going to ask you some questions about your experiences in graduate school, your career interests, and what has helped you prepare for your future careers of interest. Before we begin, I would like to confirm you are willing to participate and have our conversation video and audio recorded. You can withdraw from the research at any time, simply by telling me you would like to stop the interview. The recordings will be transcribed and analyzed for themes. Your privacy is very important to us and we will protect your confidentiality by using password protected files and pseudonyms. In addition, please refrain from naming specific people and places to protect third party identities as well as your own. If you forget, that is ok, we will use pseudonyms for everything.

Do you have any questions about the study? (If yes, answer any questions).

Do you agree to participate in this audio-recorded interview today? (If yes, continue; If no, thank the participant and close the zoom session).

We will not use your name or university in any publication of the research. Would you like to choose a pseudonym for yourself and your university?

1) Tell me about your graduate experience thus far.
   a) Major
   b) Year
2) What type of careers are you interested in after graduation? Why?
   a) How committed are you to [CAREER(S)]?
3) On a scale of 1 to 5 how prepared are you for [CAREER(S)]?
   a) Can you give me some specific examples?
   b) How did you find out about these opportunities?
   c) What skills have you developed that you think are transferable?
4) What has been the most helpful in preparing you for [CAREER(S)]?
   a) What has not been helpful in/prevented you from preparing you for your future career?
   b) In an ideal scenario, what other resources would be helpful in preparing you?
   c) Is there anything else that is important to your career preparation you have not mentioned?
5) On a scale of 1 to 5 how has your advisor helped prepared you?
6) What role has your advisor played in your experience?
   a) Frequency of interaction
   b) Relationship to: Mentor, acquaintance, friend, obstacle, adversary
7) What role has your advisor played in preparing you for [CAREER(S)]?

a) Update on progress

b) Feedback on performance

c) Opportunities/information

d) Planning

8) Does your advisor support you when you face obstacles? In what ways?

9) In which ways do you wish you had more support?

10) How would the ideal advisor help you prepare for [CAREER(S)]?

11) Who else is helping you feel prepared for you future career?

12) On a scale of 1 to 5 how much is [OTHERS] helping you prepare for your future career?

13) Have you ever thought about leaving your program? Why?

a) What makes you want to stay in your program?

14) What advice would you give to a new student entering your program/lab for figuring out what they want to do after graduation?