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Re(engineering) student success: constructing knowledge on students’ experiences in engineering education programs to encourage holistic student success

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If a group of engineering deans were asked whether students at their institutions were successful and why, what information might they immediately or subconsciously use to measure or gauge the engineering students' success? If only academic performance outcomes like GPA, individual course grades, or graduation rate race to their minds, then their rationale aligns with the majority of researchers. My research seeks to shift the mindset that frames engineering student success mainly within the boundaries of academic performance measures. By measuring students' perceived autonomy, competence, social integration and relatedness within their programs, and aspirations after graduation, one can more accurately judge whether engineering students are achieving holistic student success. By utilizing surveys and exit interviews for freshmen Summer Bridge Program (SBP) participants, interviewing continuing and past SBP participants, and surveying engineering seniors, this research gathered more in-depth information on students' experiences. In turn, one can better understand how the structures of engineering summer and undergraduate programs either contribute to or detract from student success and motivation. Results from SBP freshmen indicated that community building, structured studying, real-world experiences, residential life, and mentorship were perceived as valuable components by the students. Also, a perceived difficulty gap, based on students' prior engineering experience(s), was uncovered. For continuing SBP students, there was an emphasis on Black community, leadership, and discourse when moving from SBP to larger departments. Lastly, within the seniors, we found that students tend to choose engineering careers regardless of their undergraduate experiences. This information can be used in practice for enhancing programmatic planning and design as well as potentially developing novel program components that contribute to students becoming more self-determined, motivated engineers. It is my hope that one day in the near future, engineering education faculty, administrators, and leaders will cultivate and measure success based on a more comprehensive assessment of lived experiences and better recognize how their decisions regarding programmatic structures impact students' success and motivation.

Keywords: engineering student success, self-determination theory, motivation, aspirations, URM, undergraduate programs, engineering research to practice

DEDICATION

This dissertation is dedicated to my mom, Shelia Bradley, for the countless sacrifices she made to help me get to where I am today. I also dedicate this work to my family, friends, and supporters, who always believed in me, even when I doubted myself. I am thankful for every pep talk, listening ear, and encouraging word I received throughout this journey.

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INTRODUCTION

Context

The existing state of engineering education literature reveals a gap or disconnect concerning how we research students' experiences and how engineering programs impact those experiences. Historically, research has focused on factors that contribute to engineering students' success. However, this success is typically defined by academic performance alone. This mindset had led engineering education researchers to overlook other aspects of success that cannot be measured simply by analyzing letter grades or grade point averages. Students' experiences and success in formal learning environments are dependent on a variety of factors. Additionally, student success is impacted by experiences and interactions that may occur outside formal classroom settings.

In an attempt to critically examine the ways programs impact students, this work takes a step away from trying to figure out what students can do on their ends to be more successful. In contrast, we approach researching engineering students' experiences in programs with the question in mind, "what can programs do to better support students and ensure their success?" By investigating what information regarding which changes may need to be made at the institutional level, engineering departments will be able to best attract, serve, and support students.

A portion of this work is dedicated specifically to catalyzing progress for underrepresented students who are part of diversity programs like the Summer Bridge Program. These types of programs have had a long-standing impact on the journeys of many past and present scholars. Studies have not focused enough on the comprehensiveness of their benefits. This is partly due to historical framing and viewpoints that focused on academic preparedness for “at-risk” students. Continual improvement is essential to determine if the ways programs were run when they were created (or years ago) are still the best ways of running them today. This work calls attention to the evolving needs today's and tomorrow's students express.

The second portion of this work was geared toward generating data suggesting ways we can better assist past participants of programs like Summer Bridge once they begin matriculating through their respective degree programs. Too often, the research and support efforts cease once transition and support programs end. This work pushes for the continued support of students and sustained involvement from leaders and professionals in engineering education.

The final portion of this dissertation expanded to investigate the experiences and success of engineering seniors within various departments in a college of engineering. Within this section, the emphasis is placed on anticipated career choices and the reasons why students may make certain choices. We were highly interested in students' self-perceptions and interactions in engineering program contexts and wanted to unveil whether these phenomena had an impact on the desire to pursue jobs in similar, professional contexts.

Threading Three Groups of Engineering Students

Throughout this work, Self-Determination Theory (SDT) was used to examine engineering education programs, their components, and their impacts on students, in novel ways. The theory was developed by psychologists, Ryan and Deci, and allows researchers to simultaneously collect information on a host of constructs, students' perceptions, and their goals and aspirations, among other information (Ryan & Deci, 2000). SDT was selected for this specific study because of its ability to gather information on engineering students above and beyond the state of current engineering education research. With SDT, we were able to take a more comprehensive approach to investigate students' journeys through engineering programs.

SDT and its accompanying instruments served as the primary source for the development of surveys, interview protocols, and the codebook used in this work. The theory also allowed us to engage in meaningful discussions and provide evidence-backed practical recommendations for bettering engineering education spaces. More specifically, SDT was used to frame, document, and systematically analyze students' perceptions among three different groups of participants, at three distinct points in their engineering education journeys.

Introduction to Studies

This manuscript-style dissertation includes three studies that were designed specifically to investigate students' experiences, success, and the role engineering programs play. These studies contribute new perspectives on ways to conceptualize student success and provide insight into ways engineering education leaders and educators can enhance programs for future students.

Study 1: Success Reimagined: Examining Summer Bridge Students' Experiences and Success

Study 1 focused on incoming freshmen students who participated in the Summer Bridge Program in 2022. A baseline survey and semi-structured exit interviews were utilized to delve into students' experiences and success within the program. An emphasis was placed on investigating how the program impacted those experiences (from an SDT viewpoint).

Additionally, special attention was paid to figuring out which specific components contributed to or detracted from students' experiences and success.

Research Questions

S1-1. How does the structure of a Summer Bridge Program (SBP) affect students’ experiences from a self-determination viewpoint?

S1-2. Which SBP characteristics and experiences either contribute to or detract from students’ self-determination and success?

Study 2: Summer Bridge and Beyond: Examining Continuing Students’ Experiences

Study 2 focused on the journeys of past participants of the Summer Bridge Program who are now matriculating through their undergraduate programs in various departments. Semi-structured interviews were conducted to learn more about students' experiences during and after the summer program. Also, information was gathered and analyzed concerning differences in experiences within the two contexts (i.e., Summer Bridge versus undergraduate degree programs).

Research Questions

S2-1. How does the structure of a Summer Bridge Program (SBP) affect students’ experiences and success in engineering either during or after the program?

S2-2. Which program characteristics and experiences either contribute to or detract from past SBP students’ experiences and holistic success in engineering?

Study 3: To Be or Not to Be: Engineering Seniors’ Experiences and their Impacts on Career Plans

Study 3 explored the experiences of engineering seniors across an entire college of engineering. Using a Qualtrics survey, data was collected and used to perform a binary logistic regression. This study also allowed for further inquiry into specific concerns, experiences, and challenges that engineering seniors face as they near graduation.

Research Questions

S3-1. Using SDT as a lens, how does the structure of and experiences within an undergraduate engineering program affect engineering seniors planning to continue along engineering or non-engineering career paths?

S3-2. Are students' perceived competence, perceived choice, and relatedness scores significant predictors of engineering versus non-engineering career post-graduation plans?

Overarching Research Objectives

The main goal was to determine how engineering programs (e.g., Summer Bridge Program and undergraduate degree programs) contributed to or detracted from students' experiences and holistic success. Holistic success is operationalized as success inside and outside the classroom (but still in the context of engineering communities), as well as feeling successful within. Gauging SDT constructs like perceived autonomy, competence, and relatedness provided ways to analyze how and why certain students may experience engineering programs differently. The aim of the three included studies was to capture more telling information about the ways students feel at various points in the academic journey and the role programs play. These points include the transition period between high school and freshman year, the transition from Summer Bridge to undergraduate school, and the transition from senior year beyond.

CHAPTER II

SUCCESS REIMAGINED: EXAMINING SUMMER BRIDGE STUDENTS' EXPERIENCES AND SUCCESS

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Abstract

Through this research, we explore the journeys of eighteen students who participated in a Summer Bridge Program (SBP), with a focus on their experiences through the lens of Self-Determination Theory. A focus on how the structure of the program impacts students' perceived autonomy, competence, and relatedness in educational contexts has proven useful in non-engineering fields. Evaluating these constructs are of interest in engineering education, especially with the well-established need to attract and retain students from underrepresented backgrounds in hopes of further diversifying undergraduate engineering programs and, more broadly, the STEM workforce. In this study, we distributed a pre-program survey to establish a baseline for our constructs and then conducted one-on-one interviews to better conceptualize how the experiences of students in a SBP are affected by the design or structure of the program itself. The empirical data includes Intrinsic Motivation Inventory and Aspirations Index scores as well as transcripts from semi-structured dialogues with participants (Kasser & Ryan, 1993, 1996; Ryan & Deci, 2000). The findings indicate that although academics are the primary focus of the program (and the primarily used criteria for student success in engineering), the students deemed the most valuable components contributing to their experiences and success as those parts that increased their relatedness among peers and engineering leaders. Further, while more specific components of the program contribute to positive experiences and developments in various areas, careful considerations and intentionality is warranted to prevent potentially negative or ineffective experiences for future cohorts. This information can be used by engineering education leaders and programs directors interested in continuous improvement.

Keywords: Summer Bridge, engineering education, URM STEM, engineering program, Self-Determination Theory

Examining Summer Bridge Students' Experiences Using Self-Determination Theory

This article explores the experiences of Summer Bridge Program (SBP) participants and investigates how the program's components impact those experiences. The study is uniquely situated along the boundaries of technical engineering research, social science research, and student affairs perspectives. Examining how underrepresented students navigate the programs that have been intentionally designed for them in efforts to correct historical issues has proven useful for uncovering where the educational system falls short of properly supporting students. However, previous research has mainly focused on either academic performance alone or on one dimension of students' experiences. For example, studies typically focus on URM students' academic performance and factors impacting that performance and compare it to the performance of control groups (E.g., White students in engineering) (Grandy, 1998; Lord et al., 2009). On the other end of the spectrum, studies tend to investigate how URM students experience (or never experience) a sense of belonging or social integration at universities, without regard for other aspects of their experiences and without considering the role university structures and programs play in impacting belongingness (Ahmed et al., 2021; Pearson et al., 2018). By expanding the focus to encompass students' perceptions of autonomy, competence, and relatedness within the context of an SBP, we contribute knowledge on how the structures of engineering transition programs can impact these perceptions for many URM students. We also contribute a more comprehensive viewpoint for assessing student success in engineering education, based on direct student perspectives.

This research addresses the need to change the way engineering educators frame student success. With the existing issue pertaining to recruiting and retaining diverse engineering students, and a subsequently more diverse STEM workforce, it is imperative to examine the experiences of current students and how programs shape those experiences (Smith-Doerr et al., 2017; Watson & Froyd, 2007). This study set out to explore students' perceived competence, autonomy, and relatedness as they began an SBP for recently admitted freshmen engineering majors entering college in the Fall following the program's conclusion (Ryan & Deci, 2000). We examined how the program and its components impacted students' basic needs as well as whether and why students in the same cohort may have different experiences. Based on a baseline quantitative survey distributed at the beginning of the SBP and 18 exit interviews, we analyzed students' lived experiences and systematically organize this information. Looking across the cohort, we synthesized emergent themes about students in accordance with demographics, academic preparedness, and K-12 experiences. Similarly, we used gathered data to decipher how and why students may speak differently about their experiences completing the same program.

The current study intended to call for awareness of the holistic nature of student success in engineering transition programs at institutions of higher learning. We acknowledge the contextual nature of engineering programs and the degree of variance that may exist across institutions. Nevertheless, we are confident in the novelty and quality of the findings derived from investigating existing engineering education issues using a non-traditional theoretical lens and framing. This article sheds light on students' perceptions and delves into their pursuit of success within an SBP. It begins with a review of relevant literature, showing the position of this study and the gap it intended to fill. We detail the methodology used to develop and distribute the baseline survey. We walk through the creation of an interview protocol and accompanying codebook used to gather in-depth information in addition to the quantitative survey responses. Results are presented in hopes of telling the student participants' stories and highlighting their progress as they journeyed to and through the SBP. We provide a discussion of the results and themes as well as justifications and explanations. To conclude, we provide a brief conclusion, recommendations, and future directions. We also take a look forward toward continuing to improve SBPs, and engineering education programs in general, for future generations of students.

Situating the Study

Persistent Issues in Engineering and within typical SBP Student Populations

Educational inequalities in the United States have had and continue to pose lasting consequences on students in higher education. To begin, children belonging to a lower social class in the United States experience major barriers to reading and math preparedness (Mickelson et al., 2013; Ukpokodu, 2018; Valla & Williams, 2012). An analysis of data produced by the National Center for Education Statistics' Early Childhood Longitudinal Study conducted with the 2010-2011 kindergarten class revealed that Black and Hispanic English language learner (ELL) children begin school with the greatest disadvantage due to links between their ethnic groups and social class (García & Weiss, 2015). It is not race itself, then, but the poverty and other things that too often go along with being a minoritized child in America, that compound disadvantage (García & Weiss, 2015). Although terms such as "culturally deprived" and "disadvantaged" have become controversial in the United States, their use began in the latter 1950s in an attempt to emphasize the view that differences in educational performance were linked to environmental rather than genetic or other biological factors (Martinez & Rury, 2012).

Garcia and Weiss (2015) found that in addition to the high odds of living in poverty (as do 46% of Black and 63% of non-English speaking Hispanic children), these disadvantages include living with one parent (as do 65% of Black children) and lacking access to preschool (as do 53% of Hispanic children). These statistics become even more alarming when comparing underrepresented students' lack of access to only 40% of White children and less than 40% of Asian children (García & Weiss, 2015).

Racial inequities in STEM specifically impact the future earning power of URM groups and reinforce educational norms in the U.S. With knowledge of the persistent issues in the U.S. education system and STEM, researchers have begun to question whether the pipeline even leads to a destination that is viewed as desirable for and by URM students (Vakil & Ayers, 2019b, 2019a). A history of denying URM students, from as early as kindergarten, resources supporting their attainment of STEM degrees motivates some URM students to enter and change STEM cultures and policies. Many other URM students are deterred from STEM altogether. In turn, this lack of participation reinforces (or lets remain intact) the existing culture and imbalances within STEM fields. The role of educational inequality has even been found to cause intergenerational income persistence, meaning the children of high-income adults become high-income adults while children of low-income adults become low-income adults (Bloome et al., 2018). This vicious cycle and the reinforcement of these trends in the U.S. disproportionately affect URM students that STEM programs often try to recruit and retain.

Generating and sustaining URM student participation in STEM fields is necessary to combat imbalances. Researchers found a persistent ethnic inequality in STEM degree completion which is not prevalent in other fields (Riegle-Crumb et al., 2019). At one large, public U.S. institution, 23% of all students left engineering after declaring their major. Asian and White students left at rates at or below 23%, compared to 28% of URMs leaving engineering. While this 5% difference may not seem large at the surface, it is significant when realizing that the URM students only made up 9% of the initial total of engineering majors at the institution (Whitcomb & Singh, 2021). Even more alarming, 65% of URM students left physics majors, not including those who never reached the point of declaring the major (Whitcomb & Singh, 2021). This case is one of many illustrating the importance of retaining the URM STEM students that institutions recruit. Recruitment efforts are in vain if the proper support and attention are not dedicated to helping students succeed once they join STEM.

Student Success in Engineering

To a large extent, the examination of engineering student success has been one-dimensional. For example, researchers from Binghamton University investigated who succeeds in STEM and found that successful engineering students at their institution were disproportionately Asian students who had “good” mathematics preparation (Kokkelenberg & Sinha, 2010). They also stated that the number of female engineering students was small and made a point to define success as "declaring STEM as a major and graduating from a STEM field." Researchers at the University of Michigan suggested that the modeling of freshman engineering success be distinct from non-engineering students. The researchers based success solely on academic performance and made a controversial claim that social engagement may not be an important element for engineering students' success (Veenstra et al., 2008).

Researchers have gone to the extent of aiming to distinguish student success from thriving and coined the term *engineering thriving*. These researchers define engineering thriving as “the process by which engineering students develop optimal functioning in undergraduate engineering programs” (Gesun et al., 2021, p. 20). One could argue that student success ought not to be isolated from the concept of students thriving. Rather, engineering student success should be viewed comprehensively and encompass a wider array of factors affecting students’ development and collegiate experiences. Students' satisfaction in those areas, in turn, contributes to their thriving. In the work reported in this paper, we sought to take a step away from solely basing success on academic performance outcomes and a step toward considering holistic student success in engineering, encompassing student motivation and relatedness to the field. More recently, there have been some studies that stepped away from the academics-only approach to gauging engineering student success.

Marbouti et al. (2020) conducted a cluster analysis to examine engineering student success based on academic performance and participant demographics. Results revealed that Hispanic students were less likely to apply for aid and took fewer courses per semester, contributing to prolonged time to degrees and a greater amount of student debt. It is important to note that Marbouti et al. study's strengths stem from the attention to the role of student support systems like financial aid play in engineering student success, as opposed to studies only looking at formal learning and academic factors. May and Chubin (2003) highlighted the importance of institutional commitment over plans like affirmative action alone. May and Chubin also called attention to minority engineering programs (MEPs) focusing too heavily on academics without incorporating other "student services" aspects necessary for student success.

Boles and Whelan (2017) investigated factors contributing to student attrition from engineering and engineering student success issues at three universities in Australia through a literature review and case study investigations. Through the lens of a social-cognitive theoretical concept, self-regulated learning, Boles and Whelan found student engagement to be central to successful learning. Like Marbouti and colleagues, these researchers hold that external factors like jobs and financial pressures impact the level of student success a student is likely to achieve (Boles & Whelan, 2017; Marbouti et al., 2020). While these studies yielded important findings, they examined how factors outside the classroom affected academic performance and viewed academic performance as the "end-all." Factors like social integration and student support are treated as a means to achieve academic success as opposed to being examined in congruence with academic success as equal contributors to holistic student success.

On the other hand, some researchers in engineering fields have taken more critical approaches toward researching student success. Newman (2011) specifically investigated the role faculty relationships play in engineering success for African American students. Three major findings were presented to describe the students' views: lone wolves, low expectations of faculty, and lack of same-race faculty (Newman, 2011). Notably, the lone wolves referred to the faculty members African American students viewed as mentors for their academic and professional goals. This study highlights the importance of being socially integrated or connected within engineering education programs. Long and Mejia (2016) suggested that instructors and administrators have open dialogues with diverse student populations to develop a consciousness of barriers, challenge any deficit-based thinking, and create empowering engineering pedagogy that celebrates and includes all cultures. Holly and Mastra (2021, p. 800) called attention to the ways that researchers, and even funding institutions like the NSF, cite the issues related to underrepresentation without any discussion of how Whiteness "instituted the standards of admission, acceptance, and success that affirm the cultural norms of White people while demeaning others."

Student Success in Social Science and Student Affairs

Student affairs practitioners are guided by theoretical concepts related to holistic student development which model novel perspectives appropriate for reexamining engineering student success. Lane and colleagues (2019) discussed the importance of various capabilities students need for success during and after their undergraduate years. They contended that discipline-specific skills are not enough and that students need to develop productive mindsets and relationships with others, among other needs (Lane et al., 2019). This perspective is valuable for examining engineering programs. Existing engineering education literature shows an apparent disconnect between student success practitioners' ideals and how engineering students' success is often measured, communicated, and understood.

Psychology and student development theories and concepts are useful for examining the comprehensive picture of student success and well-being. Third-wave student development theories focus on holistic student development and push for the movement from social justice to social change (i.e., theory to practice) (Patton et al., 2016a). These theories also focus on larger structures of inequality, power, and oppression, specifically as they relate to the higher education system (Abes et al., 2019). These theories' focus on creating tangible change and analyzing students' development across multiple dimensions is in alignment with the lens used to investigate the engineering education research questions for the present study. Educational psychologists examine learners' intrinsic motivations through the use of theory and theoretical concepts. These include but are not limited to Flow Theory, locus of control, and Self-Determination Theory (Schunk et al., 2014).

Connecting the Dots

While it is apparent that academics are a major part of a successful undergraduate journey, professionals must consider how students succeed from a bigger picture. A vast amount of research has been devoted to studying how and why students performed (or did not perform) well academically. More recently, an increased number of studies focused exclusively on the role social integration plays in student success, especially among URM students. To bridge these lines of research together, we examined how an engineering transition program impacted these areas, and others, simultaneously. Figure 1 shows our conceptual framework used to examine the impact of the program.

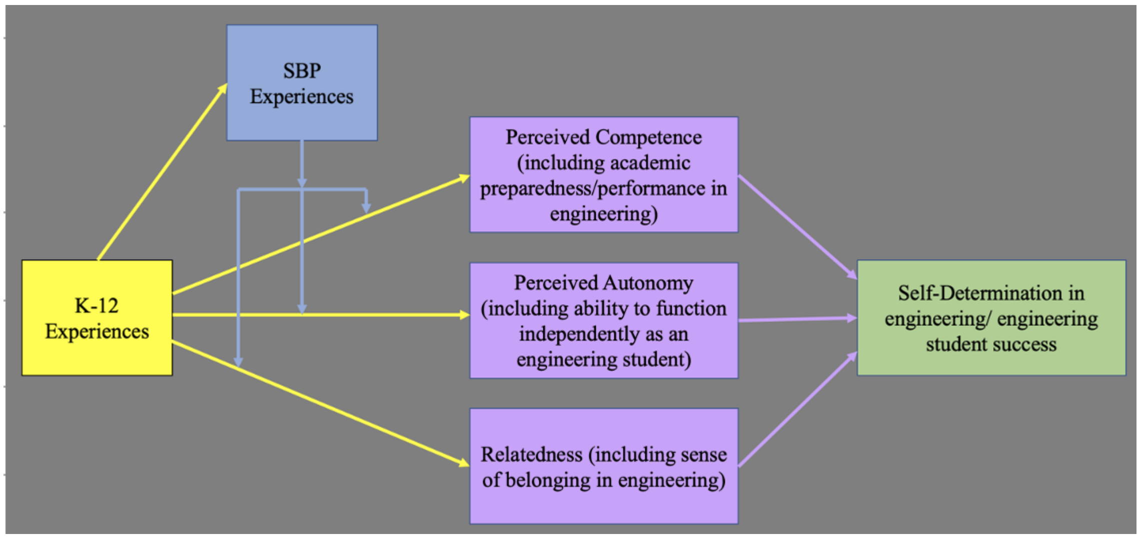

Figure 2.1 Conceptual framework.

Engineering education is uniquely positioned at the intersections of interdisciplinary fields, and SBPs serve as an optimal setting to examine student success and experiences using a comprehensive viewpoint. SBPs not only strive to ensure academic preparedness but also include components like residential life and project-based learning that impact other areas of students' overall well-being. In this study, we looked at these phenomena through the lens of Self-Determination Theory. This study was conducted to shed light on the ways an engineering program impacted multiple areas outside the typically highlighted one, academic performance. Our conceptual framework was used to guide the inquiry into two research questions.

Theoretical Lens

Self-Determination Theory (SDT) is underutilized in STEM but offers novel avenues to gain insight into persistent engineering education issues. SDT was developed by psychologists Ryan and Deci and is a macro-theory comprised of six sub-theories (Ryan & Deci, 2000). The overarching goal or intention of SDT was to offer a perspective opposing the notion that the most plausible way to persuade people to perform tasks was to reinforce their behavior with rewards (E. L. Deci et al., 2001). In the current study, two sub-theories were primarily used to guide the framing of the research questions, decisions to use certain instruments and methods, and the discussion of the results.

The first sub-theory, Basic Psychological Needs Theory (BPNT), holds that psychological well-being and optimal functioning are predicated on three basic needs: competence, autonomy, and relatedness (Adams et al., 2017). Autonomy, competence, and relatedness are thus the major components included in the BPNT. The use of SDT's BNPT allowed for additional insight and assisted in generating knowledge above and beyond the state-of-the-art present in existing engineering student success literature. As previously stated, existing literature mainly examined student success from an academic performance viewpoint or examined one specific aspect of engineering students' affective experiences as it related to academic performance. This also was typically done without making connections to how the structure of engineering programs impacted student success and motivation. Therefore, BPNT allowed for reconceptualizing these phenomena.

The second sub-theory, Goal Contents Theory (GCT), is grounded in the differences between intrinsic and extrinsic goals and their impact on wellness and motivation (Ryan & Deci, 2000). This mini-theory is directly tied to the investigation of students' aspirations and the types of goals that motivate their behavior. An appropriate, pre-existing, validated survey instrument that could be used to investigate SBT students' goals and aspirations is the Aspiration Index (AI). The AI consists of seven categories created to assess aspirations. The six categories included in the present study were wealth, fame, image, personal growth, relationships, and community. The AI allowed us to split our analysis based on intrinsic and extrinsic goal categories. The extrinsic aspiration score is based on the wealth, fame, and image subscales, and the intrinsic aspiration score includes the personal growth, relationships, and community subscales. The AI gave way to useful information about why SBP students may have chosen to pursue engineering and data on how their motivations changed as a result of SBP participation. Fittingly, the GCT helped guide the examination and discussion of the AI survey items and associated findings (Reeve, 2012).

SDT captures information missed by existing studies that utilized theories and methods with narrower or unidimensional focuses. While students may perform well in certain aspects of their college programs, such as earning a certain letter grade, students' affective connections to engineering should be more heavily weighted as a component of student success. It is the affective factors contributing to attitudes and feelings towards engineering that may more accurately correlate with students' sense of belonging and motivation to persist and engage in engineering spaces. In our work, we used SDT's comprehensive elements to investigate student success from multiple dimensions and determine how engineering programs motivate or demotivate students who enter an SBP with different levels of perceived competence, autonomy, and relatedness. Emphases are placed on practical implications for program directors, administrators, and faculty members committed to cultivating student success in engineering education. Building on studies attributing student success to more than academic performance outcomes, but also delving into student wellbeing from unique viewpoints using a framework not typically employed in engineering education research, valuable contributions were made (Bombaerts & Spahn, 2021; Dell et al., 2018; Trenshaw et al., 2016).

Research Questions

1. How does the structure of a Summer Bridge Program (SBP) affect students' experiences from a self-determination viewpoint?
2. Which SBP characteristics and experiences either contribute to or detract from students' self-determination and success?

Methods

Participants

The SBP began on June 5th, 2022, and ended on July 8th, 2022. All students were housed in an on-campus residence hall during the program. Data collection consisted of a quantitative baseline survey and qualitative interviews. Participants were part of the 2022 cohort completing the Summer Bridge Program at [university in a southern state]. Seventeen of the 19 students who began the program identified as Black, 1 identified as White, and one identified as Hispanic. One student withdrew from the SBP but completed the baseline survey. All students indicated an engineering major as their intended undergraduate major for the fall 2022 semester. Additionally, all had been accepted to those programs at the time of their SBP application. Table 1 lists the participant pseudonym and demographics.

Table 2.2 Participant summary.

Pseudonym	Engineering Discipline	Ethnicity	Reported Prior (K-12) Engineering Experience	In-State High School Rankings	Comments
Auria	Chemical	Black	Yes	B	
Brittney	Biomedical	Black	No	A	
Cameren	Electrical	Black	No	B	Non-binary
Candace	Mechanical	White/Asian	Yes	Out of state	Changed ethnicity
Gavin	Computer	Black	Yes	B	
Ken	Mechanical	Black	No	B	
Lacey	Chemical	Black	No	Out of state	
Michael	Biomedical	Black	Yes	C	
Patrick	Civil	Black	No	Private (unranked)	
Quinton	Mechanical	Black	Yes	Early college (unranked)	
Rachel	Biomedical	Black	Yes	7.00	
Shane	Aerospace	White	No	6.60	
Sydney	Biomedical	Black	Yes	Residential (unranked)	Withdrew
Taylor	Civil	Black	No	6.07	
Travis	Industrial	Black	Yes	Private (unranked)	
Victoria	Chemical	Black	No	6.40	
Warren	Electrical	Black	Yes	5.87	
Whitney	Aerospace	Black	Yes	5.80	
Zion	Mechanical	Black	Yes	6.07	

The present study coupled quantitative, baseline survey metrics and qualitative interview data to better understand how students' experiences were impacted by their self-determination in the context of the SBP. Pre-program, baseline surveys were distributed on June 8th, 2022. Exit interviews were conducted from July 5th, 2022, through July 7th, 2022.

Pre-Program Survey

A pre-SBP survey was designed based on two SDT instruments: the pre-existing, validated Intrinsic Motivation Inventory (IMI), and the Aspirations Index (AI). The beginning of the survey presented details about the study, its purpose, and appropriate contact information. It also included information about confidentiality and the right to withdraw without penalty at any time. This was followed by a voluntary consent item and demographic inquiries such as age group, ethnicity, and whether the participant had previous engineering experience (in K-12).

Six IMI subscales were used for the first main portion of the SBP baseline survey: interest/enjoyment, perceived competence, effort/importance, perceived choice, value/usefulness, and relatedness. Each subscale was comprised of 5-8 statements regarding the participants' involvement in the SBP. Some statements were intentionally written to be reverse-scored. The subscales were scored using a 7-point Likert scale, where a 1 corresponded to "not true at all," a 4 corresponded to "somewhat true," and a 7 corresponded to "very true."

The second portion of the survey included 6 subscales from the AI: wealth, fame, image, personal growth, relationships, and community. The survey presented a list of goals 3 times in 3 separate Qualtrics blocks and asked the participants to respond to the following questions: 1) How important is this goal to you 2) How likely is it that this will happen in your future 3) How much have you already attained this goal. Respondents used a 7-point Likert scale to rate the importance, likelihood of attainment, and attainment thus far. This process was comparable to the rating procedures used in the preceding IMI section of the survey. The survey concluded with an open-ended, optional item asking the participants to type any other information they would like to relay about their experiences in the SBP.

Interview Protocol Development

Semi-structured interviews are a specific type of data collection that allows researchers to ask questions based on a framework. Semi-structured interviews were fitting for this inquiry because they typically include a set of questions that must be asked, but also allow for flexibility with follow-up questions. An SDT interview protocol was crafted using the same scales included in the survey design process (IMI and AI). In alignment with many of the procedures outlined by Jacob and Furgeson (2012), a topic was selected, existing research guided the present study's questions, scripts were developed for the beginning and end, and questions were intentionally open-ended. This protocol included a section dedicated to organizing the following information about each participant and their interview: interviewer/notetaker(s), pseudonym, date/time, engineering discipline, group membership of interest, and summary of survey responses. Next, a guiding prompt to begin the interview was developed and made readily available in case the interviewer needed to reference it. The bottom of the first page included a space for any additional notes. The main body of the protocol consisted of 12 core questions or requests. Each core question or request was accompanied by probing questions that could serve as follow-up questions to typical, anticipated answers. For instance, one core request was "Tell me about your first engineering experience (K-12 or SBP)." Probing questions for that core request included "How do you think having that experience early on impacted your Summer Bridge experience?" for those who spoke about a K-12 experience or "Do you think having your first experience in Summer Bridge as opposed to K-12 impacted your Summer Bridge experience?" for those who did not speak about K-12 experiences.

Each question was directly mapped to the construct or concept it intended to gather information on (E.g., interest/enjoyment, relatedness, etc.). The end of the protocol included a guiding prompt to conclude the interview as well as post-interview tasks that the interviewer needed to complete.

Survey and Interview Procedures

Surveys were distributed via Qualtrics while students were all in the same setting. The researcher's contact information was sent, along with the survey link, from Qualtrics to the participants' school-affiliated email addresses. Participants were required to grant consent before proceeding with the survey. The survey took approximately 20-30 minutes to complete. The survey could be taken on any digital device, including laptops, phones, and tablets. All participants had access to Wi-fi because the surveys were completed in a university classroom. Individual, semi-structured exit interviews were conducted with each of the eighteen students comprising the 2022 SBP cohort. Participants were asked to sign-up for a scheduled time slot, aligning with the program schedule. Interviews were conducted over three days. The dates were July 5th, 6th, and 7th, 2022. The interviews were conducted in a reserved room within a university building on each of the three days. After each participant granted voluntary written and verbal consent, each interview was audio recorded on an Olympus recorder. The recorder was checked out from the university digital media center, and the interviewer was the only one with access to it throughout the interview dates. Interview audio files were transferred to a university-owned laptop at the conclusion of each day and were immediately transferred to a password-secured Dropbox account, thereafter. Before the Olympus recorder was returned to the library, all remaining audio files were permanently erased from the device.

Coding and Theme Synthetization Procedures

Deductive (or concept-driven) coding was adopted, meaning codes were developed from the concepts of an existing theory (I.e., SDT). In deductive coding, researchers formulate a codebook consistuing of an initial set of codes, typically based on the research questions and theoretical framework (Decuir-Gunby et al., 2011). The codebook used in this study was developed based on the research question as well as the interview protocol and its foundational SDT metrics. Each of the 23 codes was accompanied by a description. Additionally, most codes included an example of instances or quotations that could be misconstrued as aligning with the description, beneath the heading “what it’s not.” More appropriate examples were included beneath “example.” At our discretion, new codes were allowed to be added during data analysis. All codes were individually entered into Dedoose coding software, along with their descriptions.

Interviews were coded using Dedoose, and themes were synthesized during a meaning-making process. Audio files from the interviews were transcribed and returned from the Rev transcription service. Following that, each participant’s transcript was carefully analyzed, and codes were assigned to sections of text that fit their descriptions. If a section fit multiple descriptions, multiple codes were allowed to be assigned. Once this process was completed for each participant's transcript, the primary researcher reviewed the transcripts for an additional iteration to confirm that the existing coding was appropriate. This iteration also served as an opportunity to add any additional codes to text that may have been overlooked in the initial analysis.

Once all transcripts were coded, the primary researcher began synthesizing prominent, emergent themes across the SBP participants. This process entailed crafting detailed tables presenting the proposed themes and searching for quotations from each participant that could be used as qualitative evidence to support the prevalence of the themes. If adequate evidence could not be found to support an initially proposed theme, it was rejected. In contrast, if sufficient evidence was found to back the relevance of the theme, then it was included in the remainder of the data analysis and for dissemination purposes.

Validity and Reliability

The IMI and AI were originally created and validated by Ryan and Deci (R. Ryan & Deci, 2000). Since then, other researchers have added a host of validation articles for the IMI (Deci et al., 1994; McAuley et al., 1989; Plant & Ryan, 1985; Ryan1982.; R. M. Ryan et al., 1983, 1990, 1991). Likewise, the AI's validation has been corroborated in at least ten articles (Gollwitzer & Bargh, 1996; Kasser, 2002; Kasser et al., 1995; Kasser & Ryan, 1993, 2001, 2000; R. M. Ryan et al., 1996; Schmuck et al., 2000; Sheldon & Kasser, 1998; Williams et al., 2000).

Trustworthiness and credibility of the qualitative data were established through the standardization of the interview protocol and accompanying procedures. Transcripts, excerpts, and themes were directly derived from the participants' narratives. Also, each interview was analyzed twice by the primary researcher who submitted the IRB protocol, successfully passed qualitative research courses and required research trainings, and coded data on a previous project, to ensure coding accuracy. Themes were created using supporting evidence (E.g., quotes copied into organized tables for each participant who spoke about experiences or ideas supporting the prominence of a theme) to ensure that the presented findings were representative of the group. Additionally, originally proposed themes were rejected or revised if they did not have enough supporting evidence substantiating them.

Results

Quantitative Summary

The pre-survey was administered to participants during the first few days of the SBP and served as the baseline to examine their progression through the program's completion. The average scores for the six included IMI subscale constructs were as follows (out of 7 possible points): 6.00 for interest and enjoyment, 5.18 for perceived competence, 6.16 for effort and importance, 5.70 perceived choice, 6.48 for value and usefulness, 5.64 for relatednesses. The overall IMI average at the beginning of the SBP was 5.86. The averages for the reported goal importance of the items corresponding to the six AI constructs were as follows: 5.36 for wealth, 4.08 for fame, 3.43 for image, 6.74 for personal growth, 5.97 for relationships, and 6.28 for community. The average goal importance for items corresponding to extrinsic constructs (wealth, fame, and image) was 4.29, and the average importance for intrinsic construct items was 6.33.

Among the group of participants, the IMI constructs on which responses varied the most were perceived competence, effort and importance, and relatedness. The ranges and averages for each construct as well as the overall IMI and AI scores are included in Tables 2 and 3.

To create a new table in the main body, type “New table” and press F3.

Table 2.3 IMI Baseline Averages and Ranges.

Construct	Lowest Score	Average	Highest Score	Range
Interest/Enjoyment	4.57	6.00	6.86	2.29
Perceived Competence	2.17	5.18	7.00	4.83
Effort/Importance	2.60	6.16	7.00	4.40
Perceived Choice	4.29	5.70	7.00	2.71
Value/Usefulness	4.14	6.48	7.00	2.86
Relatedness	2.88	5.64	6.88	4.00
Overall IMI	4.51	5.86	6.75	2.24

Table 2.4 AI Goal Importance Baseline Averages and Ranges.

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Construct	Lowest Score	Average	Highest Score	Range
Wealth	4.00	6.00	7.00	3.00
Fame	2.00	5.18	7.00	5.00
Image	1.20	6.16	6.40	5.20
Personal Growth	5.80	5.70	7.00	1.20
Relationships	1.60	6.48	7.00	5.40
Community	2.40	5.64	7.00	4.60
Overall Extrinsic (Wealth, Fame, Image)	2.87	4.29	6.40	3.53
Overall Intrinsic (Personal Growth, Relationships, Community	3.67	6.33	7.00	3.33

The AI goal importance scores were the most variant across the group of participants for the following constructs: fame, image, and relationships. Participant responses were most similar for survey items corresponding to the importance of personal growth goals.

Qualitative Findings

In-depth, one-on-one interviews yielded data supporting the synthetization of the following 6 core themes:

Theme 1: Community building and establishing a sense of relatedness is integral to the SBP but can only happen if a student decides that some aspect of the program is valuable.

Seventeen of the 18 SBP students who completed exit interviews expressed the importance of community building and relatedness. They associated value and enjoyment with bonding with peers in their cohort. It is important to note that the one student who did not speak about anything that supported this theme identified as White, while the remainder of the students identified as being from minoritized backgrounds (Black and Hispanic) during an evaluation at the end of the program. To illustrate the students' statements regarding this theme, let's take a closer look at 2022 freshman SBP participant, Warren. Warren is a Black male who attended a high school that was rated as performing at a 'D' level by the state's Department of Education. Warren verbalized that he had engaged in prior engineering experiences, as early as 9th grade, through his high school career and technical program.

When asked what his favorite part of the SBP was, Warren spoke about "the people" in general. He expressed an appreciation for getting to interact with students from various backgrounds and having a chance to hear about their stories and upbringings. He reiterated that "aside from the academic side" he enjoyed simply interacting with his peers and soon-to-be colleagues. Later in the interview, we essentially asked Warren what makes the SBP (I.e., it wouldn't be the SBP without [blank]? Warren's response further demonstrated how he, and many other students, deemed community building integral. Warren mentioned that the SBP has to have "the team." He elaborated by explaining that although many community-building activities may not be on the official schedule, moments like late-night games and going on unplanned adventures together were pivotal. In Warren's own words, SBPs need "Team bonding, basically, because people don't look at it like this, but once you build relationships... academic-wise and everything, there's benefits from that."

Warren also explained that if a program simply gets a bunch of strangers together and program participants never truly get to know one another, they likely will not enjoy themselves. Many students express similar sentiments, related to their favorite part and/or the most valuable part of the SBP being the informal interactions and community building among the other participants in their cohort.

Theme 2: Structured studying is valuable for and instilled in all students. Allotted time for academic preparation is emphasized by students reporting lower perceived competence at the SBP's commencement while establishing a routine and socializing are often added for students with higher perceived competence.

Sixteen of the 18 students spoke of study hall as an essential component of the SBP and vocalized that the things they learned in study hall will stick with them once they begin matriculating through undergrad. Victoria serves as a great example of the overall idea that students perceived study hall as valuable for the transition from high school to a college environment. Victoria is a Black female student who attended a school rated at a 'B' performance level and had no engineering experience prior to participating in the SBP. At the start of the program, Victoria had the lowest score corresponding to the survey items for the perceived competence construct within the IMI (2.17 out of 7 on the 7-point Likert scale).

While Victoria also commented on community building as being important, when asked "It wouldn't be SBP without [blank]," she almost found it difficult to gather the words to accurately convey study hall's importance:

> *Study Hall. That's when you really... Yeah, when we're in class and stuff, we connect too, but study hall is like... First of all, they teach you how to study. They teach you study habits that you're going to need, whether they think so or not and that's just when you get closer to people, you get to see everybody's real personality and everybody comes out their shell because you don't have a phone, nothing, you're just there.*

Victoria reported feeling as if she got a "head start" on some of her fall classes. She reemphasized study hall's importance in connection to getting back in the groove of studying and learning better ways to study. Tips for more effective studying were often offered by counselors and other leaders within the SBP.

Contrasting with Victoria, while students with higher perceived competence also appreciated study hall, they more frequently emphasized the component's benefits toward establishing a routine or working collaboratively with peers. These students viewed study hall as a time to continue bonding with peers, creating a good routine, and managing their time effectively. To demonstrate this, let's revisit Warren's interview. Warren spoke a lot about the importance of community building in the SBP and had one of the highest perceived competence scores when the SBP began. Warren also viewed study hall as valuable but attributed most of that value to it encouraging him to stop procrastinating. Warren did not mention how study hall taught him how to study or made him much more comfortable with coursework. Instead, he appreciated the idea of not being left alone and cramming all his work in at the last minute.

Theme 3: Field trips, real-world experience, and hands-on experiences are interesting to students and allow them to better understand engineering and engineers. These experiences are especially impactful for students with lower baseline perceived competence scores and/or no K-12 engineering experience.

Twelve of the 18 participants spoke about how going to on-site visits for SBP company sponsors and other engineering facilities, as well as engaging in engineering laboratory work, allowed them to better grasp the perceived intricacies of engineering. Visits and labs also helped students develop a more well-rounded picture of what engineers do. Quinton provided insightful thoughts on the importance of real-world experiences, and even field trips, throughout his interview. Quinton is a Black male who attended an early college preparatory school that allowed high schoolers to earn up to two years of college credits toward a bachelor's degree.

This program was housed at a regional community college campus, and Quinton gained engineering experience through his involvement.

When Quinton was asked about his favorite part of the SBP, he briefly mentioned meeting new people and then went on to speak about doing labs with a chemical engineering professor. He even added details about his love for the lab, describing "all the little machines" that filled the room. He also talked about how he liked the chemical engineering lab too. In that lab, students worked with a graduate student at the university to study the properties of asphalt. Asphalt was directly related to the group project all SBP students were required to complete by the end of the program. Participants 3D printed asphalt tanks that they designed in AutoCAD, gave a group PowerPoint presentation to industry sponsors, and developed written reports detailing the product specifications.

Additionally, when Quinton was asked what made the SBP/it wouldn’t be the SBP without [blank], he replied:

> *Trips. The trips. It gives people stuff to do and they can actually see how engineering relates to the real world because I heard most of them say that going to [petroleum company in southern state] and these other places, they were like, "I didn’t even know that this little basic thing required this much math and stuff like that we talked about in school." So, I think they shouldn't get rid of that.*

Quinton's statement demonstrates that his peers with less K-12 engineering experience spoke, either to him or to the whole cohort, about how they began making connections to engineering concepts. Participants began recognizing the design processes necessary to produce seemingly mundane products.

To corroborate this, we can look at Shane's thoughts. Shane is a White male who attended a high school rated as an A by the state's Department of Education but reported having no K-12 engineering experience. While other students spoke about how community building was integral, Shane spoke a great deal about hands-on experience. When asked about his favorite part of the program, Shane went into detail about the different concepts and types of asphalt he learned about during the program. He talked specifically about how they tested asphalt alternatives during their experiments and the criteria they used to select the most appropriate one. When asked what made the SBP/it wouldn't be the SBP without [blank], Shane said:

> *Probably just the asphalt engineering. Because, I mean, it doesn't have to be that, but it should remain- You should do a project on something that doesn't appear very exciting because then that will cause people to look at things like... that light switch right there and then they'll be like, "Hmm, maybe there's more to that than I thought."*

Shane appreciated being able engage in hands-on engineering work that he was not introduced to in K-12 and began to realize the work required to produce everyday objects.

Theme 4: The residential life component is an important part of students' maturation, growth, and acclimation to campus from their inception into the SBP through its conclusion.

Thirteen of 18 SBP participants contributed valuable perspectives for the residential life theme. Living on campus for the duration of the SBP was the longest span that most participants had ever been away from their parents, and it served as their first introduction to what life as an adult is like. Gavin, like many other participants, expressed this through dialogue. Gavin is a Black male who attended a high school rated as performing at a 'B' level and had engineering experiences dating as far back as elementary school. At the time of the baseline survey, Gavin had the second-highest overall IMI score and was the only student who scored the perceived competence survey items as an even 7 on the 7-point Likert scale.

When asked to talk about his relationships with his peers, Gavin said that he believed everything was good. He stated that everyone supported one another and was there for each other. Gavin went on to mention being able to prepare for the fall and live with a roommate. Gavin regarded the opportunity to live in a residence hall as important for seeing what it was like to be a full-time college student. He also mentioned that residential life allowed him and his peers to engage with many other students and "see how everything works."

When Gavin was asked about his expectations of the long-term SBP impact (thinking forward), his statements were demonstrative of his increased autonomy and competence. He stated that he was more comfortable with the first day of the fall coming. Gavin mentioned the benefits of already knowing where campus buildings were and having a model for what his schedule should be like. He even mentioned knowing what time he should wake up in the morning to ensure he is on time for class. Gavin's statements, like many of those gathered from his peers, show that he viewed the residential component within the structure of the SBP as critical for his maturity and development as a college student and young adult.

Theme 5: Students perceive mentorship as valuable, and it stems from multiple avenues within the SBP. Students are more likely to recognize the value of mentorship if they are more social and/or open to asking questions in more private settings.

Mentorship, through alumni spotlights, interactions with SBP counselors (upperclassmen), and meeting past SBP participants and other engineering leaders affiliated with the program, was verbalized as being critical by 12 of the 18 participants. Travis emphasized the importance of mentorship derived from his SBP participation at several points throughout his interview and is a great representative of the evidence gathered that corresponds to this theme. Travis is a Black male who attended a private high school for his junior and senior years. Travis had previous engineering experience as a participant in Engineering Academy, which started in 9th grade and continued for at least two years.

When Travis was asked about the most valuable part of the SBP, he answered:

> *Honestly, it's like I'm going to word this answer weird but it's like... asking questions. Whether it be to the counselors, to the alumni spotlight people, to the people that came and talked to us from the companies, or to the graduate students, or from the people on the tours. That's really what I think the most helpful thing for me is just asking questions and getting feedback from A, B, C, and D.*

Travis spoke about the importance of mentorship from a past SBP graduate assistant who is getting a master's degree in the same major he planned to undertake. This mentor was able to give him advice and even inform him about some certifications that may be useful in Travis' future.

When asked about the most enjoyable part of the SBP, Travis briefly mentioned going on engineering field trips. He then went on to say:

> *'-and then I'd say for two just really... it's not really a "thing" but really having the counselors who are maybe are a year or two older, they can really relate to where we're at because they were just in our shoes a year or two ago. That's really probably one of the most enjoyable things because you can really lean on them for anything. […]But I was going to say my whole purpose of being here is to kind of get exposure, start building a network before I get here, try to get involved. That's really the whole purpose for me to just come and meet people, ask questions, that was my whole purpose for being here.'*

When Travis was asked about his relatedness with his cohort, the counselors, and other SBP leaders, he mentioned gave several details. Travis mentioned that he gets along with mostly everyone. He even mentioned that he probably talks to the counselors a bit more than his cohort at times. He openly explained his rationale:

> *I probably talk to them more than I talk to the people in the camp because like I say I'm always just asking questions. And then I feel it's valuable to be around... you know they say surround yourself with people you want to be like. I feel like it's valuable to be around people that's kind of older than you and got a little bit more maturity, who've seen different things.*

Students who proclaimed themselves as being more reserved or introverted did not speak as much about mentorship. Travis had one of the highest relatedness scores during the baseline survey. Travis was even regarded by one of his other peers, Patrick, as being one of the most social ones in the cohort. When Patrick was asked about the difficulty level of the SBP and whether it was more difficult or easier for certain students, he said:

> *I think it was easier and difficult for some people. Because some people like [Travis], he's a very outgoing person. He likes to be with people and likes to make friends. And me, it's just I'm not that good at making friends and stuff. I'm kind of antisocial. I guess when I start to know you or whatever, I like... come out and start being more interactive. But it's 50/50, I guess.*

This excerpt shows that more reserved students may believe the SBP is difficult to navigate and that the difficulty is dependent on their willingness or perceived ability to socialize.

Theme 6: Students believe the required effort, difficulty, and academic experiences within the SBP may be dependent on prior (K-12) engineering experiences as well as high school rigor.

Those with in-depth, sustained K-12 engineering experiences heavily emphasized a perceived effort/ difficulty gap between themselves and less experienced peers.

Thirteen of 18 participants believed that pre-collegiate engineering experiences and the quality of high school education and course offerings impacted the difficulty that some participants experienced when navigating the courses and tasks required within the SBP. Let's take a closer look at Whitney's journey through SBP to support this theme's creation. Whitney is a Black female student who attended a 'B' rated high school and reported having in-depth engineering experience prior to the SBP. The only IMI construct on which Whitney scored the items at an average of less than 6.0 was perceived choice.

When Whitney was asked whether her experiences in K-12 impacted her SBP experience, she said:

> *I think it did. But I came in here and knew what I was doing. But the thing is, other people didn't. They had little experience with engineering. That's fine. It was just more so they felt that I was a bit controlling, which I try not to come across that way, but it was more so I just knew what I was doing because I had done it twice before. Structured like this, like we're given a project or task and we're going to make it, print it and do slides and present it to a panel of judges. I did that with my [space company] internship, with my engineering thing, and I'm doing it here. So I feel like I'm just more, I guess, knowledgeable about it than most people in this program. But that's not to brag. It's just to say my experiences were different if that makes sense.*

As evidenced, Whitney's in-depth experiences contributed to her belief that she already had a good idea of how to succeed in the SBP. Whitney even stated that some of her peers viewed her as bossy or somewhat condescending when imparted knowledge based on her prior knowledge.

Whitney, when asked if navigating the SBP was easier or harder for some participants or if it was about the same level of difficulty for everyone (and why):

> *It was definitely harder for some people. Some people took college algebra and trig already. Some people haven't. Some people took chemistry in high school. Some people have never seen chemistry. Some people have a lot of experience with programming, and others do not. Like I said, I'm a special case. I took math all the way up to AP calculus. I took chemistry and AP chemistry, and I took AP computer science. These weren't new to me like it was to a lot of the other people. They have never seen computer programming before, and that's fine. We all have a different experience, but it definitely was not the same for everyone.*

While some students stated that they thought the difficulty was about the same for everyone, many emphasized how having more background experiences made it easier for some. However, many participants emphasized the importance of their established community for mitigating the difficulty for less experienced peers. Among the cohort, there was an atmosphere of comradery and those with prior experiences and who had taken more rigorous courses were willing to help whenever possible.

The following codes were not used when coding the frshmen SBP participants' interviews: using content from engineering, peer support, importance, extrinsic engineering motivation.

Discussion and Practical Implications

The goal of this study was to determine how the structure of the SBP impacted students' experiences, through SDT's theoretical lens. Recall the gap in literature concerning the overemphasis of academic performance for student success in STEM, coupled with the disadvantages URM students face in STEM programs that often stem from K-12 inequities. This gap is addressed in the current study's themes. Theme 1, concerning the importance of community building within the SBP, emerged because nearly every student spoke to this point and often reiterated it throughout their interview. Community building is of particular importance for URM engineering students. This is further amplified when the students attend predominately White institutions (PWIs), such as the site of the SBP included in this study. Students not only emphasized the importance of establishing a sense of community and making friends within their SBP cohort but also explicitly spoke about how they associated value with finding and creating a community of URM scholars. Regarding SDT, students' perceived relatedness increased from the point of inception into the SBP to the program's conclusion. Many students articulated that they anticipated difficulty meeting other URM engineering students at their institution. By the end of the program, students believed that the community they established in the SBP would last long throughout their undergraduate tenures and beyond.

As SBPs have historically been aimed at generating URM participation, this component or characteristic of the program should be deemed as contributing to positive student experiences (Ghazzawi et al., 2021; Stolle-McAllister, 2011). It is reasonable to infer that this successful community building would not result from a similarly structured program (in terms of academic preparation and schedule), in which URM students remain the minoritized group of participants. URM students' social integration and sense of belonging in engineering is a long-standing, persistent issue. According to SDT, the students' strengthened perceptions of relatedness within the context of the SBP will ideally increase their self-determination in engineering and engineering motivations (Ryan & Deci, 2002). The information gathered from this study can be used by intuitions and programs in need of practice-based evidence upon which to design environments conducive to community building and equitable experiences.

Reflecting on Warren's statements presented in the previous section, his thoughts were in alignment with most of the participants. Now, it would be beneficial to discuss the participant who scored the lowest on the relatedness portion of the IMI in the baseline survey (2.88 out of 7). This participant, Sydney, also reported among the lowest scores when rating survey items for the following constructs (concerning her SBP participation): effort and importance, perceived choice, value and usefulness. Her scores for those constructs all fell below 4.30. Interestingly, Sydney is the participant who ended up withdrawing from the program within the first week. We pose plausible reasons this may have happened.

To reiterate, Sydney had low scores in relatedness, effort and importance, perceived choice, and value and usefulness. However, Sydney had prior engineering experience and reported the second-highest perceived competence score. It is likely that Sydney's perceived competence, but lack of perceived autonomy and relatedness, played a role in her withdrawal. Her reported lack of effort and perceived value derived from the SBP were also factors. Other students who had lower relatedness scores at the beginning of the SBP but stayed for the duration of the program reported higher relatedness at the end of the program and associated more value and usefulness with the program from the beginning.

Likewise, students who had both high perceived competence scores and high value and usefulness scores stayed for the program's entirety and witnessed increases in those constructs, along with others. A major takeaway is that to get the most out of the community portion of the SBP, students must see the value or usefulness of completing the program. For some students, this value may stem from the need to form community, and for others, it may stem from the need to increase competence and preparedness. For Sydney, the lack of value coupled with her high initial level of perceived competence led her to not recognize a reason to "stick with" the SBP and potentially experience the benefits associated with its successful completion. Table 4 illustrates a matrix with the categories students fell into.

Table 2.5 Participant matrix for value association and incoming perceived competence.

	High value/usefulness of SBP (≥ 6.0)	**Low value/usefulness of SBP (< 6.0)**
High perceived competence (≥ 6.0)	Emphasize SBP community building and more non-academic benefits; already confident in preparedness (8 participants: Auria, Brittney, Gavin, Ken, Quinton, Rachel, Warren, Whitney)	Do not associate value with SBP; already confident in preparedness (1 participant: Sydney)
Low perceived competence (< 6.0)	Emphasize SBP more academic benefits; not very confident in preparedness coming in (10 participants: Cameren, Candace, Lacey, Michael, Patrick, Shane, Taylor, Travis, Victoria, Zion)	(No students from the 2022 SBP cohort) Do not associate value with SBP; not confident in preparedness

Theme 2 relates directly to how and why students associated success, skill development, and positive habit formation, with structured study hall, a major component of their SBP. Within the specific SBP examined in the present study, students participated in three consecutive hours of study hall each night, except for a select number of nights (E.g., holidays and Saturdays). During study hall, students were not allowed to use their cell phones, in hopes of limiting distractions. While this may have initially seemed daunting, most students vocalized that they came to realize the importance of developing self-discipline and study habits. When asked about their expectations for the long-term impact of the SBP on their academic journeys, students even spoke about carrying the routines they learned in structured study hall into the fall semester. We, therefore, determined that study hall was a structural program component contributing to positive student experiences. Mainly, competence was impacted by students' participation in study hall. They witnessed increases in their perceived abilities to plan and manage their time and felt more prepared to tackle engineering courses as a result of the BSP structure inherently encouraging them to be productive and focus on course material each day.

It is important to acknowledge that students appreciated structured study hall for various reasons, depending on their incoming attributes. For example, students coming into the SBP with lower perceived competence highlighted the importance of structured studying for academic preparation and preparedness. They appreciated having allotted time to dedicate their efforts to improving performance in their SBP courses, which were foundational engineering subjects like math, physics, programming, and chemistry. In other cases, students who came in with higher perceived competence emphasized that they derived more value from being able to establish a sound routine that they can carry with them into the fall semester. Students were also more likely to view study hall as an opportunity to collaborate and bond with their peers as the SBP progressed and they began to prepare for exams and work within assigned project teams.

Theme 3 was derived from students' voicing the importance of hands-on and real-world experience for their development as engineering students and understanding of engineering. While many programs have opted to adopt more hands-on or project-based courses for students, this is typically done later in undergraduate programs (Carbone et al., 2020; Carlson & Sullivan, 1997; Kumar & McNeill, 1999; Liu, 2016). Also, many institutions do not require students to do work that would require them to visit an engineering company unless this is an opportunity the students seek on their own (Main et al., 2021). The SBP participants in this study spoke about how participating in engineering labs, such as those focusing on the production and testing of asphalt, contributed to their early conceptualization of what engineering may entail and even offered insight into major choices. Similarly, site visits and field trips helped students better understand what engineers actually do and helped them make connections between what is taught on paper in class and what is done in real-world settings. This early exposure for incoming freshmen helped them develop more accurate engineering perceptions and ideas for the well-rounded nature of the disciplines.

More specifically, quotations from Quinton's interview demonstrated how students began to make connections between abstract concepts and seemingly simple everyday items and the intricacies involved in creating them. While Quinton emphasized the importance of these hands-on experiences and trips in the SBP, he also implied that these components were very beneficial for students with no prior engineering experience and/or lower perceived competence in engineering contexts. The data supports this assertion. Students with no prior engineering experience and lower perceived competence at the beginning of the SBP, such as Victoria, Lacey, and Taylor, all mentioned that the trips and/or hands-on labs were among their favorite parts of the program. Other students who also enjoyed trips and labs but who initially had higher perceived competence or K-12 engineering experiences tended to emphasize the community-building aspects as their favorite parts first and the hands-on and real-world components later (or as a close second). This information suggests that coming into the SBP with lower perceived competence and/or no K-12 experience may cause the impact of engaging in real-world and hands-on activities to be amplified. Additionally, students beginning with those attributes may be more familiar with real-world engineering concepts and more immediately impacted by social interactions with their peers.

The real-world and hands-on experiences culminated with a team-led presentation of a project in which students navigated the detailed process of developing an asphalt tank for a company sponsor. The team project component of the SBP served as a great example of how students' autonomy, competence, and relatedness can be simultaneously impacted. While there were many positive impacts resulting from students taking the initiative to research their project details, exercising their freedom to make engineering-related decisions, and working together to deliver a final product, some areas of the project could be a concern. For instance, some students experienced issues when working with team members, which could have detracted from their experiences, especially as it relates to their relationships with certain peers. While conflict will undoubtedly arise in many areas of students' lives, SBPs must be intentional about mediating and helping to resolve these issues to prevent them from impacting the overall experience.

Theme 4 was the result of numerous sections of coded text that stressed the role of the residential life component in the SBP as essential for maturation, independence, and acclimation to the university. The transition between high school and college is a pivotal moment in students' academic journeys (Venezia et al., 2013; White et al., 2018). In alignment with Schlossberg's Transition Theory, we understand transitions to be the internal process a student goes through when moving from the familiar to the unknown, responding to cultural, social, and cognitive challenges (Perry & Allard, 2003; Prescott & Hellstén, 2005). Students appreciated the opportunity to learn more about themselves and the degree of responsibility needed to excel at the collegiate level. As many students were away from home for the first extended period (5 weeks), they made decisions about what choices are beneficial and detrimental to their performance as scholars. Many students also spoke about the advantage of 'getting to know' the campus and believed that they may have been 'lost' had they come straight into freshmen year without participating in the SBP. Accordingly, students' perceived autonomy was impacted by the residential life component of the program.

It is important to note that a few students reported that they did not decide on their own to apply for or participate in the SBP. One might believe this impacted how they viewed the 'freedom' associated with being an SBP participant versus living at home with their parents. In other words, it is reasonable to hypothesize a student who felt more “forced” to participate in the SBP may not experience the same benefits as students who decided to attend on their own Interestingly, students with lower perceived choice at the beginning of the SBP did not appear to experience the impacts of residential life any differently from those students with reportedly higher perceived choice. Students quickly realized that, in college, their success is majorly dependent on the choices they make. Perceived choice in the context of the baseline IMI survey the participants completed related directly to their autonomy and decision to participate in the SBP.

Theme 5 focuses on the value students associated with the mentorship they received as SBP participants. Mentorship is defined as 'the guidance provided by a mentor, especially an experienced person in a company or educational institution.' While students may have mentors in a variety of contexts and view them as mentors for various reasons, the mentorship of URM students in engineering is a line of research within itself (Allendoerfer & Yellin, 2011; Atkins et al., 2020; Estrada et al., 2018; Ilumoka et al., 2017). URM students are less like to witness representation among faculty members and other engineering leaders (Beutel & Nelson, 2005; Main et al., 2022; McGee et al., 2022; Nelson & Madsen, 2018). Mentors who identify with

URM students' backgrounds, and ultimately, their unique student experiences were a critical component of the SBP. The SBP hosted alumni spotlight sessions, which allowed past SBP participants and affiliates, who are now working professionals, to come back and tell the incoming freshmen cohort about their journeys. The SBP also had several 'counselors,' who were upperclassmen serving as student leaders and helping lead the day-to-day operations of the program. Counselors stayed in the residence hall with the participants and often helped facilitate informal instances during which students continued to form a community. Students enjoyed being able to gain knowledge and pick the brains of those who were recently in their shoes and who had similar experiences as URM students at the same institution they were recently accepted to.

Students who had low relatedness scores on the baseline IMI survey and who verbalized being less social during their one-on-one interviews, like Cameren, Ken, and Zion, were less likely to speak about the value of mentorship during the SBP. While some of them still spoke about connecting with their peers as the program progressed, they did not mention making strong connections or recognizing the impact of speaking with alumni, past participants, and counselors. On the other hand, students who viewed themselves as being either naturally social or open to asking questions in more private settings, like Travis, Warren, and Whitney, spoke about the impact of mentorship throughout the program.

This information could be valuable when planning for future SBPs. For example, to try and ensure that more reserved students receive benefits from mentorship, deliberate steps can be taken to ask the questions they may fail to verbalize. More specifically, allowing students to write down questions for alumni speakers prior to their sessions will allow all students to hear the information they are interested in instead of only the students who are willing to speak up in front of an entire room of people. Additionally, counselors should be required to make more deliberate efforts to connect with students on a one-on-one basis. One more reserved student, Zion, specifically suggested this in his one-on-one exit interview when asked if he had any recommendations to improve the SBP for future scholars. These intentional connections can be made through weekly meetings with an assigned counselor, as well as periodic check-ins with counselors.

Lastly, theme 6 summarizes many students' belief that the difficulty of navigating the SBP and/or the effort required to do well depended on K-12 engineering experiences and the rigor of the K-12 education participants received. Sixteen of the 18 students attended and graduated from high schools in the same state, while 2 came from high schools in other states. Even among those from the same state, students' high school letter rankings ranged from 'A' to 'D.' Furthermore, some students attended private schools which are not ranked by the Department of Education (MS Department of Education, 2022). Some students had done programs structured like the SBP, taken AP math and science course, and even attended residential high schools offering college credits. Some students had never had the opportunity to take courses like chemistry and had never done any engineering-related work. With this wide range of experiences, it is no surprise that some students felt more or less prepared and that the SBP was more or less difficult for them to complete (Chandler et al., 2011; Fantz et al., 2011; Roehrig et al., 2012). This notion of feeling less prepared based on factors outside of students' control may have had a direct impact on students' perceived competence, particularly toward the beginning of the program.

More specifically, those students with in-depth, sustained K-12 engineering experiences heavily emphasized a perceived effort/ difficulty gap between themselves and less experienced peers. For instance, Whitney, Zion, and Warren were among the students who had engineering experiences that lasted for at least an entire year. They all mentioned that they believed it was easier for them and probably harder for some of their peers because they all had sustained engineering involvement in high school. Students who had more compact engineering experiences like a one-day or weeklong camp did not emphasize this perceived difficulty gap or see themselves as having a noticeably easier time navigating the SBP. Students who spoke about participation in the more compact engineering experiences stressed that the major benefits stemmed from their early introduction to important concepts and more generalized information about engineering.

It is also important to note that high school rigor played a role in perceived difficulty for some students, even if they had prior engineering experiences. For instance, Michael spoke about the benefits of being introduced to engineering and gaining some hands-on skills but emphasized that SBP courses were a little more difficult for him because of the offerings and ranking of his high school. Together, the qualitative data from these students highlight the advantages of having prior engineering experience coupled with a rigorous high school curriculum and a variety of K-12 course offerings.

Fortunately, this group of students emphasized how their community building and a strong sense of relatedness among their cohort laid the foundation for them to assist those peers who may not have as much experience with certain areas and concepts. Whitney, whose journey we examined in closer detail, even spoke about how she came in with a lot of K-12 engineering experience but learned a great deal about herself and how to let others share the spotlight. This information could prove useful for SBP leaders considering how to design the first week or so of their programs. Explicitly acknowledging students' different experiences, as a leader, and then communicating to them that they will be properly supported to ensure their success in the program and beyond is important. Additionally, learning more about students' backgrounds can help with the assignment of teams and aid in evenly dividing students with various degrees of experience.

"Peer support" and "using content from engineering" are codes that were not expected to be used for the freshmen, based on the way they were defined. These codes would be more aligned with upperclassmen students' experiences in engineering and were placed in the codebook for a study that consisted of past SBP participants. Statements that could have possibly been viewed as aligning with "importance" were often more strongly supported with comments about the value and usefulness of the SBP and, therefore, "importance" was unutilized. No students spoke explicitly about extrinsic motivation to become engineers, so the "extrinsic engineering motivation" code was unused for this group of participants.

Study Limitations

While these findings yield valuable information, SDT does not consider objective measures that could be used to corroborate students' perceptions. It may be useful to further study how students behave and interact with each other and engage academically after the SBP program is over. For example, observing or investigating the structured studying habits and relatedness of a cohort a semester after the program's conclusion may provide more evidence to either corroborate or call into question the validity of the themes derived from their statements made in interviews at the end of the SBP. Nevertheless, the statements and themes detailed in the preceding sections of this paper represent students' lived experiences, voices, and expectations at the end of the SBP. Therefore, it would be valuable to determine whether their expectations will become a reality or not and which supports and factors may have helped or hindered them along the way.

Conclusion, Recommendations, and Future Directions

With a deeper understanding of the experiences that students have during the SBP, we can better understand how intentionally design programs that are intended to help them transition to their first fall semester. More specifically, we were interested in investigating how the SBP affected students' experiences and success in engineering during the program (RQ1). We found that the SBP was instrumental in providing cohort community building opportunities and fostering mentorship. Additionally, we found that participants' experiences were impacted by their K-12 engineering experiences as well as the rigor of their high school coursework.

Regarding the investigation of more specific program characteristics and experiences that could contribute to or detract from holistic success in engineering (RQ2), we first found that study hall was regarded as important to students for different reasons. Namely, participants' initial levels of perceived competence influenced the benefits they stated they gained from engaging in study hall. Next, we found that real-world and hands-on experiences were especially impactful for those participants who had no K-12 engineering experience. Lastly, the residential structure or component of the SBP helped students develop a sense of independence and learn more about college and adult life.

These findings can be used as a foundation for engineering program leaders and administrators to enhance experiences for future students and practice continual improvement in SBPs. For instance, special attention should be placed on removing an apparent obstacle regarding students who report being less social being able to fully benefit from the mentorship and networking opportunities during the SBP. Students' unique experiences should be acknowledged, and students should be met where they are with support from engineering leaders and peers. In doing so, leaders can help ensure students who enter SBPs without formal, sustained engineering experiences or without previously taking rigorous high school courses can be adequately supported. In turn, that support can aid in closing the uncovered difficulty gap between them and their peers with more in-depth experiences and strong backgrounds in foundational engineering pre-requisite courses. With this, SBPs can be further enhanced to better assist everyone in the cohort as they strive to realize their potential and develop into contributing engineers. We are hopeful that practical changes will be implemented to ensure the success of future SBP students.

Looking forward, it would be useful to conduct a similar study with a larger sample size consisting of SBP participants from multiple institutions. SBPs across the country have similarities and differences, so it would be useful to examine how students in different programs experience self-determination, perceptions, and motivation and how the program's structure influences those experiences. Furthermore, engineering education researchers must begin using novel lenses, considering drawing on the work of researchers outside of STEM, and developing new perspectives and ways of approaching persistent issues like URM participation and student success. The current study begins blurring the lines at the intersections of social science, technical engineering, and student affairs. However, it is only the beginning of a call for continued efforts to create sustainable change in engineering education and ensure that the pipeline leads URM students to desirable destinations.

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CHAPTER III

SUMMER BRIDGE AND BEYOND: EXAMINING CONTINUING STUDENTS' EXPERIENCES

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Williams, S., Mohammadi-Aragh, M.J. (2023). Summer Bridge and Beyond: Examining Continuing Students' Experiences. [Unpublished manuscript]

Abstract

Support programs like the Summer Bridge Program were designed to assist students who have been historically excluded from receiving equitable resources needed to thrive in higher education. While these programs and many other student support programs are typically designed for freshmen students, we chose to investigate the effects of past participation on continuing students' experiences are they matriculated through undergraduate engineering programs at one institution. We employ Self-Determination Theory, a psychology macro-theory, as a guiding theoretical framework to shed light on parts of the college student journey typically overlooked in engineering education research. After creating a semi-structured interview protocol based on two of the theory's existing, validated survey instruments, we conducted interviews with 7 students who had participated in the Summer Bridge Program in either 2019, 2020, or 2021. The interview data was analyzed after being transcribed, cleaned, and coded, and themes were constructed to illustrate the key findings. Five core themes were developed and are related to the following topics: the role being Black in engineering played in students' relatedness, relatedness in different engineering contexts, the importance of leadership and networking with underrepresented professionals, the benefits of Summer Bridge courses and scheduling, and the impact program structure has on a Summer Bridge experience as well as the experiences that follow. We provided a discussion of these themes as well as some practical takeaways. We hope that this research will be used to call attention to the needs and experiences of students not only during freshmen support programs but also as they progress along their journeys as undergraduate students.

Keywords: Summer Bridge, engineering education, URM STEM, engineering program, Self-Determination Theory

Examining Continuing Students' Experiences

Issues regarding the accessibility of education for students from all backgrounds span back the history of the United States (Baker et al., 2018; Baker & Vélez, 1996). Until relatively recently, K-12 schools that primarily taught underrepresented students lacked many basic resources, and institutions of higher learning were not integrated (Bridges et al., 2012; R. A. Mickelson et al., 2013). Today, many K-12 districts remain in need and are subject to inequities due to a history of gerrymandering (Safi et al., 2022). Likewise, many institutions and leaders have been unequipped to properly support and guide diverse student populations (Xu & Webber, 2018). Nevertheless, several institutions have adopted methods and strategies to counteract these effects and foster more inclusive environments (Crawford et al., 2018; Decuir-Gunby et al., 2011; Peckham et al., 2007).

One concrete method to try and support the diversification of universities, as well as specific disciplines, is implementing student support programs (Johnson & Johnson, 2003; Muraskin, 1997). While many initial programs started because of educational policy in the 1960s (Kantor, 1991), these programs and programs to follow remain prevalent in 2023. One type of program, the Summer Bridge program, has been critical for underserved students' acclimation and preparedness to succeed at universities (Cabrera et al., 2013; Wachen et al., 2011). These programs typically have common characteristics, such as a residential component, academic coursework, and cohort-style communities but can differ in some ways at different institutions (Sablan, 2014). The programs are primarily for incoming freshmen students. One issue arising from this is the lack of attention devoted to continuing students (Gahagan & Hunter, 2006a). This issue is especially relevant when thinking about the underserved students who usually participate in support programs such as the Summer Bridge program.

Historically, scholars have conformed to deficit thinking and viewed underserved students as “at-risk” or lacking the skillset to excel in college (Garcia & Guerra, 2004). While these students may indeed need additional resources to ensure their successful transition, it is not because of any shortcomings on their end. It is because of the systemic issues and intentional oppression in the U.S. educational system that deprived them of equitable resources, treatment, and preparation since many of their inceptions to K-12 districts (Jackson & Holzman, 2020). We acknowledge the more progressive work and research of scholars calling out these deeply rooted issues. Modern scholars have begun examining the experiences of underrepresented students and the effectiveness of efforts designed to contribute to their positive development at universities (Howard & Sharpe Jr, 2019). These scholars often focus on academic performance after participation in support programs and initiatives or sense of belonging and social integration for students who have been previously excluded from spaces in higher education (Bradford et al., 2021; Jura & Gerhardt, 2021). The lines of research established by these scholars have provided a foundation on which additional inquiries can be investigated regarding student populations and their collegiate experiences.

The present study sought to take things a step further and simultaneously investigated three (I.e., autonomy, competence, relatedness) dimensions of the college student experience, particularly for underrepresented students who participated in support programs. This topic should be addressed because university leaders and administrators need more qualitative information on what happens after students leave freshmen support programs. Qualitative data are needed to provide in-depth narratives and paint detailed pictures of students’ journeys, beyond what can be interpreted from numbers and statistics (Watkins et al., 2012). Also, there is a lack of information combining multiple aspects of the past participants' experiences. This includes going beyond researching GPA or social integration and looking comprehensively at past program participation's effects on competence, readiness, relatedness, and motivation, among other outcomes.

By conducting semi-structured interviews, we delved deeper into the experiences of past Summer Bridge Program (SBP) participants who are now continuing students in various engineering degree programs. Our interview protocol was intentionally and systematically created based on validated survey instruments that capture information on several constructs. The questions were catered to the context of undergraduate engineering and past SBP participation. Our goal was to uncover how the students’ past participation in the SBP impacted them then and now. We looked specifically at their experiences and the lasting impacts of participation as well as how those experiences compare to and/or are influenced by previous Summer Bridge participation. We closely examined which program components played the most critical roles in those positive or negative influences and experiences both during the summer program and after.

This paper walks readers through the existing literature and the motivation driving the present study. We expose a gap this work intended to fill and detail the appropriateness of adopting a comprehensive theoretical framework that allows for the multidimensional investigation of students’ experiences. Next, we explain, step by step, the methods used to investigate the research questions. We follow with a presentation of the results, primarily in the form of themes synthesized using the explained methodology. A discussion follows to address questions arising from the results and to further explain the phenomena participants’ experienced. Lastly, limitations, the conclusion, and recommendations are presented to wrap up and emphasize the major takeaways and suggestions going forward.

Situating the Study

Historical Development and Effectiveness of Transition and Support Programs

Since the original institutions of higher education were not designed with all students in mind, it is not surprising that programs have been created up until today to help specific groups of students transition to universities (Nichols, 2020). Programs and student organizations have also been created to support students once they are at colleges and universities as well as build comradery among historically excluded populations (Thelamour et al., 2019). The United States Department of Education established the Student Support Services (SSS) program, one of the federal TRIO programs, in 1968 through the Higher Education Act of 1965. The SSS program was designed to encourage the persistence and graduation of low-income and first-generation students as well as students with disabilities (Brewer & Clippard, 2002; Paul, 2016). The program had specific requirements set forth, including providing academic tutoring and guidance for selecting college courses, among others (Keppel, 1987). Atypical of what we see in programs today, the original SSS program was even required to provide practical assistance for tasks such as completing financial aid forms and increasing economic literacy (Kezar & Yang, 2010). This program helped lay the foundation for other programs and initiatives developed in the years to follow.

The 1964 Educational Opportunity Act established the Upward Bound program, which still operates in many cities today (Seftor et al., 2009). Upward Bound was geared toward generating interest and involvement from pre-college students by exposing them to the opportunities that postsecondary education could present (Garcha & Baldwin, 1997). Similarly, in 1965, the Talent Search Program started after the Higher Education Act was passed. Talent Search has very similar goals to Upward Bound and targets "disadvantaged" youth, to get them to enroll in and graduate from college (Lee et al., 2008). The term TRIO was coined for those first three programs (SSS, Upward Bound, and Talent Search), but others were added later. As of 2023, an estimated 2.2 million students have benefited from participation in TRIO programs, culminating with their graduation from an institution of higher learning (TRIO Talking Points, 2023).

As time progressed, specific institutions, and even disciplines, began creating similar versions of their own support programs. For STEM, and sometimes engineering more specifically, Summer Bridge Programs (SBPs) have served as leading support programs across the United States (Ashley et al., 2017). SBPs were created with the intent to smooth the transition from high school to college and tend to focus on helping students develop across multiple dimensions. SBPs typically fund a cohort of students to take college preparatory courses, stay in residence halls, access meals, and sometimes even cover orientation expenses (Reisel et al., 2012). SBPs are distinct from typical TRIO programs and programs before them because of their focus on one potential career field or a small group of career fields (Doerr et al., 2014). SBPs can have various names at different intuitions but typically employ similar structures and have common goals (Gleason et al., 2010; Raines, 2012). Those goals include but are not limited to ensuring students are academically prepared to succeed in their intended undergraduate major and fostering a sense of community for students who may find it difficult to do so on their own (Suzuki et al., 2012).

Research has shown that SBPs have played important roles in postsecondary goal attainment for students from underrepresented backgrounds (Kallison & Stader, 2012; Kitchen et al., 2018; Liu, 2018). Bradford’s (2021) meta-analysis of university STEM SBPs effectiveness uncovered that participation had moderate effects on first-year retention and first-year GPA. It also revealed that SBP participants were 1.747 times more likely to be retained to the second year of their degree programs than control group students (Bradford et al., 2021). Bradford's findings were in alignment with researchers who found that students who participated in STEM SBPs were less likely to drop out than non-participants (Ghazzawi et al., 2021). While these studies provide a basis for examining the effectiveness of SBPs, they encompass a variety of STEM majors and many only examine academic outcomes. The present study sought to gather comprehensive data on a program designed specifically for students who had been accepted to undergraduate engineering degree programs at a large, predominately White institution.

Continuing Students in Engineering

While they acknowledge a need to recruit and retain diverse student populations, many undergraduate engineering programs fail to properly support and monitor students as they matriculate further into their programs (Gahagan & Hunter, 2006). Previous studies have investigated whether past SBP students went on to graduate but neglected to gather qualitative data on their experiences after the freshman transition program. Studies also have failed to look at continuing students' experiences across the board, unless looking specifically at career trajectory or graduation rate (Kitchen et al., 2018; Murphy et al., 2010). The overemphasis on freshmen and senior years leave educational research on the also important sophomore and junior years less developed. Though this is sometimes mitigated by longitudinal studies that examine students' journeys across multiple years, these studies take an extended time to be completed and disseminated (Walpole et al., 2008). To add to the issue, in the first year of many engineering programs, students are devoted to taking core courses that are non-major-specific. The sophomore and junior years may arguably be the period where students need the most assistance as they are introduced to new concepts and contemplate whether they chose a fulfilling major.

Contextual Success for SBP Students

Students' potential success across various dimensions in an SBP may not be synonymous with success in the context of their undergraduate programs. Student success in engineering has primarily been centered around academic performance (Kokkelenberg & Sinha, 2010; Veenstra et al., 2008). We find this primary focus counterproductive for tackling the larger problems regarding student retention and attrition in engineering, especially for URM students. It is possible that this focus on academic performance measures like GPA is distracting researchers and educators from looking at the bigger picture of why certain students leave engineering. Academic performance is undoubtedly an important factor for student success but is not an accurate representation of students' holistic development within engineering programs. We assert that no one factor can reliably predict students’ success in engineering or their likelihood of persistence. Instead, we positioned ourselves to analyze student experiences in engineering education from a multidimensional viewpoint, encompassing their academic preparedness, social integration, competence, and choice to engage in engineering activities, among other things.

We hypothesized that this would be especially important for students who are no longer in support programs like SBPs and who are now in the middle of their undergraduate journeys. While first-year retention rates are certainly important, the possibility of attrition does not go away after students begin their second year. Similarly, just because a student is retained, does not mean they are successful in engineering across all domains, especially affective ones that cannot be measured by academic performance. Therefore, we took a more critical approach to examine student success inside and outside the classroom and the role that SBP participation played in participants' past and present experiences.

A Different Take

By analyzing students' past experiences within an SBP and current experiences as they matriculate through their undergraduate programs, one can better understand the long-term impacts of SBP participation as well as discrepancies in different engineering education contexts. We positioned the current study in the unique position of analyzing how an engineering-specific SBP can impact the experiences of students later in their undergraduate tenures. This work is situated in the larger line of research focusing on the critical roles student support programs have played and continue to play for students transitioning to and through college. We took a unique stance and approach that intended to close a gap between gauging student success and program effectiveness based on one aspect of the college student experience. Acknowledging the holistic nature of student success at institutions of higher learning, we adopted Self-Determination Theory to shed light on persistent issues and questions in engineering education regarding the experiences of past SBP students during and after the program.

Theoretical Lens

Self-Determination Theory (SDT) has proven useful in non-engineering fields and provided insight into existing engineering education issues. SDT, developed by psychologists Ryan and Deci, has been a leading theory for investigating motivation across contexts (R. Ryan & Deci, 2000). The macro-theory, comprised of 6 mini-theories, posits that self-determination and motivation are achieved based on the degree to which 3 basic psychological needs are fulfilled: perceived autonomy, competence, and relatedness (Ryan & Deci, 2008). Autonomy was operationalized as students' free will or choice to engage in certain activities. Competence was their beliefs regarding their capabilities and knowledge base. Relatedness helped explain how they connected with others in a certain context or environment. We adopted the use of SDT specifically concerning participants' experiences in the context of the SBP and their respective undergraduate programs thereafter.

We used one of the mini-theories, the Basic Psychological Needs Theory, to closely examine how the satisfaction or frustration of the three basic needs was influenced by the SBP. We also investigated how they influenced and impacted participants’ journeys through their degree programs up until the time of data collection. We acknowledged that students could have varying levels of self-determination in different contexts, such as in engineering and at home in their personal lives. To examine engineering contexts specifically, we based our methods on two validated survey instruments: the Intrinsic Motivation Inventory (IMI) and the Aspirations Index (AI). By doing so, SDT was used to carefully construct the design of the present study and to answer the following research questions.

Research Questions

1. How does the structure of a Summer Bridge Program (SBP) affect students' experiences and success in engineering either during or after the program?
2. In relation to the Self-Determination Theory constructs, which program characteristics and experiences either contribute to or detract from past SBP students’ experiences and holistic success in engineering (during or after the program)?

Methods

This qualitative study included data documenting the lived experiences of seven students who participated in an SBP at [university in southern state] in either 2019, 2020, or 2021.

Participant Recruitment

Students who participated in the SBP in the years 2019, 2020, and 2021 were contacted via university email to inquire about their willingness to participate in an interview. Past participants' contact information was kept on file in a password-protected SBP digital folder. The goal was to get participants from each of the three years preceding the 2022 SBP. Of those who responded to schedule an interview, two participants were a part of the 2019 SBP cohort. Two were a part of the 2020 cohort, and three were in the 2021 cohort. Once students agreed to a time, they were emailed a consent form with details about the research study as well as a confidentiality statement and their right to withdraw at any time.

Interview Protocol Development

Semi-structured interview protocols were elected as a means to gather in-depth, first-hand information on students' lived experiences. The first version of the interview protocol was developed for our previous study which focused on SBP freshmen and used Jacob and Furgeson's (2012) guidelines for writing protocols and conducting interviews. For the work reported in this paper, the original protocol was edited to fit the context of continuing students who previously participated in the SBP. For example, some questions were worded to be past tense. Also, some questions were added to inquire about lasting effects of the summer program and to allow the participant to reflect and compare their past experiences to their current experiences within undergraduate departments. Using existing metrics such as the Intrinsic Motivation Inventory (IMI) and the Aspirations Index (AI), a semi-structured SDT interview protocol was developed. The IMI focuses on perceived satisfaction or frustration of the three basic psychological needs (autonomy, competence, and relatedness), gathering self-reported data using a 7-point Likert scale (Ryan & Deci, 2017). The AI focuses on goal importance and whether one is motivated extrinsically or intrinsically but also uses a 7-point Likert scale to gather reposenses (E. L. Deci et al., 2001). Six IMI constructs guided the creation of a portion of interview questions: interest/enjoyment, effort/importance, relatedness, value/usefulness, perceived choice, and perceived competence. Additionally, the following six AI constructs were incorporated into interview questions: fame, wealth, image, relationships, community, and personal growth. Additional questions were crafted based on the aim of the study and the research questions it intended to answer.

Each core question included in the interview protocol was explicitly mapped to the construct or concept it was based on. These connections were written in the protocol, along with a comment section. Each core question also was accompanied by probing questions that could serve as potential follow-up questions to anticipated responses to its linked core question. For instance, continuing SBP students were asked to “Describe any unique characteristics/differences of your SBP experience versus the experiences of those in other cohorts (I.e., 2019 vs 2020 vs 2021 vs 2022).” The probing question following that core item was “How do you think those differences impacted you and/or your cohort?" The concept these interview questions intended to capture information for was individual cohort differences (E.g., pre-and-post covid, courses offered, leadership and structure, etc.). The protocol also included written prompts to begin and end the interview, a participant information section, space for notes, and directions for post-interview tasks that needed to be completed.

Interview Procedures

Interviews were scheduled based on students' availability in response to the initial recruitment email. Interviews took place on October 17^{th}, 18^{th}, and 19^{th}, 2022. Students were emailed a location in a university building. This location was private, ensuring confidentiality, and required key access (from the researcher) to enter. Two participants from the 2020 cohort requested to do a joint interview. All other participants had one-on-one interviews. Of those who had one-on-one interviews, one participant completed his virtually due to being out of town for an internship. This participant signed his consent form electronically and returned it before the start of his interview. For all other participants, a physical copy of the consent form that they were emailed earlier to review was brought to the interview. They were allowed to review the document again and requested to provide a physical signature.

All interviews were audio recorded using an Olympus digital recorder issued by the university library's digital media center. Students were verbally informed of the point at which the recorder was turned on and off. Recorded portions of the one-on-one interviews lasted approximately 30 minutes and the one joint interview lasted for about 46 minutes. After each interview, the audio file was transferred to a university laptop, then to a password-secured Dropbox account. All participants were assigned pseudonyms, and the audio files were named accordingly. The audio files were uploaded to the Rev transcription software, and transcripts were returned in about one day. Next, transcripts were cleaned. This process entailed removing any identifying information that could be linked back to a specific participant and replacing it with a generalizable placeholder. Once all interview transcripts were cleaned, there were ready to move into the coding phase.

Coding and Theme Synthetization Procedures

Using the interview protocol in combination with the IMI and AI instruments, a codebook was developed, deductively from SDT concepts and the research questions, to aid in data analysis for our previous study focusing on SBP freshmen. The present study used the same codebook which consisted of a variety of codes appropriate for analyzing both freshmen and continuing students' experiences. The codes began with concepts included in the theoretical framework but also included concepts pertinent to the research questions. The codebook included codes along with their definition or description. Additionally, an example or scenario of each code was provided to better illustrate its meaning. The codebook also showed examples or scenarios of what a code "is not" to lessen the likelihood of a code being misinterpreted and inappropriately assigned to a section of text. The coding process took place on the Dedoose platform, designed for data analysis and organization. Dedoose allowed for the input of codes and their definitions. Then, the cleaned transcripts were uploaded to the platform. Then, the primary researcher could assign codes to sections of text within the transcripts that they fit appropriately with. Two rounds of this process were completed for each interview, by the primary researcher. It is important to note that one section of text could be assigned multiple associated codes. Once all transcripts were coded in Dedoose, one could efficiently examine which codes with used for specific participants and the frequencies of codes used across the entire group.

Based on the coded interview transcripts, themes were synthesized to capture and present the overarching findings of the past SBP participants. Theme synthetization involved examining the codes assigned across the group of past participants as well as looking closely at the codes assigned for distinct cohorts (I.e., 2019 vs 2020 vs 2021). Emergent themes were drafted to capture the common sentiments and expressions of the participants. These themes were written in alignment with the SDT constructs and the overall theoretical lens used to examine the data.

Additional Information on Validity, Reliability, and Trustworthiness

There exists a host of validation articles for the survey instruments that informed the creation of the interview protocol and codebook used in this study. Some studies that specifically focused on the IMI survey instrument include (Deci et al., 1994; McAuley et al., 1989; Plant & Ryan, 1985; Ryan1982.; R. M. Ryan et al., 1983, 1990, 1991). At least ten other studies were conducted to validate the AI survey instrument (Gollwitzer & Bargh, 1996; Kasser, 2002; Kasser et al., 1995; Kasser & Ryan, 1993, 2001, 2000; R. M. Ryan et al., 1996; Schmuck et al., 2000; Sheldon & Kasser, 1998; Williams et al., 2000).

Trustworthiness and credibility of the qualitative data were established through the standardization of the interview protocol and accompanying procedures (Stahl & King, 2020). All participants followed the same procedures. For the two students who requested to do a joint interview, both were allowed to respond to questions. There was no set order on who answered first, and they responded naturally. Both participants gave their own in-depth answers and sometimes added additional thoughts after they heard each other's answers. Transcripts, excerpts, and themes were derived directly from the participants' narratives. Also, each interview was analyzed twice on Dedoose to ensure that the codes were accurate. Themes were created using supporting evidence to ensure that narratives were representative of the group. Additionally, originally proposed themes were rejected or revised if they did not have enough supporting evidence backing them.

Results

The in-depth interviews of 7 past SBP participants led to the synthetization of 5 core themes:

Theme 1: Being Black in engineering played a major role in the relatedness students felt during the SBP and during their undergraduate program progression.

Five of the 7 SBP participants spoke about the value they associated with meeting other Black students in engineering. The sense of community established during the SBP was sustained as they began to matriculate through various undergraduate programs. To take a closer look at some of the evidence supporting this theme in action, we can look more closely at Xavier's experiences. Xavier is a Black male who participated in the SBP in the Summer of 2021. He is now a sophomore enrolled in an [engineering major] program. Xavier emphasized that the strategies SBPs use to target participation from and encourage success for URM students are central to the program.

When asked what the most valuable part of the program was, Xavier said:
‘the most valuable part was being around people that look like me, straight up… because I went to a predominantly white high school and [southern university] is a predominantly white institution. And so, before you even get up there, meeting a lot of people that look like you and that have the same goal, a lot of black engineers, you're an engineer, they're an engineer, you all can relate on so many levels just by that and talk about a lot of different things and that's what starts up conversations. So I think the value came within knowing that I'm a minority and seeing other people just like me and knowing that, "Hey, if he's struggling and I got it, I can help him out. Or if I'm struggling and he got it, we can help each other out through the process.’

Xavier's notion of the Black community and support was further demonstrated as his interview progressed. When he was later asked "It wouldn't be the SBP without [blank]/what should not change if the program had to be redesigned?" he responded:

'It wouldn't be Summer Bridge without the underrepresented minorities. Keep it within the minorities because that's what's going to build that strong community between the participants. And it's also going to have a good outlook… because if you have nothing but minorities and they all do really well throughout the program and their degree plan, then you can say, "Hey, this program's working and we can keep it going for this specific group." And then keep getting more and more people in. Also, the team-building exercises we do at the [recreation center at southern university], that was pretty fun. Just getting to just goof off with people and have fun and stuff like that.'

Xavier, along with other past SBP participants, shares the assertion that the SBP would not be the same or as effective if it was not intentionally designed for fostering URM student success. Xavier and other past participants described the importance of having a community specifically with Black students as being important for them to find their places and establish support systems. They also expressed that seeing other people who look like them succeeding in engineering contributed to them developing more positive outlooks and views of their competence and capabilities.

Theme 2: The structure of the SBP matters. Different structures and delivery modes impact students' self-determination in engineering differently.

Six of the 7 students highlighted the importance of the SBP structure, especially in terms of the delivery mode. For one group specifically, the 2020 cohort, relatedness was noticeably hindered by the SBP being conducted virtually. Summer 2020 was marked by the peak of the

Covid-19 pandemic, and many in-person activities were suspended for institutions. 2020 past participants expressed witnessing a lack of motivation, on their behalf or from actions shown by their peers, to engage through computer screens. Moreover, relatedness among the 2020 cohort differs drastically from that of other cohorts. More specifically, students who participated in the virtual SBP in 2020 had a more difficult time bonding with their peers and building support systems within their cohorts. One 2020 SBP participant stated that they started with about 15 participants in the program but only 9 completed the program, which corresponds to about a 40% attrition rate over 4 to 5 weeks. This initial attrition from the beginning to the end of the program suggests that students associated less value with dedicating their time to a virtual SBP program. Of those 9, only about 6 participants are still enrolled as engineering students. This is evidence of a 60% attrition rate from summer 2020 until October 2022. Cohorts with students who participated in in-person SBPs rarely experienced attrition and started with much larger cohorts.

While 2019 participants spoke about the importance of the cohesive nature of SBP paving the way for community-building activities and increased relatedness, 2021 participants expressed feeling amplified effects as a result of being the first post-covid SBP cohort. The participants stated that this was their first time being back in the physical presence of other scholars as the peak of the Covid-19 pandemic subsided and that made the community-building activities more important and resulted in a more intense bond between participants.

Theme 3: Leadership and connections matter. Students perceived competence and relatedness were heavily influenced by the program leader and the speakers she intentionally chose to speak with URM students.

Of the 7 student participants, 5 expressed the notion that inspirational leadership and networking during and after the SBP were critical to their development. They spoke highly of their director and her sustained involvement in their academic journeys as well as their well-being. Additionally, they stressed the importance of the unique networking opportunities that were made available to them. This often included being introduced to URM professionals in STEM fields. To illustrate the value students associated with leadership and connections, let's take a closer look at Zaina's interview data. Zaina is a Black female who participated in the SBP in 2020. She is now in the third year of her [engineering major] program. While speaking about the importance of leadership, Zaina also spoke about how it helped mitigate some of the challenges associated with a virtual SBP delivery mode.

'I really think that [SBP director]- she just carries herself so well and every time she says something it's just super insightful. So I think having her to speak a lot as a Black woman about engineering and how you have to carry herself as a Black woman in engineering- because she's very well respected on campus. So she was a really good role model to have. I think that during those couple weeks, I mean honestly if it wasn't for her…. I mean you're logging into a computer screen for a whole five weeks. All my friends are having fun [non-SBP friends]. I'm sitting at the house all day on the computer. That's not normal. So I mean if it wasn't for her and her always having something to teach me and something to share, I would not have done it.'

While speaking about challenges unique to URM students in undergraduate engineering classrooms, Zaina shared more about her background and the impact of her SBP leader:

'And luckily for me, I'm used to that because in high school I went to predominantly white school. So that wasn't new for me. And interacting with people who don't look like you is different. People telling you that you're not smart because you don't look like them. I mean that's something to get used to. You shouldn't have to get used to. But I mean its kind of important to have a network of people to talk to about things like that. So I think that having those people is definitely important. Having [SBP director] to talk to about things is definitely important.'

Several other students spoke highly of their SBP director's leadership style and the impact she had on their academic journeys. Another way participants engaged with leaders was through alumni spotlights. These sessions were included on the SBP schedule and designed to let past participants who are now working professionals come back and tell their stories. Zaina went on to make the following statement regarding the SBP alumni spotlight sessions:

'I think for us, somebody came to speak to us every day and I remember just seeing how many successful Black people- it was just kind of interesting because people make it sound like if you live in the south, you can't do big things, which is very- not true. Especially if you're Black… they like to say you can't have opportunities to do this and that. So, it's just kind of cool to see people that looked like you have opportunities and be able to say that you could do this. I went to [southern university] and I did this and it's just like, okay, so I can do that, obviously, if you did it.'

Zaina's sentiments are related directly to her increased perceived competence and relatedness and are good representations of the general consensus across all cohorts. Representation among speakers and leaders allowed students to begin envisioning themselves as professionals. This vision, coupled with academic preparation and community building increased their perceived competence, ability beliefs, and relatedness in engineering contexts.

Theme 4: Beneficial courses and strategically designed SBP schedules prepared participants for the workload of a full semester and increased their perceived competence for upcoming fall STEM courses.

Regardless of which year they participated, all 7 past SBP participants spoke about the knowledge and skills they gained because of the courses integrated into the SBP and the overall program schedule. To further demonstrate the views students had toward the SBP courses and scheduling, we present Preston's thoughts on the topic. Preston participated in the SBP during the summer of 2021. He articulated that his journey to his [engineering major] degree program differed from his peers because he took a break before going to the SBP. Preston graduated from high school in 2016 (5 years before his SBP participation), while the rest of his cohort graduated from high school during the same year the SBP took place, 2021.

When Preston was questioned about the amount of effort that was required to do well in the SBP, he responded:

'It was rigorous. That's probably the best term. It was very jam packed. Every single day was full of things. And then we only had maybe one or maybe one and a half days of actual just freedom. But I think that was good because, again, with how jam packed it was when you got to college itself, that was nothing. When you have five... It is almost how was going to a public school is. They jam-packed the whole day and then you get to college and it's like you have maybe two classes a day, maybe one day or two days out of the week, maybe you have three or something like that.'

Preston emphasized the importance of the academic preparation he received in the SBP because of his more non-traditional route. When asked if he would go back and participate in the SBP again if he had the chance, he said yes. He detailed specific courses that he received training in, including calculus 1, chemistry, and physics, among others. Preston even went as far as saying he wouldn't be nearly as confident going into his undergraduate program had he not taken the intentionally designed courses in the SBP. He stated that when he finally got into his program, it felt as though he was picking back up where he left off when he finished the SBP courses.

Similar to other students, Preston's comments on his experiences demonstrate how his perceived competence was positively impacted by the courses and schedule of the SBP. Other students spoke about how the SBP's structure increased their perceived autonomy and abilities to function independently as adults. Participants spoke about the SBP serving as a stepping stone to the fall semester, being prepared for the rigor of a full-time fall schedule, and learning more about their educational interests, among other benefits.

Theme 5: Relatedness is non-transferrable and contextual. For continuing students, relatedness in SBP and with other SBP cohorts drastically differs from relatedness in their engineering programs, impacting all SDT basic psychological needs and student experiences.

The strong statements made by 3 participants about their experiences both within and outside the SBP lead to the creation of a theme positing that relatedness is non-transferrable and contextual. This means that students who communicated positive perceptions of relatedness in one engineering context, the URM-centered SBP, or with other Black engineers, did not experience engineering relatedness in their courses and departments. To give a clearer justification for this theme, we will examine Yasmine's journey. Yasmine is a Black female from the 2020 SBP cohort and is now a third-year [engineering major] engineering student. Yasmine participated in the joint interview with Zaina, who was introduced in Theme 3.

The following excerpt was taken from Yasmine and Zaina's joint interview transcript. It illustrates responses to a question about how they thought the SBP impacted them once they went into their undergrad programs and how competent or related they felt. They were also asked whether they felt the same type of relatedness with Summer Bridge people and people in their departments. Their responses were:

Yasmine:

Do I feel like I have a family in my major?

Zaina:

Because no.

Yasmine:

Not at all.

Zaina:

Is that your question, for real?

Yasmine spoke about the ways she felt excluded in her department and with her peers. She spoke about URM engineering organizations serving as an outlet and being her support when she was not receiving what she needed in her department. Speaking on exclusion in classroom settings specifically, Yasmine said:

‘But when I don't feel that support with the people around me there [classroom], I know that I can go back to NSBE and have the support there.'

All part participants spoke about the National Society of Black Engineers (NSBE) as being sort of the "next step" after the SBP. They viewed NSBE as an organization that allowed past SBP cohorts to continue to bond and develop. However, NSBE also included other URM engineering students who may not have participated in the SBP.

When asked to elaborate on the presence of Black engineers in the [engineering major] engineering department at her institution, Yasmine stated that there were three and that they were all one year older than her. The expressed her appreciation and gratefulness toward having them as mentors who can listen to her and offer advice. She emphasized the strength of their relationships by saying:

‘And having that [relationships and community with other URM scholars in [engineering major] engineering and NSBE] makes it okay when my teacher tells us to work with partners and turn to your neighbor and then nobody turns to me.’

Discussion and Practical Implications

Theme 1 relates to students’ emphasizing the unique experiences they have had specifically as a result of being an underrepresented student in engineering, both during and after the SBP. This finding appears to be built upon the foundational finding we gathered from SBP freshmen participants in a previous study. We previously found community building to be a critical part of freshmen students’ experience, especially regarding relatedness in the SBP as they prepared for the fall semester. A distinction of the SBP past participants is that they began to recognize the importance of that community being URM as they moved away from the summer program and higher into their major-specific courses.

The two past SBP participants who did not speak about the importance of establishing a community of URM scholars in the SBP were biracial. According to Renn’s Ecological Theory of Mixed-Race Identify Development, situational identity patterns are healthy and may have allowed these students to shift depending on their environment (e.g., SBP comprised of mainly URM students to departments comprised of mostly White students) (Patton et al., 2016). Renn describes situational identity as “a fluid identity pattern in which an individual’s racial identity is stable, but different elements are more salient in some contexts than in others (Renn, 2012). This could suggest that they felt more included within communities aligning with either side of their ethnic identity. They spoke on the importance of general community building in the program but did not emphasize the criticality of the having a community of URM scholars as they matriculated through their undergrad programs like other participants.

Theme 2 was created to capture the notion that the structure of the SBP, especially before, during, and after the peak of the Covid-19 pandemic, significantly impacted students' experiences. When asked whether they believed anything made their SBP cohort unique or different from others, participants openly offered insight related to distinctions across different years. More specifically, students who participated in the virtual SBP in 2020 had a more difficult time bonding with their peers and building support systems within their cohorts.

Based on the data gathered for 2020 participants, this lower perception of relatedness in their cohorts was sometimes moderated by establishing relatedness with other SBP cohorts during the fall semester and beyond. However, this idea of bonding later with other SBP cohorts may not have been the reality for all 2020 participants, as suggested by the 60% attrition rate from the beginning of the SBP through the cohort's point of matriculation at the time of interviews. The reality for 2020 participants is that not only did they experience a virtual SBP, but in their first semester many courses were virtual or hybrid (alternating in-person and virtual lecture days). Also, student organizations did not meet in-person. Likely, it was difficult for 2020 participants to bond with each other and other SBP cohorts.

The fact that 2021 SBP participants felt amplified effects was also of interest to us. The need to use digital learning and communication shifted the United States at the time that these students were in the final couple years of high school. They emphasized, more than other cohorts, the importance of the program structure being on-campus. They were able to compare isolated high school experiences with the collaborative nature of the SBP, similar to the ways some 2020 participants compared their isolated SBP experiences to their sense of community among other cohorts in NSBE.

The key takeaway is that the 2020 participants had noticeably different experiences in the BSP, which impacted their relatedness to each other and perceived competence. Gabrielle, a 2019 participant, even pointed out that she and her peers recognized a difference in the cohort succeeding theirs. This information could prove useful for future preparation and executions of SBPs. Since the virtual program had the same formal components as the in-person programs (e.g., study hall, courses, alumni spotlights, etc.), perhaps virtual formats fall short of being a suitable means for informally building community within cohorts as well as in other contexts. For instance, one could infer that team building and fellowship among SBP counselors during virtual training may not be very effective. Similarly, virtual meetings among multiple cohorts during reunions and meetings for other organizations (that many past SBP participants go on to join) may not be as impactful when facilitated through virtual platforms. This may be especially true for groups of people who have never met in person before the time of the virtual meeting/program (e.g., Summer 2020 SBP cohort).

Regarding theme 3, participants associated value with the impact that stemmed from having inspirational leadership and professional connections in the SBP. Students spoke specifically about the leadership qualities and involvement of their SBP director. Their director sustained relationships with them even after the summer program concluded. She monitored their performance and met with them to assess their needs and well-being. Many students viewed the director not only as a leader but as a mentor and point of contact for future needs. This level of involvement positively affected participants' self-determination in all three main constructs.

Participants also emphasized the intentionally selected professional connections and networking opportunities provided by the SBP. Many of the speakers the students encountered were from URM backgrounds. Participants viewed this representation of successful professionals in their fields as evidence they too could attain their goals of successfully earning engineering degrees and beginning rewarding careers. Several participants verbalized that they would not have felt the same impact had they not essentially seen a part of themselves in the speakers and leaders. This finding should be a key consideration for SBP leaders and decision-makers when planning future programs. While it is essential to allow students to develop well-rounded networks and connections, URM students in engineering appreciate the bulk of the SBP being geared toward establishing professional contacts and relatedness with those who they feel have been in their shoes and encountered similar experiences. Participants implied that is not always enough for majority leaders and professionals to empathize with them and join as allies along their journeys. It is also critical that participants make those connections with professionals from similar backgrounds who "look like them" and best understand, first-hand, the challenges they face and the mentorship they need.

Theme 4 captures the participants' appreciation of the knowledge gained from SBP courses and the discipline instilled in them by the rigorous program schedule. This theme relates more to the formal learning experiences students had in the program. Each student across all three cohorts emphasized the role SBP courses and/or the schedule played in their successful transition to and through their subsequent semesters as undergraduate students.

Delving deeper into the discussion of one student from the 2021 cohort, who had taken a 5-year break between high school graduation and beginning college, we made connections to how the courses allowed him to increase his confidence in foundational subjects needed for engineering work that he had not dealt with in a longer period than his peers. This suggests that support programs may be of special interest to non-traditional students and transfer students entering engineering programs. Based on this information, more deliberate efforts should be channeled toward providing adequate support for students who are not like the majority of students transitioning directly from high school. While those going from high school to college have likely recently focused on many subjects deemed pre-requisite for engineering, students who took alternative paths may have unique needs warranting specialized transition programs.

Theme 5 asserts that the engineering relatedness among SBP participants is non-transferable to undergraduate programs and contextually based. Essentially, high relatedness in SBPs is critical for establishing community specifically for URM students. However, students are not properly supported and are not always met with welcoming atmospheres once they leave spaces like the SBP. Students expressed feeling undervalued and excluded when they moved into their departmental spaces. It is important to note that one student did not report negative experiences with her instructors specifically but did report them with the students in those instructors' classrooms. It is the duty of the instructor, department, and university to foster welcoming environments for all students and even call out students who fail to contribute to the attainment of that mission.

The fact that students laughed during interviews when asked whether they felt a sense of relatedness in their undergraduate programs similar to what they felt in the SBP is problematic. We reiterate that while participants expressed their discontent in their departments, they used URM communities to make up for it. This is entirely different from participants trying to change or "fit into" those spaces. This could be explained in part by Atkinson, Morten, and Sue's Racial and Cultural Identity Development Model. The scholars posited that encounters of dissonance are the catalysts for one “to question White culture and begin an interest in one’s own racial or ethnic group” (Patton et al., 2016). For continuing SBP students, dissonance occurred when they sensed being excluded in engineering classrooms after being embraced by their cohort. Findings related to the structure of SBPs and the programs’ impacts on URM participants could be foundational in developing workshops and best practices instructors can incorporate in their classrooms to continue fostering community and inclusivity for all students.

This theme gives way to a discussion on the differences between support program spaces like SBPs and undergraduate degree program spaces. If the leaders and decision-makers for programs like SBPs are the same people leading undergraduate programs and departments, then why do the attention on URM students' acclimation and success seem to fade or cease after the SBP? We call attention to the need for continuous, sustained investment in the well-being of all students throughout their journeys. This is essential to mitigate the likelihood of attrition after the first year and to ensure better experiences for students still contemplating following engineering or non-engineering career trajectories.

Study Limitations

While we gathered and analyzed rich data from students who previously participated in an SBP, it would be valuable to conduct similar investigations with more students from past cohorts. While we recognize the value of the current study’s qualitative data and resultant themes, findings may not necessarily be generalizable. It would be beneficial to gather additional narratives from past SBP participants as well as try using quantitative methods to corroborate findings. Our limited sample size was partly due to a common issue faced by researchers. Getting participants to engage in research efforts after they are no longer involved in the program of interest is difficult, but necessary.

Conclusion, Recommendations, and Future Work

With a deeper understanding of the experiences that students encounter both within the SBP and after the program concludes, we can better understand how to create and sustain impactful support systems for students throughout their entire undergraduate journey. More specifically, we were interested in investigating how the SBP affected students' experiences and success in engineering either during or after the program (RQ1). We found that the SBP was instrumental in developing the URM community both among cohort participants and between participants and their professional network. Additionally, this relatedness did not automatically translate to their social integration on a larger, institutional scale or within their engineering departments and classrooms.

Regarding the investigation of more specific program characteristics and experiences that could contribute to or detract from holistic success in engineering (RQ2), we first found that program rigor and SBP courses' content helped prepare students in the long run. Discipline to listen and focus for extended periods and organization skills to reserve study time were among the benefits associated with the SBP courses and prescribed scheduling components. Next, we find that the delivery mode and the accompanying experiences derived from that mode impacted students' holistic success in engineering. This was especially evident for the 2020 SBP, which was held virtually and resulted in lower participation and higher attrition across time.

We recommend strategizing to maximize the formal components and informal experiences that contributed to positive student experiences and increased autonomy, competence, and relatedness in engineering. In addition, we suggest that SBP leaders as well as the leaders of departments students go on to enter begin recognizing and mitigating the discourse students feel when moving from welcoming, intentionally designed SBPs to spaces where they do not express feeling that same sense of inclusivity. Efforts should be made to continue to properly support URM students after a URM-focused program has ended. The efforts of SBPs are in vain if engineering departments and colleges do not take heed of the role their sustained involvement has on the overall course of students' journeys and trajectories. We are hopeful that practical changes will be implemented to ensure the long-term success of all students.

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CHAPTER IV

TO BE OR NOT TO BE: ENGINEERING SENIORS' EXPERIENCES AND THEIR IMPACTS ON CAREER PLANS

Abstract

Emphases are often placed on figuring out how to attract K-12 students to engineering education programs and retain them through graduation. The students' journeys near and after graduation are often overlooked in literature. Adopting Self-Determination Theory as a guide, this work aimed to collect data on engineering seniors' experiences in the contexts of their programs and departments. A version of a survey was distributed with items adopted from the previously developed and validated Intrinsic Motivation Inventory and Aspirations Index. Using IBM Statistical Software for Social Sciences, we completed a binary logistic regression to uncover whether three constructs, perceived autonomy, competence, and relatedness were significant predictors of students' choices to pursue engineering versus non-engineering jobs after graduation. The regression revealed that none of the included independent variables were significant predictors. However, responses from the participants suggest that their choices may not be dependent upon the types of experiences they had in their degree programs. The data revealed that many students reported feeling underprepared to work in an engineering role. Further, students expressed feeling dissatisfied with and disconnected from professors and administrators in their departments. Surprisingly, students who shared these types of sentiments reported that they still intend to go directly into the engineering workforce. Possible explanations may include external factors and experiences outside the participants' departments which were not considered in this study. Further research should incorporate these factors and experiences and investigate whether they are significant predictors of career choice. This information is relevant for engineering leaders and faculty as well as companies aiming to hire new engineering graduates.

Keywords: engineering senior, career plans, engineering career, undergraduate programs, aspirations

Examining Seniors’ Experiences and their Impacts on Career Plans

In engineering education programs, a common assumption is that undergraduate students will work in engineering industries after graduation. A likely exception is a portion of students who decide to pursue graduate degrees, typically in engineering areas or business administration (Stiwne & Jungert, 2010). However, substantial research has not been devoted to investigating what students actually plan to do after earning their degrees. Further, fewer studies monitor where they do end up, regardless of intended occupations. A potential issue arising from this lack of monitoring is that engineering education leaders are unaware of students' attitudes toward engineering as their near graduation and make decisions about joining the professional workforce.

Ideally, professional engineers and/or engineering educators hope that engineering graduates become contributing engineers in society who have positive experiences in and feelings toward the field. In doing so, they add to the possibilities of fostering a more sustainable future (Pritchard & Baillie, 2007). However, this information may not be easily captured. Many engineering programs distribute exit surveys to graduating seniors, but the questions are typically vague. They often gather general information such as what students plan to do after graduation but neglect to use any sort of theory in an attempt to understand why students have specific plans. Theories may provide avenues for engaging in an in-depth inquiry into students' career choices as well as aid in better understanding why students make some choices over alternatives.

Many theories are devoted to investigating career trajectory, personal choices, and career interests. Bandura’s Social Cognitive Career Theory holds that people are products of interactions between external environmental factors, past and present behavior, and internal factors (Bandura, 1982; Lindley, 2005). Super’s Developmental Self-Concept Theory posits that when people make career choices, they are expressing their self-concepts and understanding of self, but these perceptions evolve over time (Betz, 1994). Likewise, Holland’s Theory of Career Choice maintains people choose careers in which they can be around people who are like them and that people who work in environments that align with their personality type are more likely to be successful and fulfilled (Reardon & Lenz, 1999). Theories related to career choice and trajectories are rarely used in engineering education research, aside from investigating why undergrad students choose engineering majors.

The present study intended to go a step further and gauge senior students’ perceptions of the engineering programs, beliefs about their capabilities, and their interactions with the engineers around them, to better understand their career goals. This should be addressed because engineering education leaders need more information on how students feel as they are about to graduate and how that translates into where they decide to go next. With this information, program leaders and administrators can better assess whether engineering education programs are successful in achieving goals outside of maintaining graduate rates alone. This may also provide clarity and insight into professional development and educational experiences students desired but failed to receive in their degree programs.

By surveying engineering seniors in one college of engineering, we delved deeper into the experiences students have in their respective degree programs and departments. The survey contained items adopted from the previously developed and validated survey instruments that are equipped to gather information on a variety of constructs. The questions were framed to specifically ask about those constructs in the context of students' undergraduate degree programs. The objective was to gather more information on how students are currently motivated within their programs and their immediate post-graduation career plans. Additionally, we posed a question related to whether they envisioned themselves in engineering occupations 5 years after graduation. In doing so, we were able to statistically examine whether the scores students reported for certain constructs were linked to their post-graduation plans of embarking on either engineering or non-engineering journeys.

In this paper, we suggest a theory that can be used to look more closely at engineering students' motivations and aspirations after graduation. With this in mind, we provide some background information and context regarding the current landscape of literature concerning college students' career choices. Then, we look more specifically at works detailing the factors influencing the career choices of engineering students. We explain the process of adopting an existing survey based on the theory and distributing it to students. We walk through the statistical techniques used to analyze responses as well as present information on the respondents. A discussion follows, providing plausible reasons the survey yielded certain results. Lastly, we recap with a conclusion and provide directions for future lines of work.

Theoretical Lens

Self-Determination Theory (SDT) is a macro-theory typically used in psychology and social sciences. SDT was developed by Richard Ryan and Edward Deci to study the needs that fuel human motivation and behavior (Ryan & Deci, 2002). Of the 6 mini-theories comprising SDT, our work employed the Basic Psychological Needs Theory. The theory posits that 3 basic phycological needs contribute to motivation: perceived autonomy, perceived competence, and relatedness (Vansteenkiste et al., 2020). The present study adopted SDT to specifically look further into students' experiences in engineering contexts. Within these contexts, autonomy was related to the independence and choice participants had to pursue engineering undergraduate programs and the choices they made while in them. Competence referred to participants' beliefs about their abilities to successfully do engineering work and tasks. Lastly, relatedness focused on the relationships and connectedness participants felt between themselves and their peers, faculty, and departments at large.

SDT provides a foundation and tools for gathering and explaining contextual information on human experiences, perceptions, motivation, and behavior. Theoretically, the satisfaction of perceived autonomy, competence, and relatedness needs should promote individuals' motivation and behavior. In the context of this study, it is reasonable to expect that the degree to which students' needs are met in their engineering programs and departments will affect their willingness to continue into engineering careers and related professions. Using existing scales from the Intrinsic Motivation Inventory (IMI) and the Aspirations Index (AI), we gathered information on the degree to which participants' 3 basic needs were met in their engineering programs. Coupling this information with participants' reported career intentions after graduation, we were able to uncover whether the 3 needs were significant predictors of immediate career choice. In turn, we contribute to the body of work combining the use of SDT and engineering education (Dell et al., 2018; Hartmann & Gommer, 2021; Trenshaw et al., 2016).

Situating the Study

Career Choice for College Seniors

Lent and colleagues (2002) conducted a study to investigate the factors impacting college students' selection and implementation of career options (Lent et al., 2002). After interviewing students at multiple institutions, they found that past work-related experiences and general interests were the primary basis for students' career choices. Contextual factors like financial opportunity and social support also played some roles (Lent et al., 2002). Similarly, Kazi and

Akhlaq (2017) studied the factors impacting career choice. Using purposeful sampling, 432 students completed a questionnaire, and 12 students participated in in-depth interviews. An analysis of variance (ANOVA) test did not reveal a significant effect of factors like parents' professions on the participants' career choices. The data suggested that only one tested independent variable, interest, yielded a significant result (Kazi & Akhlaq, 2017). Qualitative data analysis led to the following factors being connected to career choice: family influence, gender, peers' influence, media influence, academic reasons, interest, financial reasons, and influences of others (Kazi & Akhlaq, 2017). These studies delved into the external influences that impacted students’ career choices.

Lewallen (1995) examined a national sample consisting of over 20,000 students to explore whether the degree to which a student was involved and their college achievement were indicators of students being decided or undecided about career choice. Investigating 9 variables, Lewallen found only small differences between students classified by achievement and involvement for 3: persistence, student-student academic involvement, and college grades (Lewallen, 1995). Taking a slightly different approach, Wang et. al (2006) specifically inquired about the role personality plays in the level of decision-making self-efficacy college students exhibited. Through their work, they found a link between extraversion and career decision-making self-efficacy (Wang et al., 2006). These studies demonstrate a focus on how factors within the students' locus of control can impact career choices

Where are Engineering Students Going, and Why?

It is important that engineering education researchers monitor and document what happens once engineering students leave institutions of higher learning, in order to more accurately assess the success and impact of undergraduate programs. We posit that if students are not going on to do something engineering-related (e.g.,) then many engineering programs are not accomplishing their goal of increasing the engineering workforce and developing contributing engineers who take on societal issues. For engineering college students specifically, existing research can provide a better picture of the typical career paths graduates take.

Mishkin and colleagues (2016) adopted the Theory of Planned Behavior and believed that choices are dependent on attitudes, subjective norms, and perceived behavioral control. Their work investigated the differences, related to those 3 contingencies, among women and men choosing engineering careers. Based on a sample of 330 students, results indicated women were more influenced by others when contemplating career choices (Mishkin et al., 2016). Engineering Education researchers interested in the extent to which engineering graduates pursued engineering careers surveyed seniors and found that only 42% were sure they wanted engineering careers (Lichtenstein et al., 2009). Most of the remainder of the related literature focuses on investigating why incoming students choose to pursue engineering. This is distinct from the career choices graduating engineering students make related to their rapidly approaching professional lives. However, much of the existing research neglects to assess factors impacting engineering seniors and their career choices.

Further Investigating Plans After Engineering

Due to the scarcity of literature focusing on what careers engineering graduates pursue and the reasoning behind those choices, we conducted the work detailed in this paper to help fill the gap. Acknowledging that the engineering pipeline does not stop at graduation, we delved deeper into the post-graduation destinations students anticipated going to and their accompanying motivation levels. More specifically, we used SDT to investigate whether engineering seniors' self-determination scores for perceived autonomy, competence, and relatedness were significant predictors of their intent to pursue engineering versus non-engineering jobs after graduation.

Research Questions

3. Using SDT as a lens, how does the structure of and experiences within an undergraduate engineering program affect engineering seniors planning to continue along engineering or non-engineering career paths?
4. Are students' perceived competence, perceived choice, and relatedness scores significant predictors of engineering versus non-engineering career post-graduation plans?

Hypothesis (H_0) for RQ2

Students with lower SDT scores in perceived autonomy, competence, and relatedness would be less likely to work as engineers immediately following graduation.

Methods

Participants and Site

Eligible participants included senior engineering students at [university in southern state] who anticipated graduating in either December 2022 or May 2023. [University in southern state] is the largest public institution in the state. and ranks as a R1, research-intensive university. From 2017-2021 the college of engineering's enrollment steadily ranged between 4,500 and 5,000, with 65% identifying as undergraduate males, 18% as undergraduate females, 13% as graduate males, and 4% as graduate females (Bagley College of Engineering, 2022). Students from all majors in the college of engineering were encouraged to participate. A survey was developed for and distributed to seniors in the following engineering departments: Aerospace, Agricultural and Biomedical, Chemical, Civil and Environmental, Computer Science and Engineering, Electrical and Computer, Industrial and Systems, and Mechanical. Participants must have reported an anticipated graduation date of either December 2022 or May 2023.

Survey Development

The survey that the engineering seniors completed contained items adopted from the pre-existing Intrinsic Motivation Inventory and the Aspirations Index. Qualtrics was used to gather information from participants regarding subscales and constructs included in the validated instruments. The survey included six subscales from the Intrinsic Motivation Inventory: interest and enjoyment, perceived competence, effort and importance, perceived choice, value and usefulness, and relatedness. Likewise, six subscales from the Aspirations index were included: wealth, fame, image, personal growth, relationships, and community. Each Intrinsic Motivation Inventory subscale included 5-8 statements related to students' experiences within and perceptions of their undergraduate degree programs. The Aspirations Index portion of the survey included 30 goals, and participants were asked how important the goal was to them. All items from both instruments were rated using a 7-point Likert scale. For the Intrinsic Motivation Inventory were asked how true each statement was. A 1 corresponded to "not true at all," 4 to "moderately," and 7 to "very true." The importance of the goals presented from the Aspirations Index was rated on a scale where 1 corresponded to "not at all," 4 to "moderately," and 7 to "very."

The beginning of the survey included information about the current study as well as contact information for the researchers. Surveys were split into blocks for demographic and prerequisite information, the Aspirations Index, the Intrinsic Motivation Inventory, and feedback.

The blocks for the survey items that were rated using a Likert scale (for the 2 included instruments) were randomized. An open-ended feedback question was placed after the scales, in the form of an open text box. Participants were asked to leave any additional information about their experiences in their undergraduate programs. Lastly, an optional question was presented asking participants to enter their school identification tag if they wanted to be entered into a drawing for one of three $50 Amazon gift cards.

Survey Procedures

All surveys were administered electronically. We composed an email prompt that briefly described the importance of the study, outlined the closing date, and detailed contact information for the researchers. The Dean of the College of Engineering distributed and forwarded the prompt and the link to the survey to all registered engineering seniors' school-affiliated emails. The survey was open from October 31st, 2022, to November 11th, 2022. The survey took about 30 minutes to complete, and all questions were required to be answered except the optional feedback and gift card drawings. The survey took approximately 30 minutes to complete. Surveys could be completed on any digital device like laptops, tablets, and cell phones. Participants were informed of their right to withdraw without penalty at any time. Consent was requested before participants proceeded with the remainder of the survey items. All responses were anonymous. Any identification tags were used solely for the purposes of the gift card drawing. Then, they were deleted and not included in the data analysis.

Additional Analyses

To further investigate the dataset, chi-squared tests were run in SPSS to determine if significant differences for post-graduation plans were present among members of different demographic groups. Some demographic variables were collapsed for the purposes of these specific analyses (E.g., departments accounting for less than 10% of the sample, minoritized ethnicities within the site institution's engineering college, etc.). Crosstabs and row percentages for sub-groups of demographic variables were calculated.

Also, analysis of variance (ANOVA) tests were completed to determine if the demographic factors influenced the IMI sub-scale scores. First, means for subscale scores were compared for participants belonging to different demographic groups. Then, ANOVA was used to determine if any present differences (for the means) were significant. Some demographic factors (E.g., first-generation status, ethnicity, etc.), were transformed or recoded into numerical variables for the ANOVA tests. Tukey values were calculated under the "Post Hocs" option for demographic variables consisting of multiple levels (E.g., engineering departments).

Additional Information on Validity, and Reliability

In an effort to alleviate the potential effects of survey fatigue, the blocks containing items from the Intrinsic Motivation Inventory and the Aspirations Index were presented to each participant in a randomized order. The Intrinsic Motivation Inventory and the Aspirations Index were both developed and validated by Ryan and Deci (E. Deci & Ryan, 1983, 1994). Additional validation studies were completed by a host of researchers for the Intrinsic Motivation Inventory (Deci et al., 1994; McAuley et al., 1989; Plant & Ryan, 1985; Ryan1982.; R. M. Ryan et al., 1983, 1990, 1991) and the Aspirations Index (Gollwitzer & Bargh, 1996; Kasser, 2002; Kasser et al., 1995; Kasser & Ryan, 1993, 2001, 2000; R. M. Ryan et al., 1996; Schmuck et al., 2000; Sheldon & Kasser, 1998; Williams et al., 2000).

Data Analysis

The results from all 87 participants were exported to a Microsoft Excel file for easy access. Within Excel, the data was prepared and organized to make transferring it to statistical software more manageable. According to the Intrinsic Motivation Inventory and Aspiration Index's scoring guides, specified items were reverse scored. In other words, scores for items written with opposite connotations as the 7-point Likert scale were subtracted from 8. Subscale scores were calculated for each participant using appropriate Excel formulas. Once the dataset was organized, IBM Statistical Package for the Social Sciences (SPSS) was used for further analysis.

Using SPSS, a binary logistic regression was completed to determine whether students' perceived competence, perceived choice, and relatedness scores were significant predictors of engineering versus non-engineering career post-graduation plans. The dichotomous, dependent variable was post-graduation plans: directly engineering-related or non-engineering-related. Engineering-related plans were a categorical variable represented as a "1" in the dataset, and a "0" represented non-engineering plans. The independent variables were perceived competence, perceived choice, and relatedness. All independent variables were represented as their numerical subscale averages, ranging from 1 to 7.

Logistic regression is a type of non-linear regression with an outcome variable that is categorical and independent variables that are either continuous or dichotomous. Since our dependent variable had two levels, engineering or non-engineering post-graduation plans, a binary logistic regression was appropriate. To begin, initial checks to ensure linearity between the independent variables and the log odds were completed. A preliminary check was also completed to ensure there was no complete separation among the independent variables. To check linearity, a Box-Tidwell test was run to examine whether the relationship was linear between the continuous predictors and the log odds. For the linearity assumption to be met, we only needed the interaction to be non-significant.

When running the logistic regression in SPSS, the following values were calculated and/or saved: Cook's distance, probabilities, group membership, Hosmer-Lemeshow goodness of fit, casewise diagnostics, outliers outside 2 standard deviations, iteration history, and the 95% confidence interval.

Results

Participants represented a wide array of engineering departments: 24.14% mechanical, 16.09% computer science, 16.09% civil and environmental, 16.09% chemical, 8.05% agricultural and biological, 6.90% industrial and systems, 6.90% aerospace, and 5.75% electrical and computer. The total sample size was 87. The ethnic makeup of the sample was 80.46% White, 8.05% Asian, 5.75% Other, 3.45% Black, and 2.30% American Indian or Alaska Native. The breakdown for age group was 65.52% 21-22 years old, 25.29% 23-24 years old, 6.90% older than 25, and 2.30% 19-20 years old. Males and females comprised 58.62% and 39.08% of the sample, respectively. One student identified as non-binary, and one student preferred not to say (1.15% each).

About one-third of participants (32.15%) had engineering experience prior to college (in K-12), and 67.82% did not. Furthermore, 26.44% of participants took an engineering course in high school, and 73.56% did not. Only 4, or 4.60%, of respondents had participated in the Summer Bridge Program at the institution. This could have either been through the incoming freshmen program or the program designed for transfer students entering from community colleges. 24.14% of participants anticipated graduating in December 2022, the same semester they completed the survey. The rest (75.86%) reported that they intend to graduate in May 2023 the following semester. Respondents reported a large range of undergraduate start dates at their institution, from Spring 2013 to Fall 2021. First-generation college students accounted for 20.69% of the group, with 79.31% of participants indicating that at least one parent had attended college.

Based on the Box-Tidwell test which showed the relationship between the interaction of each independent variable and its log odds and the dependent variable, all linearity assumptions were met. Overdispersion was calculated from the Hosmer-Lemeshow test as chi-squared divided by degrees of freedom. An issue related to overdispersion was present only for the perceived competence variable, meaning the variance of the responses for perceived competence was greater than what was assumed by the model.

A binary logistic regression was performed to examine how perceived competence, autonomy, and relatedness predicted job choice among engineering seniors, and the results are summarized in Table 1. The Wald test indicated that none of the predictors significantly related to the outcome.

Table 4.1 Results of logistic regression.

Variable	*B*	*SE B*	Wald	*OR*	95% CI for *OR*	
					LL	*UL*
Constant	1.17	2.14	.65	5.58		
Competence	-.20	.26	.61	.82	.50	1.35
Autonomy	.07	.33	.04	1.07	.56	2.02

Relatedness	.14	.23	.37	1.15	.73	1.79

Note. Model $\chi^2(3, N = 87) = .91$, $p = .82$, Nagelkerke $R^2 = .02$. *OR* = Odds Ratio; CI = confidence interval; *LL* = lower limit; *UL* = upper limit.

While the independent variables were not found to be significant for predicting immediate engineering versus non-engineering post-graduation plans (Reject H_0), the survey yielded some surprising findings for students' experiences and perceptions of engineering abilities as they prepared to go into their professional fields. The open-ended feedback question regarding senior students' experiences in their undergraduate programs suggests incongruence with their perceptions of the field, scores on SDT constructs, and career decisions. Many students reported feeling underprepared to enter their respective career fields. Frustrations were common and frequent among respondents. Several students emphasized the notion that they did not feel competent enough to be engineers. One student even said:

> *I do not think that my engineering program prepared me to go into the engineering industry in a practical manner. I have not enjoyed a majority of my engineering program.*

However, this same student indicated that she plans to go directly into an engineering job and that she sees herself in engineering in the next 5 years. Another student said:

> *I don't feel prepared to be a [specific type of engineer] in the field. I feel like a lot of [specific engineering degree program] is just throwing problems at us without taking the time to teach us the concepts […] I wish my professors would yell and get frustrated at us less. […] Overall, I am quite unsatisfied with my [specific engineering degree program] education, but I hope it will still serve me well in my chosen field. […] Quit trying to weed students out. The material will do that on its own.*

This student, like others who expressed similar sentiments, plans to go directly into and stay in an engineering career for at least the next 5 years.

This student's quote begins to highlight another major concern raised among participants, aside from feeling underprepared. Many participants express a shared dissatisfaction with the quality of teaching and learning experiences as well as their relatedness to professors in their departments. Students expressed thoughts like "*I had several teachers that seem to only be at [university in Southern state] so that they can do research" and "ALOT of qualified and short-term professors, department heads don't really care to build community."* While one of the 2 students who made these specific statements plans to work outside of engineering immediately after graduation, both indicated that they will likely be in engineering careers in the next 5 years.

Another student left in-depth information about the experiences within a program, saying:

> *The [specific engineering discipline degree] program has been extremely lacking in well trained teachers my last two years. This does not mean I haven't had some great teachers that have taught me a lot, but there are many who seem to have no knowledge on how to teach. I think it should be a requirement for teachers to take a course on how to teach engineering courses specifically*.

One other student said, "*maybe the tactic shouldn't be, to make the material so unlearnable that folks refuse to try, drop out, and/or change majors."* As evidenced, participants have some problems concerning the learning experiences they engaged in as well as the mannerisms and lack of commitment to teaching excellence exhibited by some professors.

Contrary to the concerns raised above, a handful of students emphasized positive feelings and experiences associated with their undergraduate departments. It is important to note that the students who shared positive experiences were outnumbered and not part of the same departments as their counterparts who expressed negative experiences. Further, all students did not give responses for the open-ended optional feedback survey item.

Additional Analyses Results

For the sample of 87 engineering seniors, chi-squared tests revealed there were no significant differences for engineering versus non-engineering career choice, immediately after graduation or 5 years after graduation. The following demographic variables were tested for the aforementioned relationships: first-generation status, ethnicity (collapsed to White and non-White), in-state or out-of-state status, previous engineering experience, engineering course in high school, gender, engineering department (collapsed).

Analysis of variance (ANOVA) tests revealed that first-generation students had significantly lower perceived competence scores ($F(1,85) = 6.723$, $p = .011$). On a scale of 1 to 7, first-generation students averaged 4.71 for perceived competence, and non-first-generation students averaged 5.60. A significant diference was also found for the perceived effort/importance reported by students in the chemical engineering department versus those in the civil and environmental department ($F(4,82) = 2.859$, $p = .028$). Seniors in the chemical engineering department had the highest mean for the effort/importance subscale (6.44 out of a possible 7.00), while students in the civil and environmental department had the lowest (4.99 out of 7.00). Finially, students with no prior engineering experience had higher average scores for the effort/importance subscale ($F(1,85) = 4.457$, $p = .038$). Average effort and importance scores for participants with previous engineering experience and those without prior experience were 5.506 and 6.105 (out of 7.00), respectively.

Discussion and Practical Implications

Perceived competence, choice, and relatedness were non-significant predictors of career choice for engineering seniors. More specifically, the ways students scored in these areas did not correlate with their intended choice of engineering versus non-engineering jobs after graduation. Because about 85% of respondents indicated that “yes” they plan to go immediately into engineering jobs, the baseline logistic regression model was already the best fit for viewing the data. In other words, since most respondents said "yes" they will immediately work in engineering-related roles, adding independent variables to a logistic regression model did not allow for a more accurate prediction of the likelihood of a participant saying "yes." Due to the uneven distribution of responses for the outcome variable (post-graduation job plans), the added independent variables were non-significant for better predicting post-graduation job plans. For the independent variables in this type of test to be significant predictors, we would need a sample in which more people said “no” and anticipated working in non-engineering roles. Additional reasons the independent variables may not have been significant predictors could be related to external influences and factors not captured in the present study’s survey. These could include financial pressures and family obligations, to name a few.

In theory, students with high self-determination scores would be more motivated in their engineering programs and when doing engineering tasks. However, this motivation does not seem to necessarily translate to post-graduation career choice. We witnessed students with both high and low scores perceived competence, autonomy, and relatedness scores elect to go directly into engineering careers. Additionally, students who specifically reported, through the open-ended survey question, that they felt unprepared to work as engineers and/or disconnected from their programs and departments still plan to become engineers upon graduation. How do we begin to explain the frequent failure to satisfy the three basic psychological needs in undergraduate programs and students' decisions to work in engineering occupations regardless?

First, we must acknowledge that students likely engage in experiences contributing to engineering identity development outside the context of their departments. In the present study, the survey items were related to their departments and programs specifically. This may present an issue when gauging the relatedness component. For instance, those students who expressed having issues with relatedness to professors may have felt a sense of relatedness in engineering contexts like co-ops and internships. Those environments and feelings may have had a greater influence on their decisions to become engineers, despite their experiences at the individual department level. Likewise, their perceived choice or autonomy within their degree programs may not be synonymous with the autonomy they expect to while working in professional engineering roles. In retrospect, we recognize that the degree of satisfaction of basic needs within undergraduate programs may not be as influential for career choice as the satisfaction they hope to feel after graduation or previously felt in real-world experiences (e.g., co-ops).

Drawing on Holland's Theory of Career Choice, which maintains that people choose careers in which they can be around people who are like them, the data may suggest more than what is seen at the surface level. If engineering students have been involved in their programs for the most recent years of their lives, it is plausible that they become accustomed to being around other engineers. This years-long exposure is not dependent on whether the experiences within programs are positive or negative. Therefore, students simply may not know what other career option may be appropriate and, they likely view engineering careers as the logical next step.

If students are persisting along engineering career paths regardless of their experiences, how does this impact the work they do as engineers? Are students who report feeling underprepared able to learn on the job, or do they have to find new jobs and contribute to high turnover rates in their respective companies? Scenarios related to the information gathered in the present study could translate into work environments and not only affect the graduates but also affect their co-workers, companies, stakeholders, and the surrounding communities. Research on job satisfaction for students who expressed concerns in their undergraduate contexts but elected to pursue engineering careers may provide more insight into their thought processes.

Another consideration to explore is whether students are reflecting to accurately judge reality. While students were asked to indicate their immediate plans after graduation, other factors may influence whether those intentions are met. Inquiring about whether participants have a solidified job offer, call-backs from any interviews, or acceptances to any programs could give way to more accurate predictions of where they may end up after graduation.

Students with lower GPAs or students who have never participated in a co-op with a company may be less likely to be accepted to engineering graduate programs or hired for engineering-related roles than their peers with higher GPAs, experiences, and established connections established through co-ops or internships. Also, it would be useful to monitor what happens to those who expressed lower perceived competence. If students struggled in their engineering degree program, are they more likely to struggle within the engineering workforce? Does this affect the amount of time they spend in the engineering workforce? These are all ideas that could provide more clarity on the present study's findings. The work reported in this paper resulted in valuable learned lessons. Unlike many engineering studies which take place in contexts that can be controlled, engineering education research is subject to be impacted by confounding variables. Therefore, non-significance in educational settings like those included in this work may not necessarily signify that the variables of interest are completely non-related.

Inquiry beyond the initial logistic regression revealed some significant different on specific subscales for participants belonging to different demographic groups. Namely, first-generation students had lower perceived competence scores. This finding suggests reasons to explore the unique experiences that first-generation engineering students have and provides a basis for potential, additional support needed within engineering departments. This aligns with previous studies that found first-generation engineering students to have different competence beliefs (Verdín et al., 2018). Further, results revealed that students in the civil and environmental engineering department associated less effort and importance with their engineering programs than those in the chemical engineering department. This suggests that significant differences exist in either the ways information is communicated to students in the two departments or the incoming characteristics of students comprising those departments.

The last significant finding from the ANOVA tests concerned participants without K-12 engineering experience associating more effort and importance with their engineering programs/degrees. This provides critical insight into the ways K-12 pipelines and resources impact engineering students' undergraduate experiences. Perhaps specific strategies are warranted to communicate the value of formal engineering education to students who come begin college with their own unique engineering experiences. Likewise, more intentional classroom group assignments could help evenly distruibute the effort exerted by all students (E.g., no group with no prior experience and no group with all experienced students). This finding aligns with our previous qualitative study which uncovered a perceived difficulty/effort gap between students with K-12 engineering experience and less experienced peers.

Study Limitations

One limitation of this study is that adequate information was not available to combine with the contextual information gathered from the survey. For instance, data on which students completed co-ops, as well as contextual information on their experiences within them, may have aided in clarifying why the SDT needs were not significant predictors of job choice. Also, other external factors such as socioeconomic status and financial pressures may have played a role in students choosing to work as engineers regardless of their experiences in undergraduate degree programs. Additionally, having a larger number of respondents may have helped mitigate any overdispersion issues for the perceived competence variable.

Conclusion, Recommendations, and Future Work

This study aimed to provide insight into the choices that engineering seniors make regarding career choices after graduation. More specifically, Self-Determination Theory was employed to gauge students' perceived autonomy, competence, and relatedness as they neared the end of undergraduate engineering programs. A logistic regression did not provide evidence that any of the SDT constructs of interest were significant predictors of whether a student reported plans to pursue engineering versus non-engineering careers. This is probably due to factors external to their program or departmental contexts, which the survey in the present study honed in on.

However, the data does suggest incongruence between their SDT levels, feedback, and choices. In fact, students expressing issues concerning perceived competence and relatedness still report that they plan to enter engineering roles. It may prove useful to look more closely at students' attitudes and beliefs as they near graduation. More specifically, in-depth interviews or focus groups may be viable avenues for determining students' mindsets as they prepare to embark on post-graduation journeys. Also, it may be beneficial to follow up with students from this study. Reaching back out to students who stated they were not prepared to work as engineers but who decided to do so anyway may provide a better understanding of their reasons, professional experiences, and the impact their undergraduate engineering education programs had on them.

Additional research could provide insight into why first generation engineering students report lower perceived competence. Also, follow-up studies are warranted to delve deeper into departmental differences within the same institution (E.g., civil and environmental versus chemical). Lastly, it would be benefitial to study the value associations that students with and without prior engineering experience have regarding their undergraduate engineering programs and the reasons supporting those associations.

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CHAPTER V

CONCLUSION

In this final chapter, a summary of each research study is presented as well as challenges faced during their design, execution, and/or analyses. Suggestions for future researchers and possible directions for further work are included. Contributions to the engineering education research community and contributions to practice are explained. Lastly, the chapter concludes with closing remarks.

Summary of Studies

Study 1

Research Questions

S1-1. How does the structure of a Summer Bridge Program (SBP) affect students' experiences from a self-determination viewpoint?

S1-2. Which SBP characteristics and experiences either contribute to or detract from students' self-determination and success?

Study 1 focused on gathering, analyzing, and interpreting the experiences of incoming freshmen who participated in the Summer Bridge Program (SBP) at Mississippi State University in 2022. The aim was to investigate how students' experiences and success were affected by the structure of the program (e.g., specific components, characteristics, informal social interactions, etc.). While investigating this, we also were able to assess how these experiences may have been influenced by students' self-determination levels. Self-Determination Theory (SDT)and its accompanying instruments were used to develop a baseline survey that was distributed to participants via Qualtrics. Next, a semi-structured interview protocol was created. We also developed a codebook to aid in the analysis of the qualitative data and support theme synthetization.

Answers to RQS1-1 and RQS1-2

Overall, many of the SBP components and characteristics were found to be positive contributors to students' experiences and success within the program. Some of them included community-building opportunities and interactions, structured study hall hours, real-world and hands-on experiences, mentorship, and residential life. We emphasize that students may have experienced these components differently based on their SDT scores. For instance, students with higher perceived competence highlighted the importance of study hall for collaboration, while students with entered the SBP with lower perceived competence emphasized the importance of study hall for consistently focusing on academic coursework without distractions. Students who reported being more reserved or quiet did not speak much about the mentorship benefits. Additionally, students with more K-12 experiences and higher perceived competence expressed that the program may be more difficult for their peers with fewer experiences or who had less rigorous K-12 coursework.

Study 2

Research Questions

S2-3. How does the structure of a Summer Bridge Program (SBP) affect students’ experiences and success in engineering either during or after the program?

S2-4. Which program characteristics and experiences either contribute to or detract from past SBP students’ experiences and holistic success in engineering?

In study 2, continuing students who previously participated in the SBP provided insight into their experiences within the summer program and in their undergraduate departments. Using a variation of the SDT interview protocol developed for study one, semi-structured interviews were conducted with 7 participants.

Answers to RQS2-1 and RQS2-2

Participants spoke about the importance of community building in the SBP. Unlike the freshmen in Study 1, continuing students emphasized the importance of this community being comprised of mostly underrepresented engineering scholars as they matriculated through their various departments. Students emphasized that this community continued through their involvement in other organizations like the National Society of Black Engineers and by sustained contact facilitated by their SBP director.

Continuing students from different cohorts highlighted important information regarding the importance of program structure and delivery. For the 2020 cohort specifically, participants did not feel high levels of relatedness among their peers after finishing their virtual program. For those included in this work, the effect was somewhat moderated by their involvement in NSBE afterward. However, all students did not experience this, as evidenced by the 60% of students who left engineering either before the SBP concluded (July 2020) or at some other point before this study (October 2022). Another emergent theme was related to the involvement of the SBP director and other leaders who came back to speak and mentor participants. Representation among mentors strengthened students' beliefs that they too can become professional engineers. Students appreciated how the SBP schedule and courses equipped them to succeed in the rigorous semesters that followed. Notably, we found that relatedness in the context of the SBP is seemingly non-transferrable to undergraduate programs and departments. Participants felt as though they must reconnect with their SBP cohort and other cohorts to make up for the lack of inclusivity in formal learning spaces like classrooms.

Study 3

Research Questions

S3-3. Using SDT as a lens, how does the structure of and experiences within an undergraduate engineering program affect engineering seniors planning to continue along engineering or non-engineering career paths?

S3-4. Are students' perceived competence, perceived choice, and relatedness scores significant predictors of engineering versus non-engineering career post-graduation plans?

Hypothesis (H_0)

Students with lower SDT scores in perceived autonomy, competence, and relatedness would be less likely to work as engineers immediately following graduation.

Many researchers are interested in attracting students to engineering programs and even investigating the factors that influence incoming engineering students' choices. However, engineering seniors and their career choices post-graduation are not investigated as much. Study 3 aimed to gather more information on how students scored on SDT constructs and whether this is linked to the likelihood that they will pursue engineering careers after they leave undergraduate degree programs. 87 engineering seniors completed a Qualtrics survey that inquired about their experiences in the context of their respective programs and departments. A binary logistic regression was completed to determine if perceived competence, autonomy, and relatedness scores were significant predictors of students' intentions to go directly into engineering jobs versus non-engineering jobs.

Answers to RQS3-1 and RQS3-2/Conclusion for H_0

Surprisingly, the logistic regression did not suggest that any of the included scores were indicative of career choice (H_0 rejected). Even more, students who specifically expressed feeling unprepared to work as engineers and disconnected from faculty in their department reported that they anticipated going into engineering jobs. This suggests that some external factors may be more influential and significant predictors of career choice. These could include financial and family pressures. Moreover, students may have had more positive experiences in engineering contexts like internships, co-ops, and student organizations. These experiences could have been reasons why students would continue on engineering career paths regardless of what happened in their specific programs and departments. Lastly, career choice theories suggest that people are more likely to choose careers in which they work around people who are like them. Since respondents have spent the last few years of their lives around other engineering students and faculty, engineering may simply seem like the only logical next step. Additional inquiry yielded results suggesting that first-generation students report lower perceived competence, students with prior engineering experience report lower effort/importance for their programs, and students in the chemical and civil engineering departments differ significantly in terms of the associated effort and importance of their engineering education.

Challenges

Study 1

A challenge for study 1 involved the initial idea of comparing students' baseline scores with survey scores at the end of the program through a statistical analysis like a t-test. Unfortunately, the data for the post-program assessment was not indicative of students' actual experiences or progress. Many students randomly marked answers, with many choosing the same answer for the entire survey. One-on-one exit interviews and qualitative data were more accurate depictions of participants' experiences and progress and were thus used in congruence with the baseline survey data. If repeating this study or similar pre-and-post-survey designs, the researcher should ensure that the survey is taken at a time when participants can focus solely on it. Preferably, the survey should not be distributed as the last task participants must complete before getting a break.

Study 2

A challenge for study 2 was the number of willing continuing students who responded and completed an interview. Luckily, we were able to interview at least two students from each of the 2019, 2020, and 2021 cohorts and gain clarity on the similarities and differences between their experiences. However, having more participants would have been beneficial. To circumvent this challenge, future researchers should consider asking deans to forward the interview request emails to students using their university accounts. Also, incentives may attract more upperclassmen to participate as opposed to freshmen who are still currently in the SBP, easily accessible, and willing to sign-up (as in study 1).

Study 3

In study 3, the main challenge was explaining the data and logistic regression results. We are confident in the attention given to the statistical methods and tests. However, students' open-ended feedback regarding competence and relatedness seemed to conflict with their intended career choice. We acknowledged that this is likely due to either external factors or experiences not included in the survey. Nevertheless, study 3 contributes important information on why students may not be fulfilled in engineering, and some may simply be going through the motions.

Furthermore, additional statistical analyses helped mitigate the main challenge and uncovered unanticipated differences among demographic groups.

Future Work Recommendations

Future directions to build on study 1's findings include repeating similar studies with SBPs at various institutions to determine if themes are generalizable. Different SBPs tend to have unique features and different characteristics. For instance, determining whether a SBP for all STEM majors, a SBP for transfer students, and a SBP for engineering freshmen share the common themes we found in study 1 or produce new themes would provide additional knowledge needed to determine what elements of SBPs are transferrable to different institutions and student types.

Also, future work should be focused on implementing changes based on the findings, repeating the study, and analyzing whether students receive more maximized benefits from the program components. Consider the following scenario. If the SBP included in this work added some type of special component or resources for students entering with no prior engineering experiences and less rigorous K-12 coursework, either before or during the program, would this close the uncovered difficulty and effort gap? Recall that the difficulty and effort gap was between participants beginning the SBP with more engineering experiences and coursework in K-12 who noticed their peers not having those same backgrounds. Questions like these are critical for ensuring that program components are enhanced for future cohorts and can be developed based on the different experiences students had in the SBP as well as their SDT scores.

Study 2's future work should include further inquiry into the experiences that continuing part participants of SBPs have as they matriculate through their degree programs. Plausible next steps include longitudinally interviewing students from the cohorts included in this work. By doing this, researchers would generate additional knowledge on the matriculation of students and how the SBP impacts their development and experiences across time. Further, investigating the experiences of these past participants through their initial years as working professionals could prove instrumental for learning how their experiences within engineering contexts may evolve.

Researchers may also be able to draw upon the actions that other SBPs take after the program ends. By researching ways to better support students after the SBP concludes, engineering leaders and educators will be better versed in support strategies for continuing students. This is especially important for departmental contexts. Since students expressed feeling disconnected and excluded from communities in their departments, more research is needed on how support programs like the SBP and undergraduate departments and programs can work in congruence to ensure that students continue to have positive experiences once they transition between programs.

The findings from study 3 warrant additional inquiries into the thought processes that engineering students make regarding their careers. For instance, interviewing students who reported feeling unprepared to work as engineers but who intended to go into engineering jobs anyway may provide clarity on other factors influencing their decisions. Additionally, surveying a larger population of students across multiple institutions to see if the significance of the results is similar may be useful for determining if the factors vary. Consider the following situation. Two students both report feeling unprepared to work as engineers, as graduation nears. One student attends an affluent, prestigious institution and has a higher socioeconomic status. The other student attends a more rural university and has a low socioeconomic status. Is the latter student more likely to work as an engineer after graduation? These are the types of information that could contribute to the work started in study 3.

Another future direction for study 3 is investigating whether those students who venture into engineering jobs after expressing low perceived competence and preparedness leave jobs more quickly. These types of inquiries could provide further insight into reasons behind higher turnover rates for some engineering professionals as well as expose a leaky pipeline at career path stages (beyond undergrad).

Contribution to Engineering Education Research Community

All three studies contribute to the strides that engineering education researchers have taken. Blurring disciplinary boundaries, SDT, which is typically used in psychology and other social sciences, was adopted to investigate questions specifically related to engineering education programs. In doing so, valuable information was gathered on a variety of constructs that are not presently measured in engineering contexts. These constructs and the SDT lens overall allowed the studies in this work to approach engineering student success and students' experiences in a novel way. Beyond standalone academic performance or sense of belongingness data, we were able to capture a holistic picture of students' perceptions across multiple areas.

The immediate or localized contribution was a better understanding of the state of engineering education programs and departments at the study site. This work serves as a basis for examining potential differences that exist across degree programs and departments. This information is intended to be reported to the appropriate leaders who can create changes within them and/or highlight the positive work currently being done. An additional immediate contribution is the amplification of the voices and lived experiences of engineering students at various stages of their engineering education journeys. This was done in hopes of systematically organizing their responses in hope of providing research-backed evidence to support any necessary reform as well as recommending and justifying any additional support students need.

This work aimed to assist in reframing the way we view student success in engineering education research. Much of the existing engineering education literature equates student success to academic performance measures like course grades, GPA, or even graduation rate. Studies that focused on other aspects of success like social integration and relatedness viewed those factors as contributors to academic performance (with academic performance being above them in a hierarchy) as opposed to treating them as equal contributors to holistic student success. Institutions of higher learning, STEM fields, and engineering fields more specifically, have all evolved over time. The ways we establish student success standards, particularly for underrepresented students in engineering should continue to evolve accordingly.

Contribution to Practice

All three studies included in this work contribute valuable insight into the practices currently used in engineering education programs and suggest changes that should be implemented. The overall work took an evidence-and-theoretically-backed approach to encourage a shift in how the majority of engineering leaders and literature frame student success in engineering. With a focus on student success at its core, this work delved into the contexts of three different groups in engineering programs and gathered information supporting practical changes that will enhance future students' experiences.

Study 1

Study 1's findings and implications are very applicable to engineering education practice. First, it provides specific information regarding components of an SBP that are most impactful in practice. By highlighting and building upon those positive components, like study hall, community building, and residential life, programs can continue to ensure students have the best possible experiences. These experiences span beyond what we measure and see on paper and contribute to freshmen students' early engineering identity formation. Study 1 also serves as a guide for altering some aspects of the program to ensure all students receive maximized benefits regardless of their expressed personality traits and incoming competencies (e.g., being more introverted, or attending lower-performing K-12 schools with fewer engineering opportunities). The study calls attention to engineering transition programs like SBPs meeting students where they are and practicing continual improvement processes.

Study 2

Study 2 is unique because it investigates parts of the engineering student journey that are often overlooked unless part of a longitudinal study. It allows for reflection on the ways students navigate SBPs and support programs and how they navigate their larger departments and programs. Discourse is apparent in the support and inclusivity students feel while in the SBP and when matriculating further into their programs. These discrepancies could not be easily noticed if only looking at these continuing students' grades or retention. Study 2 calls attention to the persistent need to increase diversity, equity, and inclusion and cultivate welcoming learning environments for all engineering scholars.

The information gathered in this study provides a foundation upon which SBP leaders, engineering deans, and faculty in departments can better assess whether students are being properly supported throughout the entirety of their academic programs.

Study 3

The final study contributes information on students' perceptions as they prepare to begin working as professionals. This was done by using the generated knowledge base concerning which factors from the Intrinsic Motivation Inventory and Aspirations Index scales may be the most significant predictors of engineering vs non-engineering trajectories. For engineering students, the intent to work in engineering-related jobs does not appear to be directly linked to their perceptions of their competence to work in these roles or to their relatedness to current professionals like professors. In theory, engineering programs hope that their students go on to work as contributing members of society, mainly in engineering roles. In practice, the contributions of engineers may not be assumed as automatic if they report working as engineers.

With this information, we can implement changes in practice to ensure that students feel well-equipped to work as engineers after leaving college. This includes connecting students with professionals in their fields, allowing those professionals to communicate the skills they are looking for, and allowing students to hone those skills in engineering education degree programs. Simply having career fairs and guest speakers is not enough. Aside from students who decide to do a co-op, incorporating specific skills that employers value into courses is the only way they will gain them prior to graduation. These skills are not perceived as useful if students fail to recognize their application to the jobs they desire. Engineering educators and practitioners must do a better job of being intentional, preparing students for their desired careers, and helping them realize the level of preparedness they possess even as new graduates.

(Re)Engineering Student Success

Revisiting the question that guided the framing of this work, we are now better equipped to answer, "what can programs do to better support students and ensure their success?"

According to National Science Foundation, women, Black, Hispanic, and Native American or Alaskan Native citizens remain underrepresented in the STEM workforce relative to their share of the country's population (National Science Board, 2022). Other challenges of the U.S. STEM education system relate to K-12 disparities across ethnic and socioeconomic groups and cost barriers to higher education (National Science Board, 2022). While engineering degrees have been awarded at a somewhat steady rate (only a .45% decline in 2020), gender and ethnicity imbalances remain prevalent areas of concern. Data from Women, Minorities, and Persons with Disabilities in Science and Engineering (2023) tells us that while underrepresented groups made up 37% of the U.S. population in 2020, they accounted for 26% of science and engineering (S&E) Bachelor's, 24% of S&E Master's, and 16% of S&E doctoral degrees. Additionally, Black students earned higher shares of social science degrees (12% in 2020), in comparison to earning 5% of engineering bachelor's degrees (National Science Foundation, 2023). Similarly, women earned over 60% of the social science degrees at all three levels (bachelor, master, and doctoral), but remained underrepresented recipients at all three levels in physical sciences, math, computer science, and engineering (National Science Board, 2022). Although specific institutions and certain areas of the engineering workforce have witnessed measurable changes, there is more work to be done to broaden participation in engineering as a whole entity.

The need for more holistic student development and success viewpoints in engineering education is critical. This entire work was designed and executed to challenge engineering education researchers and practitioners to begin looking beyond the surface level. As society, the landscape of higher education, and employers' needs continue to evolve, engineering programs must be more adaptable to and willing to evolve. This evolution not only includes the ways we think about and gauge success in engineering but also the practical ways we educate students within programs. Delving deeper into the ways students perceive themselves within engineering environments and the ways they interact in engineering communities, contexts, and programs is vital. Positively contributing to those perceptions and interactions is contingent upon our discovery of tangible strategies to refine programs and their components. It is also imperative that engineering education leaders begin holding each other accountable for implementing strategies to catalyze change.

I am thankful to have had the opportunity to be a part of progressing engineering education research and practice while learning more about topics I am passionate about. I am hopeful that engineering education leaders will continue to make strides and keep students' success at the core of their thoughts, plans, and actions. As we continue to evolve as a field, I am optimistic that my work and its implications will be impactful in creating better environments for students and cultivating their greatness from inception to college, through college, and after graduation. I am grateful to have had the opportunity to amplify current students’ voices and lived experiences and hope future researchers will follow suit.

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APPENDIX A

INTERVIEW PROTOCOLS

Summer Bridge Program Freshmen Interview Protocol

Constructing Knowledge on how Program Structure Effects Student Motivation and Success

Interview Information Sheet- (Interviewer should complete before interview)

Interviewer(s)/Notetakers:

Pseudonym:

Date/Time:

Engineering Discipline:

Group Membership of Interest: Summer Bridge Program Participant

Summary of Survey Response(s):

Guiding Prompt to Begin Interview:

"Hello! I want to start by thanking you for participating in this interview process. Before we begin, please review this consent form that outlines the study methods and plans to protect participants' confidentiality. If you agree to the items on the form and would like to participate in the study, please sign one copy for research records and you can keep the other copy for your records. As detailed on the consent form, this interview will be audio recorded for later transcription and analysis. We use two recorders just in case one dies or we have poor sound quality. May I turn on the recorders?"

[If yes, proceed to interview questions. If no, proceed with interview and taking notes, but do not record the interview.]

Additional notes (if any):

Figure A.1 Freshmen interview protocol (page 1).

	Core Question/Request (structured)	Probing Questions (semi-structured)	Construct/concept item is mapped to	Comments (if any)
1	Tell me about your first engineering experience (K-12) or SBP.	If K-12: How do you think having that experience early on impacted your SB experience? If SBP: Do you think having your first experience in SB vs K-12 impacted your SB experience? Were you aware of any opportunities in K-12? If yes: Why didn't you participate? If no: What type of experience do you think would benefit younger students still in K-12?	Pre-collegiate engineering experiences/ exposure	
2	Tell me about the part of the SBP you found most interesting or enjoyable.	What stood out to you the most about that part of the program compared to others?	Interest/Enjoyment (IMI)	
3	What about your least interesting or enjoyable part of the program?	Why do you think you felt that way about that particular part? What could be done to improve that part for students who may participate in the next SBP?	Interest/Enjoyment (IMI)	
4	How would you describe the difficulty level completing the SBP tasks you were assigned?	How do you think your peers would describe the difficulty (was it about the same for everyone)? Do you think work ethic or natural talent is more important for performance on engineering tasks and why?	Perceived competence (IMI)	

Figure A.2 Freshmen interview protocol (page 2)

5	Talk to me about the amount of effort required to do well in the program.	How much effort did you put in? How do you think it paid off?	Effort/Importance (IMI)	
6	How did you hear about the SBP and why did you decide to apply?	Did anyone tell you that you should participate or did you decide on your own?	Pressure/Tension (IMI)	
7	What other factors persuaded you to apply and actually come participate?	Would you participate again if you could back in time and had the choice? Why?	Perceived Choice (IMI)	
8	Talk to me about what you found most valuable or useful from participating in the program?	What goals do you think your SBP participation will help you achieve? Why are these goals important to you?	Value/Usefulness (IMI)	
9	How would you describe your relationships to your peers in your cohort?	How did those relationships shape or impact your SB experience? What about your relationships with the SB counselors and leaders? Describe your SB cohort relationships in 1 would and explain why you chose that word.	Relatedness (IMI)	
10	Thinking ahead, what impact/effect do you believe your SBP participation will have on your undergraduate journey through college graduation?	Do you expect that the relationships you formed in SB will be similar when you are a graduating senior?	Long-term SB expectations (Cross-section with reverse answers from engineering senior interviews)	Engineering seniors who did SB will be asked reflective questions to determine whether expectations are being met

Figure A.3 Freshmen interview protocol (page 3)

11	What do you dream of doing or aspire to do after you finish college?	Describe the life you envision for yourself personally and professionally. Why is that important to you? How does engineering fit into the life you envision? How has your vision either changed or solidified since you started SB up until this point?	Aspirations/ Motivations (AI)	
12	[Any additional questions based on individual interview answers/final notetaker questions]	[open to researcher's discretion]		
13	What was the most important part of SB and why?	Imagine that the program is going to be completely redesigned next year, what one component do you think the Diversity Director should keep doing?	Importance, Pressure/Tension/ Program Structure	

Guiding Prompt to End Interview: Sample Post Interview Text:

"That concludes the questions I have for you. Thank you again for participating in this study and sharing your experiences. Do you have any remaining questions for me about the study?"

If no:
"Thank you again for your time! I really appreciate it."

If yes, answer questions then read the line above.

Post Interview Tasks

The interviewers will debrief on the interview to discuss what went well and what could be improved with the research team. They will also talk over their initial observations and then write a memo about the interview. Following the interview, recordings will be immediately transferred from the recording devices to a password protected computer or external hard drive. Notes and the memos will be scanned and saved on Dropbox. One of the audio files will be sent to be transcribed by an external transcription service (rev.com). The audio file will be named

Figure A.4 Freshmen interview protocol (page 4)

with the participant's pseudonym to ensure their identity is protected. When the transcription is returned (typically within 24-48 hours of submission), a researcher will listen to the interview while reading the transcript to confirm accurate transcription and remove identifiable information from the transcript. The cleaned transcript will be uploaded to Dropbox and Dedoose for coding.

Figure A.5 Freshmen interview protocol (page 5)

Summer Bridge Program Continuing Students' Interview Protocol

Constructing Knowledge on Student Motivation and Aspirations in Engineering Education Programs: Supporting Holistic Student Success

Interview Information Sheet- (Interviewer should complete before interview)

Interviewer(s)/:

Pseudonym:

Date/Time:

Engineering Discipline:

Group Membership of Interest: Summer Bridge Program Past Participant

Guiding Prompt to Begin Interview:

"Hello! I want to start by thanking you for participating in this interview process. Before we begin, please review this consent form that outlines the study methods and plans to protect participants' confidentiality. If you agree to the items on the form and would like to participate in the study, please sign one copy for research records and you can keep the other copy for your records. As detailed on the consent form, this interview will be audio recorded for later transcription and analysis. We use two recorders just in case one dies or we have poor sound quality. May I turn on the recorders?"

[If yes, proceed to interview questions. If no, proceed with interview and taking notes, but do not record the interview.]

Additional notes (if any):

Figure A.6 Continuing students' interview protocol (page 1)

	Core Question/Request (structured)	Probing Questions (semi-structured)	Construct/concept item is mapped to	Comments (if any)
1	Tell me about your first engineering experience (K-12) or SBP.	If K-12: How do you think having that experience early on impacted your SB experience? If SBP: Do you think having your first experience in SB vs K-12 impacted your SB experience? Were you aware of any opportunities in K-12? If yes: Why didn't you participate? If no: What type of experience do you think would benefit younger students still in K-12?	Pre-collegiate engineering experiences/ exposure	
2	Tell me about the part of the SBP you found most interesting or enjoyable.	What stood out to you the most about that part of the program compared to others?	Interest/Enjoyment (IMI)	
3	What about your least interesting or enjoyable part of the program?	Why do you think you felt that way about that particular part? What could be done to improve that part for students who may participate in the next SBP?	Interest/Enjoyment (IMI)	
4	How would you describe the difficulty level completing the SBP tasks you were assigned?	How do you think your peers would describe the difficulty (was it about the same for everyone)? Do you think work ethic or natural talent is more important for performance on engineering tasks and why?	Perceived competence (IMI)	
5	Talk to me about the amount of effort required to	How much effort did you put in? How do you think it paid off?	Effort/Importance (IMI)	

Figure A.7 Continuing students' interview protocol (page 2)

	do well in the program.			
6	How did you hear about the SBP and why did you decide to apply?	Did anyone tell you that you should participate or did you decide on your own?	Pressure/Tension (IMI)	
7	What other factors persuaded you to apply and actually come participate?	Would you participate again if you could back in time and had the choice? Why?	Perceived Choice (IMI)	
8	Talk to me about what you found most valuable or useful from participating in the program?	What goals do you think your SBP participation will help you achieve? Why are these goals important to you?	Value/Usefulness (IMI)	
9	How would you describe your relationships to your peers in your cohort?	How did those relationships shape or impact your SB experience? What about your relationships with the SB counselors and leaders? Describe your SB cohort relationships in 1 would and explain why you chose that word.	Relatedness (IMI)	
10	Thinking ahead and reflecting, what impact/effect do you believe your SBP participation has had &will have on your undergraduate journey through graduation?	When you were a participant in the SBP, how did you envision/expect the relationships you formed in to be after the program ended? How does that compare to your current reality? How do you expect the relationships to be as you continue through your program & beyond?	Long-term SB expectations (Cross-section with reverse answers from SBP engineering frshmen interviews)	Engineering freshmen who did SB were asked about their expections going forward
11	What do you dream of doing or aspire to do after	Describe the life you envision for yourself personally and professionally.	Aspirations/ Motivations (AI)	

Figure A.8 Continuing students’ interview protocol (page 3)

	you finish college?	Why is that important to you? How does engineering fit into the life you envision? How has your vision either changed or solidified since completing SB?		
12	Describe any unique characteristics/ differences of your SBP experience versus the experiences of those in other cohorts (i.e., 2019 vs 2020 vs 2021 vs 2022).	How do you think those differences impacted you and/or your cohort?	Individual cohort differences (e.g., pre-and-post covid, courses offered, leadership and structure, etc.)	
13	How do you think SBP impacted your autonomy, competence, and relatedness within your undergraduate program? (each term will be explained)	Do you think your peers from similar backgrounds who did not participate have had different experiences? Explain.		
14	[Any additional questions based on individual interview answers/final notetaker questions]	[open to researcher's discretion]		
15	What was the most important part of SB and why?	Imagine the program is going to be completely redesigned next year. What's one component that should keep doing? Why?	Importance, Pressure/Tension/ Program Structure	

Figure A.9 Continuing students' interview protocol (page 4)

Guiding Prompt to End Interview: Sample Post Interview Text:

"That concludes the questions I have for you. Thank you again for participating in this study and sharing your experiences. Do you have any remaining questions for me about the study?"

If no:
"Thank you again for your time! I really appreciate it."

If yes, answer questions then read the line above.

Post Interview Tasks

The interviewers will debrief on the interview to discuss what went well and what could be improved with the research team. They will also talk over their initial observations and then write a memo about the interview. Following the interview, recordings will be immediately transferred from the recording devices to a password protected computer or external hard drive. Notes and the memos will be scanned and saved on Dropbox. One of the audio files will be sent to be transcribed by an external transcription service (rev.com). The audio file will be named with the participant's pseudonym to ensure their identity is protected. When the transcription is returned (typically within 24-48 hours of submission), a researcher will listen to the interview while reading the transcript to confirm accurate transcription and remove identifiable information from the transcript. The cleaned transcript will be uploaded to Dropbox and Dedoose for coding.

Figure A.10 Continuing students' interview protocol (page 5)

APPENDIX B

CODEBOOK

Table B.1 Codebook for interview analyses.

Number	Code	Definition	What it's not	Example
1	Pre-collegiate engineering experiences/ exposure	Formal or organized engineering experiences prior to the start of the engineering program	Informal; "building things" as a child	Middle school engineering camp
2	Interest/Enjoyme nt	Things a participant finds fulfilling, fun, or intriguing	Things done to achieve something	Reading for fun (i.e., hobbies)
3	Perceived Competence	Whether participants view themselves as being capable of doing something in context of the engineering program	A direct correlation with actual performance	"I think I am good at solving engineering problems"
4	Effort	What energy (or lack thereof) participants put into some component of the program	Program requirements	"I had to put in a lot of hours in study hall and look up things on my own to do well in Chemistry"
5	Importance	What participants view as being vital to the program and their experience	Not necessarily the most enjoyable program component	"The most important part of the program is the mentors because they provide inside information we will need when we start college"

Table B.1 (continued)

Number	**Code**	**Definition**	**What it's not**	**Example**
6	Pressure/tension	Anything the participants feel as though they were forced or coerced to do	Something they chose to do that ended up being difficult	"My mom made me apply to the SBP when she saw an email about it."
7	Perceived Choice	Anything the participants feel as though they decided to do (or declined to do) on their own		"I chose to apply to the SBP because I wanted to learn more about engineering before the Fall."
8	Value/usefulness	Things that participants view as having some utility towards them reaching a goal	Something done for pure interest/enjoymen t	"Study hall was really helpful for ensuring we all mastered the concepts from class."
9	Relatedness	Participants' state of being either well-integrated or isolated from their peers, mentors, teachers, or program leaders; social connectedness/sense of belonging in the engineering program	Relatedness with people (e.g., friends) outside of the engineering program	"I have formed friendships since starting the SBP, and we all seem to have similar goals." "I have a great relationship with my mentor"

Table B.1 (continued)

Number	Code	Definition	What it's not	Example
10	Long-term SB expectations	Any lasting effects the student thinks the SBP will have on their academic journey	What they wish they could have seen happen in the SBP	"I think the structured study time routine will be something that stays with me throughout undergrad" "My SBP cohort will probably be many of the friends I keep throughout my undergrad program."
11	Aspirations	Any specific future career/personal goals the participants express	Short-term goals	"After college, I want to be a chemical process engineer."
12	Intrinsic Engineering Motivation	Participants alluding to pursuing engineering because they find it fun and enjoyable; participants finding SBP engineering work fun and enjoyable	Seeing utility in engineering work	"I love working on Tinker software because I can be creative and make new things I like"

Table B.1 (continued)

Number	Code	Definition	What it's not	Example
13	Extrinsic Engineering Motivation	Participants alluding to pursuing engineering because they need to get something external; participants finding SBP engineering work essential for getting something in return	Engineering work done for enjoyment	"I worked hard on the Tinker software so the Ergon judges will be impressed during judging"
14	Peer support	Classmates or friends who help a participant through a challenge		"Everyone in my group was willing to help each other succeed."
15	Engineering perception	How the participant views engineers or engineering		"Engineers are people who make things happen using math and science" "Engineering is only for people who …."
16	Program Structure	Anything related to the specific engineering program structure	Program objectives	"Study hall was way too long and we rarely worked the entire 3 hours"

Table B.1 (continued)

Number	Code	Definition	What it's not	Example
17	Experience as a minority in engineering	Experiences unique to being a minority in engineering. "Women, persons with disabilities, and three racial and ethnic groups—blacks, Hispanics, and American Indians or Alaska Natives—are underrepresented in S&E" (Science and Engineering)		"I do not think the guys in the program really listened to my input."
18	Autonomy	Statements about having free will or creative freedom; choosing what to do	Refusing to do things (i.e., defiance)	
19	Interest in engineering	Statements about why a student is interested in engineering, or experiences that drew them to engineering		"I have always loved math and science, so I thought I should try engineering"
20	Real World Application	Instances of applying formal engineering learning to practical situations and/or projects	Case studies	"Going on the trip to Ergon and doing project work made me realize how what we are learning translates to the real world"

Table B.1 (continued)

Number	Code	Definition	What it's not	Example
21	Engineering experience	Statements from students about the engineering skills/knowledge/experience they gained during co-ops/research/jobs before or outside of college classes	Experiences not related to engineering work	
22	Using content from engineering classes	Statements about how students apply their acquired knowledge from engineering classes in their daily basis tasks/ their coops/ their other classes		
23	Family dynamics	Actions from a family member that helped a student make a decision, succeed, overcome a challenge or other impactful events; Actions from a family member that hindered a student from making a decision, succeeding, etc.		"My mom would make me come home every weekend to watch my siblings, so I couldn't participate in program events on the weekends."