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EXAMINING THE INFLUENCE OF THE CLASSROOM ENVIRONMENT ON MOTIVATION, BELONGING, AND ACADEMIC CONFIDENCE IN ENGINEERING EDUCATION: A RELATIONAL DEVELOPMENTAL SYSTEMS APPROACH

A Dissertation
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy
Learning Sciences

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by
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August 2023

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ABSTRACT

This dissertation explores the impact of the classroom environment on undergraduate engineering students by integrating three manuscripts using the process-person-context-time (PPCT) model within Bioecological Systems Theory. Each manuscript focused on students’ sense of belonging, motivation, and academic confidence. The study confirms prior research suggesting a link between students' perceptions of the environment and their sense of belonging, motivation, and academic confidence. The findings highlight the complex nature of student and classroom environment relationships throughout their college experience. Moreover, the results are demonstrated across different engineering majors.

Chapters two and three utilize secondary data analysis to examine student perceptions of the classroom environment in a specific engineering major. Those results underscored the importance of students' perceptions, which significantly predict students’ sense of belonging, motivation, and academic confidence. A key finding suggested sense of belonging as a mediator for juniors and seniors. This emphasized the need to foster a positive classroom environment throughout students' academic journey. Results from chapter three revealed non-linear trends in students' perceptions, indicating fluctuations within the classroom environment over time.

Chapter four collected from sophomores, juniors, and seniors across five engineering majors. That explored the relationships between classroom environment perceptions, sense of belonging, motivation, and academic confidence, while also considering negative daily life experiences, such as racial and nonracial microaggressions. Results indicated direct and indirect effects of negative daily life experiences on students’ sense of belonging, motivation, academic confidence, and their perceptions of the classroom environment. Moreover, the results supported prior research concerning the existence of a unifying engineering identity regardless of major.

Overall, this dissertation highlights the significance of understanding the complex interactions between students and their classroom environments in engineering education. It emphasized the need to create more inclusive and supportive classroom environments that have the ability to enhance students' sense of belonging and motivation. These findings have implications for engineering educators seeking to foster positive learning experiences for all students, regardless of their background or major.

DEDICATION

I dedicate this dissertation to my dearly beloved family for pushing me through this PhD journey, even when they didn't fully understand any of it. But most of all, I dedicate this to Mae. Friend, confident, but mostly Mom!

ACKNOWLEDGMENTS

The phrase, “it takes a village” resonates extremely well for those on the doctoral journey. It truly does take a “village” of people to get you to the end of the journey. For that, I want to, first, acknowledge and thank the five people who guided me through this doctoral journey—my dissertation committee. My chair, Dr. Debi Switzer, the ever consummate leader and person who was always in my corner. Your words and wisdom over the years have been an inspiration. This dissertation uses quantitative methods and that wouldn’t have been possible without the help of Dr. Matthew Madison. I sincerely appreciate your kindness, humor, and willingness to let me try things out. No dissertation committee is complete without the assistance of content experts. Luckily for me I found three individuals who each lent their expertise to the project. Dr. Natasha Croom, probably the committee member I’ve known the longest thank you for your inspiration and challenges on this journey. Dr. Heather Brooker, the levelheaded one and person who was always asking me to look forward; I appreciate your insights and comments throughout this process. Finally, Dr. Edmond Bowers, the theory expert and committee member with the editor’s eye. Your feedback has been instrumental in helping this dissertation to be stronger.

There are countless others who’ve helped on this journey, and I want to especially name a few. CJ – the Eccles to my Wigfield; Steph – my first officemate and fellow hell raiser; my Learning Sciences family, my CLAD family, and my GSG family—you all have supported me over my time here at Clemson and for that I am forever grateful!

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CHAPTER ONE

INTRODUCTION

Human existence can be thought of as a complex web of interconnections, and as researchers, we work towards understanding the growth and development of humans across their life span. Developmental scientists generate theories aimed at explaining human development and over time revisions to developmental theories occur due to better understanding of human life or better methods to explain phenomena. For example, Bandura (1978) posited individuals' response to stimuli is partially based on prior experiences and perceptions. In this view, a person's behavior works in a reciprocal relationship with personal factors and the environment, forming a triadic relationship. Additionally, this triadic relationship becomes interlocked with nested ecological systems over a lifespan (Bronfenbrenner, 1977). Moreover, while the triadic relationship varies due to individual differences it can also differ depending on the context in which those relationships occur (Bandura, 1977, 1978; Bronfenbrenner, 2001). For example, students enter classroom contexts with differing educational backgrounds and have differences due to influences from their home and community environments.

Prior knowledge comes from interactions of the developing person, situated in a context influenced, bidirectionally, by nested ecologies over time (Bronfenbrenner, 2001). Taken as a whole, behavior in a classroom context is further understood through external forces acting upon a mutual triadic reciprocal relationship. In the context of post-secondary education, as students enter a new ecological context, they are met with a series of new experiences—from living away from home for the first time to new classroom environments. How because of the multiple person-context interactions, the impact of this ecological system may not be the same for all students (Belsky & Pluess, 2009; Bornstein, 2019; Freeman et al., 2007; Good et al., 2012; Lizzio et al., 2002; Walton & Cohen, 2011).

Students spend a substantial amount of time in classrooms across their educational experiences. While navigating differing classroom environments, students develop relationships and have experiences that can shape developmental trajectories. Bornstein (2017, 2019) states that as individuals spend more time in specific environments, the impact of those experiences can exacerbate differences in individuals, particularly when those experiences occur during key developmental stages. Moreover, if student behaviors and development depend on increasingly complex interactions between students and their environment, then there is a need to better understand the impact these environments have on students over time (Canning et al., 2020; Gummadam et al., 2016; Lee et al., 2020; Scheidt et al., 2020). Therefore, if institutions of higher education want to better understand how students develop a sense of belonging, are motivated academically, and believe they can be successful in their major, then research must be done to examine the longer-term implications of students' experiences in the classroom.

One potential area in post-secondary education where there is a need to better understand the environment's impact on a student is in science, technology, engineering, and mathematics programs (STEM majors). STEM majors encompass a wide variety of classroom environments with variations in how environmental factors impact students across STEM fields (Baber, 2015; Cromley et al., 2016; Wilson et al., 2015; see also

Bottia et al., 2015; Mau, 2016; O'Hara, 2022). However, it is unrealistic to fully examine all STEM areas in one study because of the complexity in developmental processes situated within specific contexts. Geldhof et al., (2013) discussed methodological problems associated with using a systems framework. From a relational developmental systems theory (RDST; e.g., Overton, 2013) standpoint, human development consists of bidirectional person ←→context relationships. In this framework, objects and events occurring within a context are related to those contexts. That is, to truly understand the impact classroom environments have on students, we must consider the context itself, the individual students in that context, specific aspects of the students, where they might be developmentally, and what changes might be occurring. The very nature of RDST makes it almost impossible for a single study to encapsulate all parts effectively at the same time.

Therefore, it is reasonable to assume researchers would separate students by individual academic areas (e.g., engineering or math) to better examine the impact of the classroom environment. While engineering offers a unique opportunity for researchers in that there is a collective identity as an engineer despite there being several different engineering majors (Godwin & Lee, 2007; Hernandez et al., 2017; Kirn et al., 2016; Murphy et al., 2015; Nadelson & Fannigan, 2014; Patrick & Borrego, 2016; Perez er al., 2014; Rodriguez et al., 2018), the larger context of STEM education provides some real world issues that this research can draw from. For example, the challenge the United States faces to increase STEM education to remain globally competitive (National

Academy of Sciences, 2011; National Science Board, 2022; National Science Foundation [NSF], 2019a; The White House, 2009).

Still, students can often be pushed out of STEM programs for not being “smart enough” or deemed incapable of doing the work; often these students are from minoritized populations (Bottia et al., 2015; Rodriguez & Blaney, 2021; Sarac, 2018; Strayhorn, 2015; Wilson et al., 2015). Yet, not being “smart enough” or incapable of doing the work may be a result of unequal educational backgrounds due to some students having more or better access to STEM experiences in secondary schools (London et al., 2021; Lord et al., 2019; Malcom & Felder, 2016; Mau, 2016; O’Hara, 2022). Overtime, these instances result in a less diverse STEM workforce and diminished capacity to meet the demand for more STEM graduates. Ultimately, the goal of this research was to examine the ways in which aspects of the engineering classroom environment impacted undergraduate students’ sense of belonging, motivation, and academic confidence to provide critical information engineering programs can use to implement effective interventions within engineering education. Studies have shown (e.g., Good et al, 2012; Freeman et al., 2007; Park et al., 2018; Wilson et al., 2015; Won et al., 2018; Zumbrunn et al., 2014) the varied ways these constructs can impact student success and persistence across the educational spectrum. However, given the highly contextual nature of learning and development, this research focused on a specific educational context to provide targeted information.

Aspects of the Classroom Environment

Development is a complex and multifaceted process, and situating development within specific contexts adds an additional layer of complexity to the understanding of human behavior. Contexts can either enhance or inhibit growth and development. For example, positive classroom environments help students target motivation and self-efficacy (Copeland & Levesque-Bristol, 2011) while toxic classroom environments can have the opposite effect (Cromley et al., 2016; Wilson et al., 2015). When it comes to understanding why environments affect students, it is beneficial to examine the ways in which the context is constructed. Situating understanding in such a way allows individuals to better understand the source of the problem.

In this dissertation, the classroom environment was broken into three aspects: ideological, cultural, and structural. Ideological refers to a set of political, economic, and social values or beliefs, and assumptions shared by groups of people or societies. For example, ideas about what education should look like and who should have access to education come from an ideological point of view. Cultural, on the other hand, is a set of knowledge, values, beliefs, and symbols interpreted similarly by members of the same group. Often cultural norms are informed by ideological beliefs of community members over time. For this research, cultural refers to the general culture of engineering programs. For example, a cultural aspect of the engineering classroom might be the use of competition and meritocracy as markers of achievement and reflect the values and practices of the profession. Finally, structural refers to how engineering classrooms are organized and who benefits the most from that organization. For example, STEM education often operates from a single epistemology and pedagogy (Ladson-Billings, 2009; Wilson et al., 2015). Structurally, this can manifest itself as a singular right way to teach and learn in the STEM classroom. As a result, the types of class interactions and features we would observe are heavily influenced by the structure of the classroom. Often this structure discounts lived experiences and other types of knowledge students bring with them to the classroom.

Taken together, if we think of ideologies as being beliefs and values held by people and groups of people, then cultures are the orientation from which ideological values and beliefs are drawn. Structural, then, is the mechanism by which ideologies and cultures manifest themselves throughout the classroom. A key point to remember is students who are entering engineering classrooms come with their own ideologies and cultural norms informed by their upbringing and prior experiences which may conflict with those of the engineering classroom (citation). Viewing the engineering classroom from ideological, cultural, and structural aspects allowed the research to make sense of the overlapping differences between the student and their classroom environment which in turn can aid engineering programs in addressing problems of student motivation, sense of belonging, and academic confidence (Bondi, 2012; Donnor, 2013; Malcom & Feder, 2016, O'Hara, 2022; Owen, 2007).

Linking Statement

This integrative statement is provided to theoretically and conceptually link the three manuscripts discussed within this dissertation research. Theoretically, the manuscripts are linked using a relational developmental systems theory framework.

Specifically, Bronfenbrenner’s (2001) bioecological systems theory. Conceptually, the manuscripts are linked both by building off one another and leveraging aspects of a process-person-context-time model (Bronfenbrenner & Morris, 2006) to examine constructs of interest in various ways. The first manuscript examined the relationships between student perceptions of their classroom environment and their motivation, sense of belonging, and academic confidence across academic years. Manuscript two took a deeper dive into each academic year and explored the trends within sophomores, juniors, and seniors over a 4-year period, specifically looking at changes in trends as one department implemented cultural and curriculum changes. The third manuscript introduced individual student lived experiences to help make sense and provided explanation for differences observed in sense of belonging, motivation, and academic confidence. Five different academic majors were introduced, in the third manuscript, to explore potential differences across academic years and majors. The overall purpose of this research was to better understand the impact classroom environments can have on undergraduate students’ motivation, sense of belonging, and academic confidence by examining the classroom environment through ideological, cultural, and structural lens.

THE CURRENT STUDY

Current aims in engineering education seek to better understand ways in which they can improve the undergraduate experience as a means of retaining and graduating students into the engineering workforce. Prior research has articulated the interconnectedness of motivation, sense of belonging, and academic confidence in college students. What is lacking from that research is an explicit focus on the dynamic and reciprocal relationship between students and specific classroom environments over time. Research has demonstrated the disparities across minoritized groups in higher education, particularly for those racially minoritized groups in STEM programs (Ladson-Billings, 2012). As a result, there is a critical need for research that demonstrates the impact classroom environments have on the motivation, sense of belonging, and academic confidence in students as they progress through an engineering program. This study aimed to discover, create, and promote ways of understanding how structured learning environments impact undergraduate engineering student populations.

The overarching research question guiding all aspects of this dissertation research was: To what extent do cultural, ideological, and structural aspects of the engineering classroom impact sense of belonging, motivation, and academic confidence in undergraduate engineering students?

Problem Statement

Recent research in STEM, particularly engineering, education has demonstrated the interconnectedness among sense of belonging, motivation, and academic confidence in undergraduate students (Freeman et al., 2007, Hernandez et al., 2017; Morelock, 2017; Robinson et al., 2019; Sarac, 2018; Strayhorn, 2012; Wilson et al., 2005). These results have suggested that the impact of these constructs might not be the same (Belsky & Pluess, 2009; Bornstein, 2017, 2019; Freeman et al., 2007; Good et al., 2012, Lizzio et al., 2002; Walton & Cohen, 2011). Furthermore, research has shown academic disparities across minoritized groups in higher education (Byars-Winston et al., 2016; Cano et al., 2018; Han et al., 2017; Ladson-Billings & Tate, 1995; Mau, 2016; Park et al., 2018;

Perez et al., 2014; Strayhorn, 2015), particularly for racially minoritized students in STEM programs (Baber, 2015; Bottia et al., 2015; Cromley et al., 2016; Donnor, 2013; Geisinger & Raman, 2013; Grossman & Porche, 2014; Ladson-Billings, 2009, 2012; Ladson-Billings & Tate, 1995; López & Burciaga, 2014; Strayhorn, 2012, 2015). Although many factors might contribute to these disparities among groups in STEM, the classroom environment potentially contributes to much of that disparity (Canning et al., 2020; Ladson-Billings, 2012; Ladson-Billings & Tate, 1995; Zumbrunn et al., 2014). In other words, systemic issues in STEM classrooms potentially perpetuate disparities between minoritized groups in higher education. A drawback to these studies is the focus on a single behavior or psychological construct. Moreover, they lack an explicit focus on the dynamic and reciprocal relationship between students and their classroom environments over time.

Conceptual Framing

People can experience the same event and come away with different outcomes because understanding experiences are not wholly shaped by the experience itself. Take, for example, Bornstein's (2017, 2019) Specificity Principle which states that understanding development over the lifespan relies on a set of specifics because of the nuanced nature of development. Experiences impact specific individuals in specific ways at specific times and the unique interactions of those specifics theoretically drive the differing outcomes we see. Relational developmental system theories (RDST, Overton, 2013, 2015) are one group of developmental theories that captures this sentiment. RDST emphasizes the reciprocal multidirectional relationship between developmental systems where an individual and their environment influence one another. These types of developmental theories view humans as complex and interconnected organisms whose development is a product of "mutually influential relations between developing individuals and the multiple levels of their complex and changing contexts" (Geldhof et al., 2013, p. 67). Bornstein (2019), called for RDST research to breakdown aspects of development and build models that are empirically testable in practice. One RDST theory capable of meeting that challenge is Bronfenbrenner's bioecological theory of human development (Bronfenbrenner, 1977, 1992, 2001; Bronfenbrenner & Morris, 2006).

Bioecological Systems Theory

Bioecological Systems Theory explains human development as "phenomenon of continuity and change in the biopsychological characteristics of human beings both as individuals and as groups…extends over the life…through historical time, both past and present" (Bronfenbrenner, 2001 p. 3). Over the course of a lifespan, individuals experience increasingly complex reciprocal interactions with proximal and distal forces stemming from nested ecological levels (Bronfenbrenner, 1992, 2001; Bronfenbrenner & Morris, 2006). This can be best understood in two ways 1) the importance of interrelated ecological levels nested together as micro-, meso-, exo-, and macro-systems, and 2) the process-person-context-time (PPCT) model.

Following, other developmental systems theory (e.g., Overton, 2013, and Geldhof et al., 2013), the individual is placed at the center of their own development. Imposing the most influence on the individual's development is the microsystem. Microsystems are comprised of, for example, immediate family, schools, communities, and individuals who interact with those entities daily. When two or more microsystems interact with one another, they form a mesosystem and the interaction of the two microsystems constitute an additional influence on the individual. For example, parent-teacher conferences bring together the family microsystem and school microsystem. Micro- and meso-systems are ecological systems in which individuals are directly involved. At the exosystem level, individuals are not directly involved; however, the quality of microsystems are influenced. For example, most students are not involved in creating educational policy at the state or national level. However, those policies influence the types of experiences students have in the classroom. Macrosystems are further removed from the individual and indirectly influence individuals' lives. Examples of macrosystems include cultural values, the political climate, and economic patterns. Influences from the various ecological levels shape the developmental outcomes experienced by individuals. Finally, the chronosystem encompasses the impact time has on development. For example, the lingering effects of COVID-19 on education would be an aspect of the chronosystem that can moderate educational effectiveness. Taken together, the bioecological systems theory provides an understanding that development is a function of the developing person, situated in a context, with changes happening over time.

Process-Person-Context-Time Model

Within the PPCT conceptual model, process refers to the increasing complex reciprocal interactions that occur between an individual and their immediate environment. Often referred to as proximal processes, these are considered the "engines of development" (Bronfenbrenner & Evans, 2000, p. 118). The person component refers to the individual and the various biological, cognitive, affective, and behavioral characteristics that make up their person. Context refers to the environment and ecological system the individual is currently situated within. Time involves the understanding of the multiple levels of temporality that make up the chronosystem impacting change over time (Bronfenbrenner, 2001; Bronfenbrenner & Morris, 2006). Within this study, the PPCT is conceptualized as the student (i.e., person) and their classroom environment (i.e., context) interacting (i.e., process) throughout their post-secondary careers (i.e., time). In this view, the classroom becomes the microsystem and the changes observed over time are indicative of proximal processes occurring.

Elements of the PPCT interacting together determine the strength and power of development. What is gleaned from this model is an understanding of how developmental differences are a result of the interaction between the developing person, situated in a context where proximal processes are occurring, with changes happening over time connected to the lived experiences of individuals. Development is dynamic; when individuals enter new environments, they do not enter with clean slates. Prior development has created subjective interpretations of previous situations that reciprocate with new environments.

Nonetheless, bioecological systems theory is not without its faults. Developmental theorists have called into question the use of bioecological systems theory when studying the development of children of color. Specifically, the theory's lack of emphasis on unique developmental processes experienced by children of color inhibits the ability to adequately address development in children of color (Garcia Coll et al., 1996; Lee, 2008; Nasir & Hand, 2006; Spencer, 1999; Spencer et al., 1997; Vélez-Agosto et al., 2017; Velez & Spencer, 2018 Williams & Deutsch, 2016). Within the microsystem we see the structures and processes that contain the individual in the most immediate setting (e.g., home or classroom). Operationalized through the process-person-context-time model, we understand that individuals experience reciprocal interactions between themselves and the persons, objects, and symbols within that environment interacting with both proximal and distal influences on the developing person (Bronfenbrenner, 2001). Developmental outcomes, then, are a function of those interactions over periods of time. Yet if we hold that culture is a system of objects, symbols, and practices with specific meaning to specific groups of individuals that can adapt and change over time, then its absence at the core of the individual makes it difficult to fully understand the true impact of the environment on children of color (Lee, 2008; Nasir & Hand, 2006; Vélez-Agosto et al., 2017).

A developmental model that addressed concerns with Bioecological Systems Theory is the work of Margaret Beale Spencer and colleagues (Spencer et al., 1997; Velez & Spencer, 2018). The Phenomenological Variant of Ecological Systems Theory or PVEST, introduced alternative developmental pathways that might be normalized pathways for children of color. PVEST (Spencer et al., 1997; Velez & Spencer, 2018) addressed issues of risk, vulnerability, and resiliency children of color face in their environments while adding the importance of individuals perceptions and attitudes of their identities and environments when examining development. Within the PVEST framework, children of color often placed at risk when navigating certain environments.

Navigating these environments forces children of color to constantly go through a self-other appraisal process which ultimately influences their developmental outcomes (Spencer, 1999; Spencer et al., 1997). The contribution of PVEST to developmental research with children of color is its ability to "capture the individual's intersubjectivity" (Spencer et al., 1997, p. 828) which allows for researchers to better understand the dynamic influence of culture in specific environmental contexts and the influence it can have on developmental outcomes. Later iterations of PVEST recognized the need for adolescent developmental outcomes to be understood from both macro- and micro-systems to better understand how youth make sense of their environments through systems of oppression and the incorporation of intersectionality (Crenshaw, 1991; Velez & Spencer, 2018).

Velez and Spencer (2018) reconceptualized PVEST to make intersectionality more prominent by placing emerging identities at the forefront of the framework bringing together both the dynamic interlocking ecological levels with interlocking systems of oppression in a way that pushes back on dominant additive or deterministic models of development. While the intent of PVEST was to illustrate individual's development within and between contexts while emphasizing the individual's meaning making process; by adding intersectionality to the framework systems of power and privilege at the forefront. Intersectionality also connected social expectations and norms to the formulating identities of children of color. Altogether, this adds to research interpreting the complex, dynamic relationships between individuals and their environments.

While PVEST serves as one example of a critique to Bioecological Systems Theory, there are common threads among various enhancements to the original theory. One common proposition is that developmental pathways taken by children of color are not inherently deviant or an indication of some developmental deficiency (citation). Rather these developmental outcomes are a result of unique experiences that children of color have because of their position in society. Mainstream developmental models failed to incorporate these unique experiences. Another proposition of revised bioecological systems theories models different from more main-stream models is that these revised models incorporate systemic issues of oppression, discrimination, and prejudice that are critical factors of development for children of color (Garcia Coll et al., 1996; Lee, 2008; Spencer et al., 1997). Part of this research was informed by PVEST and framed how the results were interpreted.

Operationalizing Constructs

Sense of Belonging

Since the work of Maslow (1954), researchers have examined one of the most basic levels of human need: the need to feel belongingness to something. Sense of belonging is contextualized by a person and their environment. For example, sense of belonging could be defined as interpersonal connections one has with a school (Goodenow, 1993). Other research has characterized sense of belonging in a multitude of ways; from defining it as perceptions of acceptance, fit, or inclusion (Bollen & Hoyle, 1990; Locks et al., 2008; Museus & Maramba, 2010; O'Brien et al., 2001) to correlating it with goals, achievement, and engagement (Freeman et al., 2007; Good et al., 2012;

Walton & Cohen, 2011; Walton et al., 2012). In this dissertation research, sense of belonging was conceptualized as a feeling, or perception, of a sense of connection to specific areas of their educational experience (Ahn & Davis, 2019; Freeman et al., 2007; Strayhorn, 2012; Wilson et al., 2015).

Motivation

Substantial research relating to motivation and the classroom have been completed with student populations ranging from kindergarten to college (Abeysekera & Dawson, 2015; Ames, 1992; Belland, et al., 2013; Imms & Byers, 2014; Mellat & Lavasani, 2011; Pintrich, 2004; Tinberg & Weisberger, 1998; Young, 2005). Further research discussed the impact environments have on student learning via motivation, self-efficacy, or self-regulation (Brooks, 2011; Chiu & Cheng, 2017; Imms & Byer, 2014; Linden, 2018; Young, 2005), and pedagogical methods used to influence learning via motivation, self-efficacy, and self-regulation (Abeysekera & Dawson, 2015; Cano et al., 2018; Chyr et al., 2017; Evenhouse et al., 2018; Gordon & Ball, 2017; Hargis & Marotta, 2011; Kim et al., 2013; Linden, 2018; Nash-Ditzel, 2010; Tinberg & Weisberger, 1998).

Additionally, there are substantial substantive areas of research that cover broad aspects of motivation. For example, self-determination theory (Deci & Ryan, 1985; Ryan & Deci, 2000) focuses on competence, autonomy, and relatedness facilitated by social-cognitive factors. The work of Pintrich and colleagues (Pintrich, 2003, 2004; Pintrich & Zusho, 2002; Pintrich et al., 1991) looked at motivation in the context of teaching and learning and focused on college-aged students. In this sense then, we can think about motivation as being specific to the context in which students experienced it (Kaplan et al., 2012, 2019; Nolen, 2020).

In this dissertation study, motivation was viewed through situated expectancy-value theory (SEVT; Eccles & Wigfield, 2020). SEVT is a reconceptualization of expectancy-value theory (EVT; Eccles-Parson et al., 1983; Wigfield & Eccles, 2000) that places the importance of the context (i.e., the situated part) in the forefront. Expectancy-value theory introduced a broad theoretical framework bringing together research from cognition, development, and sociocultural perspectives. Originally designed for examining children's beliefs (see Eccles-Parson et al., 1983; Wigfield & Eccles, 2000) the framework has expanded across all levels of education. Within EVT, the individual's developmental process is placed in the middle and serves as a mediator between expectancies about success, academic performance, and personal experiences. Eccles and Wigfield (2020) have stated themselves that much of the research with EVT has focused on individual's academic performances and expectations for success without considering other aspects of the theory.

Framing SEVT with the PPCT model within Bioecological Systems Theory brings in the individual's culture and socialization that impact how individuals develop expectations for success and perform academically. Placing emphasis on the individual situated in multiple contexts over their lifespan and the developmental processes that occur, provides a better view of how the cultural milieu, perceptions of socializers, and personal characteristics of individuals shape how they approach expectancies for success, understand their ability, and ultimately are motivated for success academically.

The theory focuses on perceptions of abilities, expectations students have for success, and a broad area termed subjective task values. Subjective task value used in this research include:

- Interest Value or the value derived in anticipation of deciding or completing a task and the enjoyment received from it.
- Attainment Value or the value of attaining or achieving a task/goal because it is connected to one's sense of self.
- Utility Value or the usefulness of the task at hand as it relates to one's goals or identity (Eccles & Wigfield, 2020; Wigfield & Eccles, 2000).

Academic Confidence

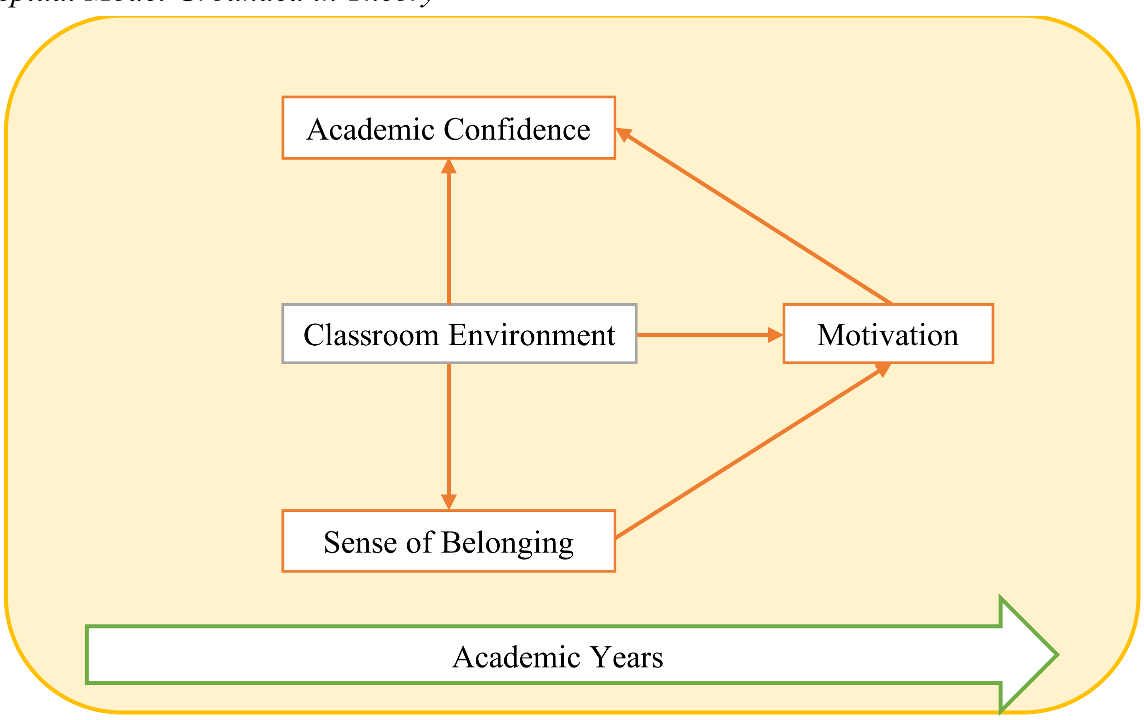
Academic confidence is conceptualized as the perception that one feels confident in their academic ability to succeed both in courses and subsequently their field of work. Stemming from the work of Sander & Sanders (2006, 2009), academic confidence is rooted in beliefs that students hold regarding their ability to succeed given the demands of a particular major. Theoretically speaking, academic confidence draws from several frameworks to help researchers understand the complexity of how students view themselves academically. Academic confidence borrows from motivation theories: expectancy-value theory (Wigfield & Eccles, 2000), self-efficacy theory (Bandura, 1977); and, from social comparison theory (i.e., Skaalvik & Skaalvik, 2002). Within this study, academic confidence was conceptualized as students' confidence in behaviors needed to be successful academically. Moreover, it was thought of as a perception that students have regarding feeling confident in their academic abilities to succeed in courses and within their field of study (Patrick & Borrego, 2016; Rodriguez et al., 2018).

Conceptual Model

Figure 3 below represents a conceptual model that fused the operationalized constructs and ecological systems framework. The large box represents the mesosystem of classrooms and students interacting with one another. Situated within that context is the complex and dynamic relationships between the classroom environment, sense of belonging, motivation, and academic confidence as illustrated by the arrow-headed lines in the figure. The arrow across the bottom of the figure represents the changes over time, in this context it was across academic year (e.g.., First year to Senior year). The results were understood as a function of the strength and direction of relationships, classroom environment, and time. That is as students engaged in their classroom environment, the

Figure 3

Conceptual Model Grounded in Theory



ideological, structural, and cultural influences of that classroom environment were exerted on the student. Likewise, the students were exerting their own forces on the classroom environment. This was done through their responses to stimuli in the environment, social interactions, and prior experiences in an academic setting. Overtime, these influences were hypothesized to dynamically change the strength and directions of the constructs' relationships between students situated in that environment. Moreover, this process was repeated both as students engage in different classrooms on campus and as they made progress toward their degree.

RELEVANT LITERATURE

The constructs of sense of belonging, motivation, and academic confidence are not new to educational research (Copeland & Levesque-Bristol, 2011; Good et al, 2012; Freeman et al., 2007; Park et al., 2018; Strayhorn, 2015; Vaccaro & Newman, 2016; Walton & Cohen, 2011; Walton et al., 2012; Wilson et al., 2015; Won et al., 2018; Zumbrunn et al., 2014). They show a positive correlation with one another meaning increases in one lead to increases in the other.

For example, Freeman et al. (2007) wanted to examine the relationship between sense of belonging at the classroom level and overall university level. The study found that sense of belonging at a classroom-level influenced motivation and academic achievement in first-year undergraduates. Yet, those results were less clear regarding the relationship between classroom level sense of belonging and university level sense of belonging. Similarly, Zumbrunn et al. (2014) wanted to explore how student perceptions regarding sense of belonging, motivation, and engagement mediated the relationship between aspects of the classroom environment and academic achievement. The study compared two statistical models with follow-up interviews about contextual characteristics of the classroom. While both models examined sense of belonging and motivation, the paths they chose differed. The first model predicted sense of belonging and motivation to be predicted by a supportive classroom environment and model two included sense of belonging as a mediator between motivation and perceptions of the classroom environment. They found that sense of belonging mediated the influence students' perceptions of the classroom environment on motivation and engagement: demonstrating the influence sense of belonging has on motivation and success. However, Zumbrunn and colleagues (2014) conceptualized supportive classroom environments as student perceptions of the instructor's academic and social support while not looking more holistically at the classroom environment.

Regarding STEM student populations, Wilson et al. (2015) found that sense of belonging is more than just being connected to the campus. The construct was responsive to students' engagement, self-efficacy, and interest in STEM. Regardless of institution type, sense of belonging at the classroom level impacted how students approached their feelings about the class. The authors intended to push thinking about sense of belonging in the STEM field to be more than just how a student feels connect to a campus. Scheidt et al. (2021) sought to characterize how noncognitive factors interacting might form patterns that could help engineering educators better understand what drew students to engineering. London et al. (2021) discussed the representation of minoritized populations was not enough to motivate students—STEM education must consider the structural, cultural, and ideological forces that inhibit minoritized participation in STEM education.

Taken together, these studies highlight the relationship between sense of belonging, motivation, and academic confidence. However, they fail to encapsulate specific aspects that would paint a fuller picture of engineering education. Freeman et al. (2017), Zumbrunn et al. (2014), and Wilson et al. (2015) limited themselves to data at a singular timepoint and failed to capture how these processes interact overtime in sustained environments. Scheidt et al. (2021) discussed the lack of minoritized participants and environmental issues in the study as limitations.

Potentially addressing some of these shortcomings came from the work of Main and colleagues (2021). In this research, the authors discussed how individuals, social, and structural factors converge in ways that influence how students chose engineering majors. This research aligned with prior research demonstrating influences from factors such as race/ethnicity (e.g., Lord et al., 2019), identity (e.g., Godwin et al., 2016), and academic achievement (e.g., Tan et al., 2021). The contributions of the authors combine previous engineering education research into a conceptual model that can aid interventions. However, the research is limited in that it does not include structural inequities that may drive some of the results.

Main et al (2022) used a life course framework to explore interactions between social, demographic, and education-related factors at various stages of a student's life. For example, the authors discussed role models and access to STEM courses in high school as an indicator for choosing an engineering major. This study provided evidence for disparities in why people chose to go into engineering, but we need to know what happens to those who choose to go into engineering. For example, do the same factors influence their experiences? Moreover, following previous engineering education research, Main et al (2022) focused on early college (i.e., first-year students) populations.

When students have a strong sense of belonging, are motivated, and are engaged in an engineering culture, the more likely they are to form a strong identity as an engineer and ultimately enter the workforce (Benson et al., 2017; Godwin et al., 2016; Kirn et al., 2016; Lee et al., 2020; O'Hara et al., 2020; O'Hara et al., 2021; Verdin et al., 2018; Wilson et al, 2015). Yet, aspects of the engineering classroom struggle to create environments that support and enhance these constructs. From an ideological standpoint, the classroom is shaped by government, higher educational policy, and sociohistorical contexts (Lee et al., 2020). Closer to the classroom, there are internal factors that shape engineering classrooms like institutional diversity (Lee et al., 2020). Within the classroom itself, students are faced with messages regarding the competitive and individualistic nature of engineering culture (Canning et al., 2020). For example, pitting students against one another in a zero-sum environment that often results in negative course outcomes for all students coupled with unrealistic expectations (Eastman et al., 2019) can leave students feeling unmotivated and like they do not belong in that environment. Dewsbury (2017a; 2017b) has described the engineering classroom as devoid of social thought and social evolution while structurally dealing with a history of forced cultural assimilation. Moreover, it is situated in a higher educational landscape that is perpetuated behind prevailing social structures. Overall, these aspects of the engineering classroom influenced outcomes in students and at the same time potentially impacted students differently across an array of demographic indicators. In that sense, it may not be enough for faculty to just know their students. They need to know them through the contextual lens shaped by ideological, structural, and cultural aspects of the classroom.

RESEARCH DESIGN

Research has stated the isolated nature of disciplines and the conceptualization of what is considered scientific study limits the ability of researchers to effectively understand the dynamic and complex relationships of bioecological systems (Cole, 2007; Helms et al., 2005; Lee, 2008; Lee et al., 2003). This dissertation research theoretically and conceptually linked three manuscripts through a RDST framework. Each manuscript was centered around the reciprocal relationship between individuals and their nested ecological systems. It explored the ideological, cultural, and structural aspects of the engineering classroom and the impact on motivation, sense of belonging, and academic confidence in undergraduate engineering students. All three manuscripts, collectively, captured the PPCT model in bioecological systems theory (Bronfenbrenner, 2001). The first manuscript focused on proximal processes by using a multigroup structural equation model (SEM) that examined relationships and indicators of development. The second manuscript focused on the context aspect of the PPCT using a trend analysis that examined proximal processes overtime in a singular department. The final manuscript looked at differences across academic majors and academic years with a focus on individual lived experiences and represented the person within the PPCT model.

Designing the research this way allowed for the research questions to move beyond traditional socially constructed factors that explain differences we might observe in students (Williams & Deutsch, 2016). Theoretically linking three manuscripts together created the opportunity to look at intersections of the constructs of interest across ecological levels. As students navigate an academic major—and college in general—they should change how they make meaning of their experiences. How they perceive their classroom environments might influence other constructs one way when a student is a sophomore versus when the student is a senior. Thinking through this lens adds a layer of complexity to how the ideological, cultural, and structural aspects of the classroom could change over time. These complexities are important because together they help engineering education meet the demands of future engineers by tackling the challenges of sustainability, the fourth industrial revolution, and employability skills (Hadgraft & Kolmos, 2020). The remaining of this chapter discusses the layout of the dissertation, including summaries of chapters two thru five.

Chapter Two: Student Perceptions of the Classroom Environment: The Unseen Impact

Differences between students matter when it comes to understanding how students perceive their environment. Understanding perceptions of the environment in specific contexts is important because of disparities in higher education (Byars-Winston et al., 2016; Cano et al., 2018; Han et al., 2017; Ladson-Billings & Tate, 1995; Mau, 2016; Park et al., 2018; Perez et al., 2014; Strayhorn, 2015), particularly for minoritized students in science, technology, engineering, and mathematics programs (STEM majors;

Baber, 2015; Bottia et al., 2015; Cromley et al., 2016; Donnor, 2013; Geisinger & Raman, 2013; Grossman & Porche, 2014; Ladson-Billings, 2009, 2012; Ladson-Billings & Tate, 1995; López & Burciaga, 2014; Strayhorn, 2012, 2015). Yet, even with this research and knowledge we still are faced with classrooms that perpetuate cultures that disenfranchise populations of students. Chapter two sought to understand how motivation, sense of belonging, and academic confidence of students differs between sophomores, juniors, and seniors.

Guided by the research question: To what extent does the relationship between student perceptions of the classroom environment and their sense of belonging, motivation, and academic confidence differ across academic years (Sophomore, Junior, Senior)? That question was broken into two sub-questions: (1) what is the relationship between sense of belonging, motivation, and academic confidence, and (2) what is the relationship between those constructs and perceptions of the classroom environment? The data were analyzed using a bivariate correlation analysis and multi-group structural equation model (SEM).

Results indicated statistically significant correlations between sense of belonging, motivation, and academic confidence with small to large effect sizes using Cohen (1988) as a guide. Those results informed the construction of the multi-group SEM. SEM results indicated similarities across academic years except for one aspect of motivation, which became significant only in the Senior year group. Small changes in path coefficients were observed between the academic years, however, sense of belonging remained the strongest path. That suggested that regardless of academic class, sense of belonging was influenced more by perceptions of the environment. In sum, the first paper provided evidence that students' motivation, sense of belonging, and academic engagement differs across academic years. What was lacking was a look at how these relationships change, within academic years, over time.

Chapter Three: Pursuing Pavements: Trends of Students in Civil Engineering

Building on the limitations of chapter two, chapter three examined how sense of belonging, motivation, academic confidence, and their relationship to perceptions of the classroom environment trended over a four-year period. Chapter three used data collected from a National Science Foundation funded research grant aimed at enhancing student's educational experiences through structural and/or cultural changes (NSF, 2019b.). The driving research question for chapter was: what is the trend of the relationships among sense of belonging, motivation, academic confidence, and perceptions of the environment? This question was broken down into two sub-questions. The first focused on characterizing trends for sophomores, juniors, and seniors over a four-year data collection period. The second examined to what extent do the trends differ as undergraduates progress through an engineering program undergoing cultural and curriculum changes. The changes implemented by the department focused on diversity, equity, and inclusion issues faced by students and aimed to create cultural transformations within the department. Analysis included comparing differences between academic years to corresponding curriculum and cultural changes implemented by the department.

A trend analysis using estimated factor scores calculated with the regression method in SPSS (Version 27) was conducted for each of the constructs of interest (DiStefano et al., 2009; Skrondal & Laake, 2001). Trend results were interpreted as either above the sample average if the estimate was above 0 or below the sample average if the estimate was below 0. Additionally, trend lines were characterized as linear or polynomial. Results indicated that changes overtime were not all linear as the presence of polynomial trends indicates unequal changes over time. Results for the second sub-question used the first year of the project (2018) as baseline data for each academic classification and provided a sense of how students perceived aspects of themselves and the department, on average. Changes happened, on average, at the beginning of each academic year so by comparing the trend from 2018 to 2019, for example gave an indication of how students were responding to those changes. Results supported prior research stating that the environment may not always influence students in the same way while also demonstrating the need for a multi-prong approach to curricular and cultural changes in a department.

Chapter Four: Unlocking Success: Motivation, Sense of Belonging, & Academic Confidence in Engineering Classrooms

Attempting to understand how the classroom environment can impact undergraduate students should start with students' own perceptions and attitudes of that environment. Those perceptions provide insights into how students make sense of those environments. The importance of those perceptions stem from the understanding that prior deficiencies or inequalities in their lives come with them to college (Spencer, 1999;

Spencer et al., 1997; Velez & Spencer, 2018) which can highlight the notion that not all students have had the same educational experiences. Moreover, these differences matter because they might provide some explanation into students' experiences (Belsky & Pluess, 2009; Bornstein, 2017, 2019; Freeman et al., 2007; Good et al., 2012; Lizzio et al., 2002; Walton & Cohen, 2011). Chapter three aimed to expand the understanding of the classroom environments impact on students by examining differences between engineering majors, academic classifications, and potential interactions between the two. Additionally, it included indicators of student's daily life experiences as phenomena impacting how students make meaning of those experiences.

Guided by the central question of the extent to which characteristics of the individual person are attributed to individuals and their daily life experiences versus academic majors and classifications. Analysis included a multilevel model and a nested multigroup structural equation model using a primary data source. Results highlighted the direct and indirect effects daily life experiences had on student characteristics through students' perceptions of the environment. Moreover, roughly 6% of the variance between the differences in force and resource characteristics was explained by the academic majors and academic classifications. These results indicate the lack of difference between groups explaining phenomena in students suggesting a need to further explore other areas for explanation.

CONCLUSION

The overall purpose of this dissertation study aimed to discover, create, and promote ways of understanding how structured learning environments impact undergraduate engineering student populations. Moreover, the dissertation was guided by an overarching research question: What cultural, ideological, and structural aspects of the engineering classroom impact sense of belonging, motivation, and academic confidence in undergraduate engineering students? Through theoretical and conceptual methods, this dissertations links three empirical studies examining sense of belonging, motivation, and academic confidence in undergraduate engineering students and how those constructs are impacted by the classroom environment.

The use of a RDST paradigm aids the readers understanding of how ecological systems work together in a PPCT model to better understand the classroom environment's impact on undergraduate students. Additionally, viewing the engineering classroom through an ideological, structural, and cultural lens can allow for making sense of the overlapping between students and the classrooms that benefits programs in addressing problems relating to students' motivation, sense of belonging, and academic confidence (Bondi, 2012; Donnor, 2013; Malcom & Feder, 2016, O'Hara, 2022; Owen, 2007). The final chapter provides an overall conclusion to the dissertation. Summarizing the results across chapters two through four, chapter five responds to the overarching research question, discusses implications for practice, and overall limitations of the research study. Next, we begin the journey with a look at how the constructs are related to one another in a specific context.

CHAPTER TWO

STUDENT PERCEPTIONS OF THE CLASSROOM ENVIRONMENT: THE UNSEEN IMPACT

A phrase often heard in education goes something like, "We are more alike than we are different." While this colloquial idiom may be true to an extent, there still are differences in students, and those differences matter a great deal when it comes to understanding how students perceive their educational environment (Canning et al., 2020; Gummadam et al., 2016; Lee et al., 2020). Student perceptions are formed through reciprocal relationships (Bandura, 1978) between a student's personal factors (e.g., upbringing), the environment, and their responses to the environment. However, this reciprocal relationship does not occur in a vacuum—it is informed by prior perceptions. The impact of which may not be the same, even for those who have had similar experiences (Belsky & Pluess, 2009; Bornstein, 2017; Freeman et al., 2007; Good et al., 2012; Lizzio et al., 2002; Walton & Cohen, 2011).

For students pursuing a potential STEM (Science, Technology, Engineering, Math) related degree, their prior experiences matter a great deal (Duckworth et al., 2007; London et al., 2021; Scheidt et al., 2020). STEM education relies on students having a particular set of experiences and those who do not often fall behind or drop out (London et al., 2021). For example, engineering majors might perceive they need specific coursework in math and science from high school and without it, they would not be successful in the engineering field (Main et al., 2022; Wang & Degol, 2017). Regardless of whether this is the case, as most students are required to take a set of general engineering courses their first year of post-secondary education, to students, their perception is their reality (Perez et al., 2014; Robinson et al., 2019). Those feelings of not being able to be successful in engineering might be perpetuated by how students perceive their classroom environment.

Purpose of Study

Disparities faced by students in higher education is a major drive behind researchers need to understand student perceptions of the environment in specific contexts (Byars-Winston et al., 2016; Cano et al., 2018; Han et al., 2017; Ladson-Billings & Tate, 1995; Mau, 2016; Park et al., 2018; Perez et al., 2014; Strayhorn, 2015). The disparities are particularly pronounced for racially minoritized students in STEM programs (Baber, 2015; Bottia et al., 2015; Cromley et al., 2016; Donnor, 2013; Geisinger & Raman, 2013; Grossman & Porche, 2014; Ladson-Billings, 2009, 2012; Ladson-Billings & Tate, 1995; López & Burciaga, 2014; Strayhorn, 2012, 2015). Yet even with this robust body of research, we still are faced with classrooms that perpetuate cultures that disenfranchise populations of students.

As a result of the continued disenfranchisement of students, this study aimed to better understand students' motivation, sense of belonging, and academic confidence in relation to perceptions of their classroom environment between academic classifications. Specifically, this study uses a quantitative secondary-data analysis to answer the following, overarching research question:

- To what extent does the relationship between student perceptions of classroom environment and their motivation, sense of belonging, and academic confidence differ between academic classifications?

Background Information

While research has demonstrated the various factors that might cause disparities in student experiences, scholars across the spectrum have researched and discussed systemic racism (e.g., Bonilla-Silva, 2014; Delgado & Stefancic, 2017; Lopez, 2006) and specifically systemic racism in education (Delgado Bernal, 2002; Donnor, 2013; Ladson-Billings, 2009, 2012; Ladson-Billings & Tate, 1995; Sheth, 2018) as contributing to a large portion of these disparities. For example, assuming the intelligence of a student based on skin color is a form of systemic racism presented as a cultural stereotype that students of color might experience in the classroom (Grossman & Porche, 2014; Sheth, 2019).

Other examples of systemic racism in the classroom environment include curriculum and assessments (Ladson-Billings, 2009) and classroom design and pedagogies (Huet, 2018; Kranzfelder et al., 2019) that do not take diverse backgrounds and experiences into consideration. These issues negatively impact, among others, students' motivation, sense of belonging, and academic confidence (Carpi et al., 2017; Cromley et al., 2016; Grossman & Porche, 2014; Nadelson et al., 2017; and Wilson et al., 2015).

LITERATURE AND CONCEPTUAL FRAMING

Before addressing what impact perceptions of the classroom environment might have on students' motivation, sense of belonging, and academic confidence, we need to situate the research question in a larger developmental paradigm. We need to understand how perceptions shape people in general and then understand how those perceptions might change over time depending on external forces, the individual, and/or a combination of both. Bioecological systems theory (Bronfenbrenner, 1977, 2001; Bronfenbrenner & Morris, 2006) offers a mechanism that allows researchers to situate both the individual and context at the center of the research question.

Bioecological Systems Theory

Bioecological systems theory details human development through various, nested, ecological levels. Humans interact and move through micro-, meso-, exo-, and macrosystems that explain human development over a lifespan (Bronfenbrenner, 1977). Originally developed to focus on the roles context and environment played in development, Bronfenbrenner (2001) reintroduced the theory centering on the individual and emphasizing the role developmental processes plays in development (Bronfenbrenner & Morris, 2006) resulting in the bioecological systems theory we have today. What emerged as the bedrock of the theory was the Process-Person-Context-Time Model (PPCT). The model is a way to simultaneously examine the impact of ecological systems to better understand development.

Process-Person-Context-Time (PPCT)

Process. This component of the model speaks to the developmental process by with individuals interact with environments. The process component is often referred to as proximal processes and are the mechanisms that produce human development.

Person. The person component refers to the individual and the various biological, cognitive, affective, and behavioral characteristics that make up their person. These characteristics are sometimes referred to as demand, force, and resource characteristics.

Context. Human development is situated within the bioecological systems theory and involves the types of environments individuals interact in—microsystems to macrosystems.

Time. Time involves the understanding of the multiple levels of temporality that make up the chronosystem impacting change over time.

Operationalizing ecological systems theory through the PPCT model allows for the understanding that individuals interacting with their environments through proximal processes are influenced by both proximal and distal forces within nested ecological systems. Moreover, this theory provides the understanding that people, objects, and symbols of these environments and ecological systems can and do change over time resulting in changes to how the individual perceives their environment.

Construct Literature

Recent research in STEM, particularly engineering, education has demonstrated the interconnectedness among motivation, sense of belonging, academic confidence, and the environment (Freeman et al., 2007, Hernandez et al., 2017; Morelock, 2017;

Robinson et al., 2019; Sarac, 2018; Strayhorn, 2012; Wilson et al., 2005). We have come to understand that when students have a strong sense of belonging and are motivated and engaged in an engineering culture, the more likely they are to form a strong identity as an engineer and enter the workforce (Benson et al., 2017; Godwin et al., 2016; Kirn et al., 2016; Lee et al., 2020; O'Hara et al., 2020; O'Hara et al., 2021; Verdin et al., 2018; Wilson et al., 2015). Main et al (2022) discussed how individual, social, and structural factors converge in ways that influence how students choose engineering majors. This research aligns with prior research demonstrating influences from factors such as race/ethnicity (e.g., Lord et al., 2019), identity (e.g., Godwin et al., 2016), and academic achievement (e.g., Tan et al., 2021). The contributions of the authors combined with previous engineering education research form a conceptual model that could aid interventions. While many of these studies highlight the relationship between motivation, sense of belonging, and academic confidence, they also point out the lack of research on the influence from environmental contexts. Moreover, much of the focus of previous research has been on early college (i.e., first-year students).

Motivation

Aligning with Bioecological Systems Theory, motivation in this study is understood through the lens of situated expectancy-value theory (SEVT; Eccles & Wigfield, 2020; Wigfield & Eccles, 2000, 2020). While a fully detailed review of SEVT is outside the scope of this paper (see Eccles & Wigfield, 2020 for review), a brief discussion is warranted. SEVT holds that expectancies for success and values influence academic-related choices. Expectancies for success are generally understood as the perceptions students have of being successful and encapsulates a broader perception of students' own competence and capacity to succeed in a task (Dietrich et al., 2019). Specific achievement-related tasks or tasks the student engages with are based on the value those tasks have in achieving an overall goal. Within SEVT, values consist of interest value, attainment value, and utility value. Interest or intrinsic value (Eccles & Wigfield, 2002) is the value derived from enjoying a task. Attainment value refers to the drive to be successful on a task because it is connected to one's identity (Eccles, 2005, 2009; Wigfield & Eccles, 2000). Utility value relates to the usefulness of the task at hand (Wigfield & Eccles, 2000).

These constructs are, in turn, influenced by individual characteristics, including but not limited to identity, understanding of ability, and general self-schemas (Conley, 2012; Eccles, 2005, 2009; Eccles & Wigfield, 2020; Eccles-Parson et al., 1983; Gaspard et al., 2018; Gaspard et al., 2020; Wigfield & Eccles, 1992, 2000, 2020). Motivation, then, is the collective understanding of the expectations students have for being successful, their ability to situate and organize expectations into goals, and the subjective value students place on various academic tasks.

Sense of Belonging

Explored in various ways throughout literature, sense of belonging is the perception or feeling of connection students have in relation to their environment and experiences (Ahn & Davis, 2019; Freeman et al., 2007; Strayhorn, 2012; Wilson et al., 2015). For example, as an interpersonal connection with one's school (Goodenow, 1993); as a perception of acceptance, fit, or inclusion (Bollen & Hoyle, 1990; Locks et al., 2008;

Museus & Maramba, 2010; O'Brien et al., 2001); and correlated with goal setting, achievement, and engagement (Freeman et al., 2007; Good et al., 2012; Walton & Cohen, 2011; Walton et al., 2012). In this study, sense of belonging is conceptualized as students perceiving a feeling or connection to areas of their educational experience.

Academic Confidence

Academic confidence draws from various theoretical frameworks such as expectancy-value theory (Wigfield & Eccles, 2000), self-efficacy theory (Bandura, 1977), and social comparison theory (e.g., Skaalvik & Skaalvik, 2002). In this study, academic confidence is understood as the perception that one feels confident in their academic ability to succeed in courses and within their field of work (Patrick & Borrego, 2016; Rodriguez et al., 2018; Sander & Sanders, 2006, 2009).

Environment

There are many elements that impact students in the classroom. For example, Canning et al. (2020) discussed perceived competition in STEM classroom and the stress it placed on first generation college students. Lizzio and colleagues (2002) found that perceptions of classroom environment impacted learning outcomes. Prior research posits that when it comes to the classroom environment influencing students, little is known about how aspects of the environment impact motivation, sense of belonging, and academic confidence (Freeman et al., 2007; Zumbrunn et al., 2014). In this study, the environment is operationalized as the general perceptions and feelings that students have regarding their engineering classrooms.

Conceptual Model

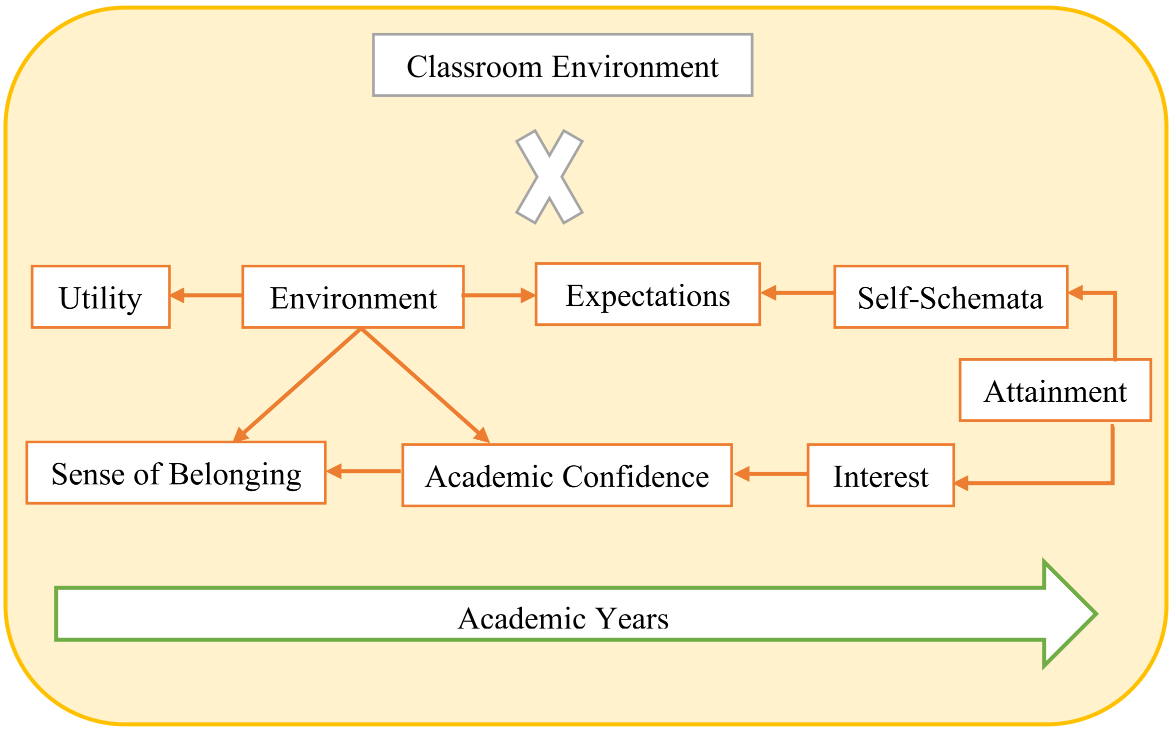
Grappling with the complex process of individuals interacting with their environments over time can be a daunting task. In the context of this study, as students engage in their classroom environments, that environment exerts influence on the student. In turn, those exerted influences interact with dynamic internal processes of the student and the response to environment reciprocates back into the environment. Over time, these reciprocating influences are hypothesized to dynamically change the strength and direction of a student's motivation, sense of belonging, and academic confidence situated in a classroom environment. As students move from sophomore to junior to senior status, the complex and dynamic process is repeated.

Figure 1 is a visual representation of the process described above. This static, two-dimensional conceptual model utilizes the process-person-context-time model (PPCT) of Bioecological Systems Theory as a lens to explain what is happening conceptually. Context is visualized by the large box encompassing the elements of the model labeled classroom environment. For this study, the context is an engineering classroom environment. Within the context, we first encounter the process, pictured as an "X" to indicate an interaction term. Below the interaction term is the relationships between motivation, sense of belonging, and academic confidence. This mini-path diagram represents the person component of the PPCT. Finally, the left to right arrow at the bottom of the figure represents the time component. In the context of this study, it is the progression across academic years (i.e., sophomore, junior, etc.). Taken together

Figure 1 demonstrates the process and person interacting in a specific context across academic classifications.

Figure 1

Conceptual Model Grounded in Theory



METHOD

Research Design

The central research question for this study was: To what extent does the relationship between student perceptions of the classroom environment and their motivation, sense of belonging, and academic confidence differ between academic classifications? That question was further broken into sub-questions:

1. What is the relationship between motivation, sense of belonging, and academic confidence?
2. To what extent does the relationship between those constructs and perceptions of the environment differ between Sophomores, Juniors, and Seniors?

Data for this study come from a National Science Foundation (NSF) funded project aimed at examining engineering students' experiences when an engineering department makes curricular and cultural changes. What follows is a description of the NSF project to set the context for the data analyzed in this study.

RED Project

With the changing landscape of engineering education, and, to an extent, STEM education overall, programs are challenged to create innovative ways to educate and train students for the workforce. One mechanism an engineering program can use to answer the challenge is through funding from NSF. Specifically, the Improving Undergraduate STEM Education (IUSE)/Professional Formation of Engineers (PFE): Revolutionizing Engineering Departments, or RED for short. While grants are aimed at enhancing engineering education and preparation for an engineering workforce, a central component to the work is a focus on cultural and organizational change (National Science Foundation [NSF], 2019).

Arch Initiative. Aimed at developing a culture of inclusion and innovation, the Arch Initiative consisted of three overarching goals: curricular, cultural, and community transformations. This study focused on the first two goals of curricular and cultural transformations. Curricular transformation took the form of redesigning the senior capstone course to flow more like a capstone-sequence that starts in the sophomore year. These courses were designed to develop skills in professionalism, communication, and teamwork. Additionally, the new course structure allowed for faculty to engage early on to help students make the connection between coursework and broader departmental learning outcomes (see Sarasua et al., 2020 for further review). Cultural changes were centered around a flexible department structure. Project leaders wanted to create an environment that fostered teamwork and inclusive teaching. As a result, faculty were organized around critical constraints and curricular demands instead of the traditional sub-discipline breakdown. Another area of cultural changes was the implantation of a peer-mentoring program that paired incoming Sophomores with current Juniors and Seniors. This program continues the types of supports first-year students in general engineering would receive. Specifically, the program focused on psychological and emotional support, goal setting and career paths, academic subject knowledge support, and existence of a role model (see Ogle et al., 2020 for further review).

Data Collection and Population

Data were collected each semester (i.e., Fall, Spring) from Fall 2017 to Spring 2021 while students were taking one of three required labs for the major. Responses were recorded using a Qualtrics® designed instrument. A graduate student associated with the project went to each lab during data collection with a script outlining the purpose of the survey and project. The instructor for the lab provided the link to the survey on the course management system. The sample consisted of 1,387 respondents. However, three cases were dropped due to no response on any of the instrument items. This resulted in a final sample size of 1,384. Initial questions on the instrument asked students to indicate the current semester and course (i.e., lab) they were currently taking. These items served as grouping variables by academic classification (see Table 1). Following their responses to the instrument constructs (discussed below), participants were asked a series of demographic questions. Table 2 provides sample demographic information based on participant responses using the racial and gender categories contained in the instrument.

Table 1

Sample Breakdown by Academic Classification

Academic Classification	*n*
Sophomore	589
Junior	479
Senior	316
Total Sample	1384

Table 2

Demographic Information of Sample

Demographic Information	Count	Percentage of Count [a]
Race	1460	
American Indian or Alaskan Native	15	1.03
Asian	54	3.70
Black or African American	79	5.41

Hispanic, Latino, or Spanish origin	39	2.67
Native Hawaiian or Pacific Islander	7	0.50
White, non-Hispanic	1121	76.80
Other	63	4.32
Missing	82	5.62
Gender	1424	
Female	321	22.54
Male	951	66.80
Agender	1	0.07
Genderqueer	4	0.28
Cisgender	31	2.18
Transgender	5	0.35
Other	26	1.83
Missing	85	6.00

Note. Counts do not add up to sample size because participants were allowed to check all that applied for Race and Gender items.

[a] Since demographic info is count data, this statistic was found by taking the quotient of count of the specific category and the overall count for that demographic

Data Preparation

The required labs where the data were collected occurred in the sophomore, junior, and senior year. Students took the lab once a year either in the Fall or Spring depending on their overall academic schedule, so students took the survey once a year.

Because the focus of this study is change across academic years, the Semester variable (indicating distribution of the survey) was collapsed into a new variable called Year. This transformation occurred using the Course variable as the reference. For example, “Fall 2017” and “Spring 2018” variables were collapsed to create “Year 1” variable with data separated for each of the three courses. Due to this transformation, the Course variable became synonymous with academic classification (e.g., Course = 1 = Sophomore). Shaping the data this way allowed it to be aggerated by academic classification across the four-year period of data collection.

As stated above, only three responses were removed due to no data on all items of interest. Partially completed items were kept and included in analysis due to the use of a maximum likelihood estimator. A Shapiro-Wilk’s test of normality was significant (p>.05) indicating non-normal distribution. However, because these tests are sensitive to large samples, a visual inspection of Q-Q plots indicated acceptable normality (Azen & Walker, 2011; Pituch & Stevens, 2016). Moreover, as an additional precaution, a robust maximum likelihood estimator was used in the final analysis.

Instrument

This study focused on the motivations and perceptions of students in a RED program. Because this study uses a secondary-data source, survey items were adapted and reconceptualized through a different theoretical lens. A total of 57 items were adapted and used representing motivation (28 items), sense of belonging (15 items), academic confidence (9 items), and perceptions of the environment (5 items) on a 7-point Likert Scale. The items pertaining to motivation were sub-divided into items relating to utility value, expectations for success, self-schemata, attainment value, and interest value to align with the use of situated expectancy-value theory as the frame for motivation (Eccles & Wigfield, 2020; Wigfield & Eccles, 2000, 2020).

Utility value items centered on the usefulness of the course in relation to their academic life. For example, one item asked students if the class was useful in proving to their peers that they were a good student. Expectations for success asked questions related to what students were expecting out of the course and if they were satisfied with what they wanted from the course. The self-schemata scale was completely reverse-coded and asked items relating to students' abilities and thoughts for setting goals, while the attainment value scale asked students how much they agreed with attaining those goals. Finally, the interest value scale asked students about their interests in science and engineering. Taken together, these scales give an indication of a student's motivation to be successful in engineering education and the broader engineering field. A list of the 57 items grouped by constructs can be found in the supplemental materials (Table 8).

Items in the sense of belonging scale centered around the connection students felt at the institution and within the engineering community. Academic confidence items asked students about their confidence in an engineering major and the engineering field overall. Finally, the perceptions of the environment scale asked students if they were accepted, comfortable, and supported in their engineering classroom. Since the items do not necessarily align with the constructs as defined in the MAE instrument, a Cronbach's Alpha estimate was used to measure internal consistency of the grouped items. Other indications (e.g., model fit statistics) of the appropriateness of the latent factor structure for the grouped items is discussed below in the results section. Table 3 lists each construct as well as their Cronbach's Alpha.

Table 3

Constructs and Cronbach's Alpha

Construct	# Of Items	Cronbach's α
Sense of Belonging	15	.94
Utility Value	4	.91
Expectancy Value	3	.91
Self-Schemata	6	.83
Attainment Value	6	.80
Interest	9	.90
Academic Confidence	9	.90
Environment	5	.89

Statistical Analysis

Statistical analysis for this study was carried out in three phases in aggregate form. Thus, the level of analysis occurred at the group level (i.e., sophomore, junior, and senior). Phase one consisted of measurement invariance tests needed for group comparisons. Phase two used a bivariate correlation analysis (Field, 2009) to answer sub-question one. Phase three implemented a multigroup structural equation model (SEM) to answer sub-question two.

RESULTS

This study was guided by an overarching research question: To what extent does the relationship between student perceptions of classroom environment and their motivation, sense of belonging, and academic confidence change within academic classifications over a four-year period? To help answer that question, it was broken down into two sub-questions.

1. What is the relationship between motivation, sense of belonging, and academic confidence?
2. To what extent does the relationship between those constructs and perceptions of the environment differ between Sophomores, Juniors, and Seniors?

Phase 1 – Measurement Invariance

Recall that the latent constructs in this study were adopted using a previously valid and reliable instrument. No additional items were added or dropped from the original MAE instrument; rather, some sub-constructs' items were combined or shifted. We felt comfortable with this approach due to the acceptable ranges ($\alpha > .70$) in Cronbach's Alpha for each of the constructs (see Table 3). However, we still wanted to determine how the latent constructs were invariant across academic classification.

Measurement invariance testing was done on the latent constructs using Mplus (version 8.1). To test measurement invariance, a series of nested models are compared across four levels. The first level is establishing configural invariance (i.e., same factor structure across groups). Next, factor loadings for each group are constrained to be the same to measure metric invariance. If metric invariance is achieved, then the intercepts for each group are constrained. This third level of invariance testing is called scalar invariance. If scalar invariance is achieved, then the final level of invariance testing is called strict invariance and refers to the errors being the same across groups. Partial scalar invariance is needed to compare groups. However, some researchers have suggested that scalar invariance is not needed (see Hancock et al., 2009).

A multi-group Confirmatory Factor Analysis Model (CFA) was analyzed. All parameters were freely estimated for each group. All parameters were freely estimated for each group. Adequate model fit would indicate configural invariance, meaning the factor structure (i.e., items loading onto latent constructs) was the same across groups. Model fit indices used were the Root Mean Square Error of Approximation (RMSEA) and the Standardized Root Mean Squared Residual (SRMR). For RMSEA, smaller values indicate a better model fit. Values below .08 indicate acceptable fit (Kline, 2011). Similarly, SRMR values less than .08 indicate acceptable model fit (Kline, 2011; MacCallum et al., 1996). For the freely estimated model, RMSEA = .074 (.073, .075) and the SRMR = .079, thus indicating acceptable model fit. Next factor loadings were constrained across groups and a likelihood ratio test (LRT) was conducted to determine if the constrained model fit the data just as well as the freely estimated model. The null hypothesis of the LRT is the constrained model fits as well as the free model and the alternate hypothesis is that the constrained model does not fit as well. Table 3 includes the relevant statistics needed for the LRT.

Because a maximum likelihood robust estimator (MLR) was used, traditional model comparison tests cannot be conducted. However, Satorra & Bentler (2010) created formulas to calculate an adjusted test statistic that is distributed on a chi-square distribution and is useful in comparing nested models. The Satorra-Bentler chi-square statistic can be estimated using the Log-Likelihood values when the MLR estimator is used in Mplus and is demonstrated in equations 1 and 2 below. First, the corrected scaling difference is calculated where p^0 is the number of parameters in the null model, p^1 is the number of parameters in the free model. Additionally, c^0 is the scaling correction for the null model and c^1 is the scaling correction for the free model.

$$cd = (p^0 \times c^0 - p^1 \times c^1) \div (p^0 - p^1)$$

(1)

Next, the Satorra-Bentler statistic is calculated where L^0 is the log-likelihood for the null model and L^1 is the log-likelihood for the free model.

$$TRd = -2 \times (L^0 - L^1) \div cd$$

(2)

From there, a *p*-value can be found by using the *TRd* as the chi-square statistic and the difference in model parameters as the degrees of freedom.

Table 4

Likelihood Ratio Test for Invariance Models

Model	LL[a]	*df*	Parameters	Scaling	AIC	BIC
Null	-108764.567	4647	483	1.7113	218495.130	221022.540
Free	-108590.851	4533	597	1.7031	218375.702	221499.644
TRd[b]	208.248***	114[c]		1.6684[d]		

Note. The null is the constrained model and the free is the freely estimated model.

[a] Log-Likelihood of the model.

[b] Satorra-Bentler Chi-Square difference test estimate.

[c] Difference in parameters.

[d] Corrected difference in scaling

*** $p < .001$.

The significant *p*-value here suggests we reject the null hypothesis and state that the freely estimated model fits better. This also indicates metric invariance was not met indicating that factors loadings are different across groups. At first glance, this seemed like we would need to reevaluate the constructs used. Although, it makes sense, theoretically, that factor loadings on the individual items would differ across academic years. As students move from one academic year to the next, we would naturally see changes in how they respond to items from each of the constructs. However, a full-scale psychometric analysis of the instrument is beyond the scope of this paper and what was more of value in the context of this study was that factor structures remained the same across groups.

Phase 2 - Bivariate Correlation Analysis

A bivariate correlation analysis was conducted to examine the strength and direction of the relationships between sense of belonging, motivation, and academic confidence for Sophomores, Juniors, and Seniors. Considering we failed to achieve metric invariance, we decided to use factor scores instead of taking mean of the items for each construct. Factor scores account for the variation in factor loadings on each of the items and the estimates are a more accurate reflection of latent construct values. Using the regression method (see DiStefano et al., 2009; Skrondal & Laake, 2001) factor scores were estimated for construct. Those estimates were then used in the correlation analysis. Tables 5-7 present descriptive information and bivariate correlations for each group.

Table 5

Correlations for Sophomores

Construct	*n*	*M*	*SD*	1	2	3	4	5	6	7
Belonging	584	5.66	.930	—						
Utility Value	576	4.01	1.49	.063	—					
Expectancy Value	576	5.96	1.13	.385**	-.041	—				
Attainment Value	575	5.04	1.01	.283**	.186**	.083*	—			
Interest Value	560	5.75	.942	.331**	.166**	.390**	.268**	—		
Academic Confidence	575	5.45	1.03	.581**	.014	.514**	.197**	.445**	—	
Self-Schemata	574	5.43	1.17	.205**	-.082**	.188**	.112**	.140**	.264**	—

Note. Means and Standard Deviations are calculated as a grand mean for each construct.
** $p < .01$.
* $p < .05$.

For Sophomores, there were three correlations that were not statistically significant. Utility Value and Belongingness, Utility Value and Expectancy Value, and Utility Value and Academic Confidence. Recall that Utility Value items centered on the usefulness of the course in their overall academic life and the lack of significance indicates this aspect of motivation does not uniquely explain any of the variance in belongingness, expectancies for success, and academic confidence. Interestingly, Utility Value and Self-Schemata share a negative correlation meaning when one construct increases the other decreases. However, this may be due to the reverse-coded nature of the items in the self-schemata construct; the more negative a student feels about setting goals, the less useful a course might be overall.

Table 6

Correlations for Juniors

Construct	*n*	*M*	*SD*	1	2	3	4	5	6	7
Belonging	463	5.80	.817	—						
Utility Value	467	4.10	1.62	.067	—					
Expectancy Value	469	5.90	1.03	.317**	.120**	—				
Attainment Value	472	5.12	.995	.178**	.067	.085	—			
Interest Value	457	5.81	.862	.357**	.131**	.317**	.146**	—		
Academic Confidence	472	5.56	.910	.499**	.114*	.419**	.165**	.418**	—	
Self-Schemata	472	5.81	.862	.169**	.033	.161**	.179**	.203**	.210**	—

Note. Means and Standard Deviations are calculated as a grand mean for each construct.
** $p < .01$.
* $p < .05$.

The relationship among the constructs for Juniors looks slightly different than that of the Sophomores. The non-significant correlations are between Utility Value and Belongingness, Utility Value and Attainment Value, and Utility Value and Self-Schemata. Additionally, there was no significant correlation ($p = .067$) observed between Expectancy Value and Attainment Value. However, this correlation for Sophomores was weakly significant (p = .047) and suggest that the linear relationship between the two variables is not very strong.

Table 7

Correlations for Seniors

Construct	*n*	*M*	*SD*	1	2	3	4	5	6	7
Belonging	315	5.83	.874	—						
Utility Value	312	4.06	1.55	.176**	—					
Expectancy Value	312	6.05	1.17	.465**	.319**	—				
Attainment Value	311	5.04	.994	.265**	.096	.217**	—			
Interest Value	301	5.90	.821	.314**	.051	.289**	.244**	—		
Academic Confidence	310	5.79	.950	.469**	.224**	.522**	.112*	.292**	—	
Self-Schemata	310	5.54	1.10	.115*	.064	.197**	.134*	.220**	.225**	—

Note. Means and Standard Deviations are calculated as a grand mean for each construct.
** $p < .01$.
* $p < .05$.

When it came to the construct relationships for Seniors, things began to look different. Utility Value and Self-Schemata maintained a non-significant correlation, but the correlation became significant for Belonging and Expectancy Value, respectively. Those changes, coupled with a lack of a significant correlation with Utility Value and Attainment Value, and Utility Value and Interest Value. These might suggest subtle shifts in students' development as it pertains to finishing coursework and transitioning into the engineering profession.

Overall, the correlations indicate significant positive relationships with other constructs, apart from the one negative correlation found in Sophomores. Moreover, it seems as if Utility Value shares a somewhat tenuous relationship with other types of values relating to students' motivation. Using Cohen (1988) as a general guide for effect sizes we were able to determine many of the correlations observed between the constructs was small. That is, most of the correlations were less an absolute value of .3 ($r = \pm .3$). However, moderate to large effect sizes (.3 to .5) were observed in correlations with Belongingness as well as Academic Confidence. Moreover, the largest effect sizes were seen between Belongingness and Academic Confidence suggesting that a student's connection to their school and engineering major has a strong positive relationship with their overall academic confidence. These results helped form the hypothesis for subsequent analysis.

Phase 3 – Multigroup Structural Equation Model

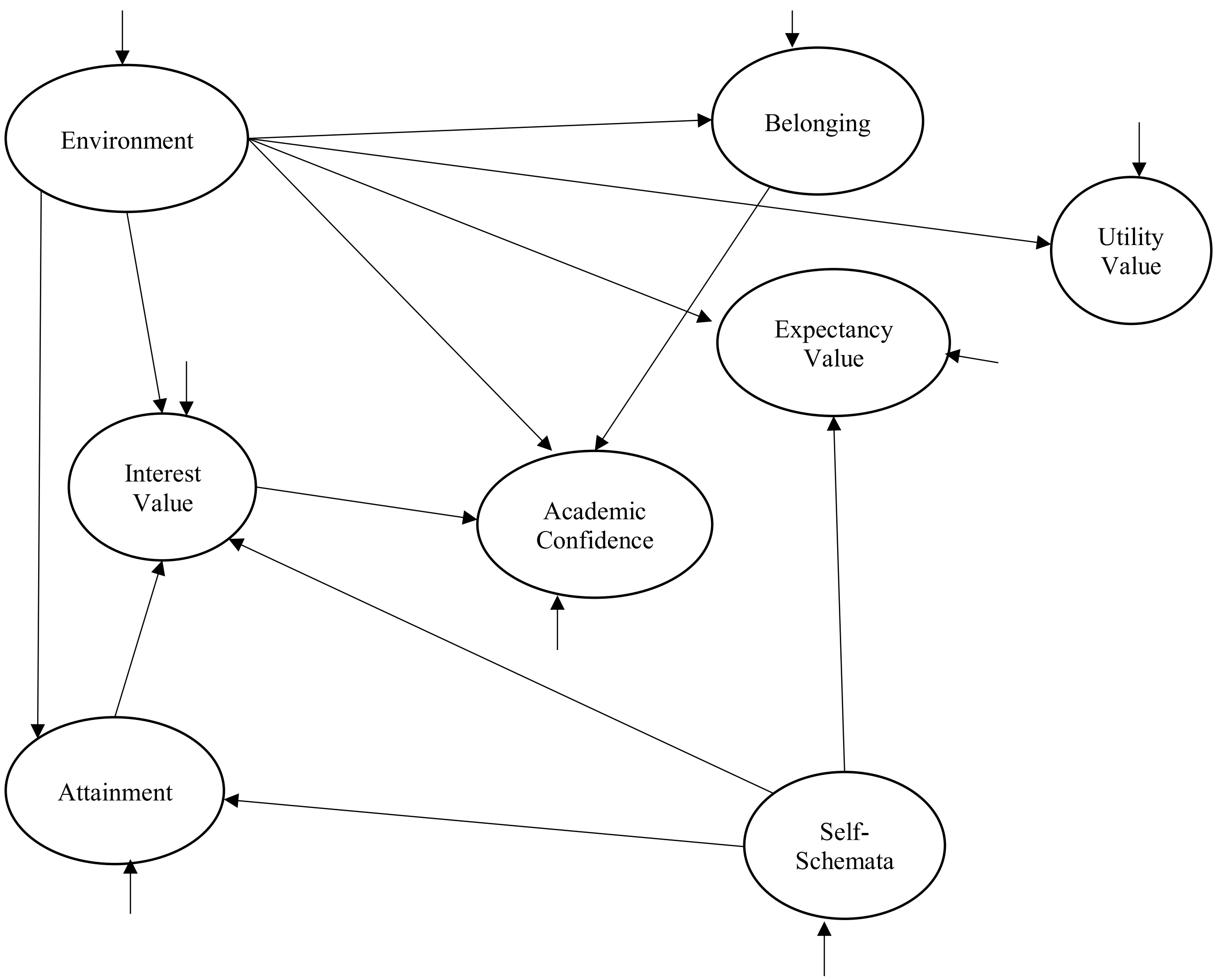
A multi-group structural equation model (SEM) was used to answer sub-question two and examine the extent to which the relationship between motivation, sense of belonging, academic confidence, and perceptions of the classroom environment differ between Sophomores, Juniors, and Seniors. The SEM was constructed using the conceptual model (Fig. 1) and results from the bivariate correlation analysis. We hypothesized that the strength of the relationships would change as students' progress from their first year to last year in their undergraduate studies.

Specifically, we looked at the direct effects perceptions of the environment had on Sense of Belonging, Academic Confidence, and the four aspects of motivational constructs. Figure 2 is the hypothesized model for each academic group without the measurement portion for clarity. Table 8 (see supplemental material) contains the standardized regression coefficients and standard errors for the measurement aspect of the SEM. This model was informed by the central portion of the conceptual model presented in Figure 1 above. The model hypothesized that environment would influence Sense of Belonging, Academic Confidence, Utility Value, Expectancy Value, and Interest Value. This is shown by the arrows coming from Environment to the other latent constructs. Additionally, we hypothesized that Attainment Value would influence Interest Value. Sense of Belonging and Interest Value were hypothesized to influence Academic Confidence. Finally, we hypothesized Self-Schemata would influence Interest Value, Attainment Value, and Expectancy Value.

We also examined potential indirect effects using the model indirect command in Mplus. We looked at the indirect effect of Attainment Value had on Academic Confidence through Interest Value through Self-Schemata. Additionally, we examined the effect Environment had on Academic Confidence through Sense of Belonging. Lastly, we looked at the indirect effect Self-Schemata had on Interest Value through Attainment Value.

Figure 2

Hypothesized Multigroup Structural Equation Model (SEM) Without Measurement Model



The multi-group SEM consisted of three groups: Sophomores (n = 589), Juniors (n = 479), and Seniors (n = 316). The total sample size for the data set was 1,384 respondents. Data were screened for violations of assumptions. Individual items failed the test for normality. This result was to be expected due to scaled survey responses as most responses were skewed in the positive direction (see below). Using the recommended cutoff of -10 to +10 for kurtosis of items in an SEM (Brown, 2006), we found no extreme values of kurtosis. Lastly, less than 10% of the overall sample was missing. Due to the large number of observed variables, a covariance matrix for all observed variables can be requested from the author.

The SEM was estimated using a maximum likelihood robust (MLR) estimator. In Mplus, MLR produces estimates and standard errors using a sandwich estimator that is robust to issues of non-normality and non-independence (Muthén & Muthén, 2017). Due to the large sample size, the test for global fit was significant, $\chi^2(4765, n = 1384) = 16785.279$, $p < .001$. Therefore, more localized fit statistics were used to measure model fit. Model fit for the multi-group SEM indicated acceptable model fit, RMSEA = 0.074 (0.073, 0.075) and SRMR = 0.096 (Kline, 2011). This implies that the model constructed is one of many adequate representations of the data. What follows is a review of the results separated by groups.

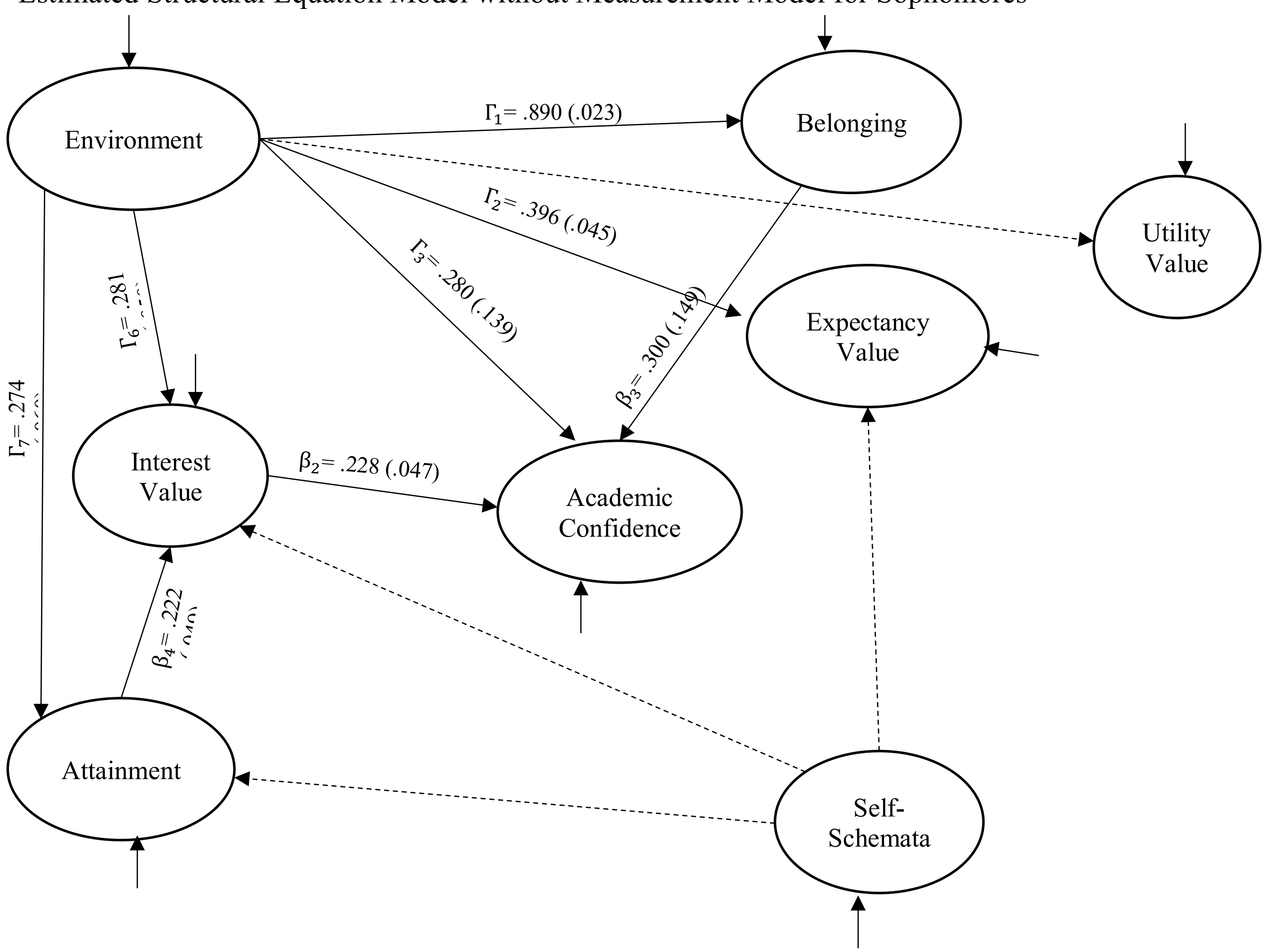
Sophomores

The first item for each latent construct were fixed at 1 and the corresponding latent construct's variance was freely estimated. This is the default parameterization in Mplus. Results are presented using standardized factor loadings and path coefficients.

Additionally, structural model results will be presented without the corresponding measurement model. Observed factor loadings for latent constructs and their associate p-values are representative in table form in the supplemental materials. Figure 3 displays the estimated SEM for the Sophomore group. Results indicated significant path coefficients for all paths except Utility Value on Environment path, $\Gamma = .044, p = .367$ and the paths involving Self-Schemata. Regarding indirect effects for Sophomores, model

Figure 3

Estimated Structural Equation Model without Measurement Model for Sophomores

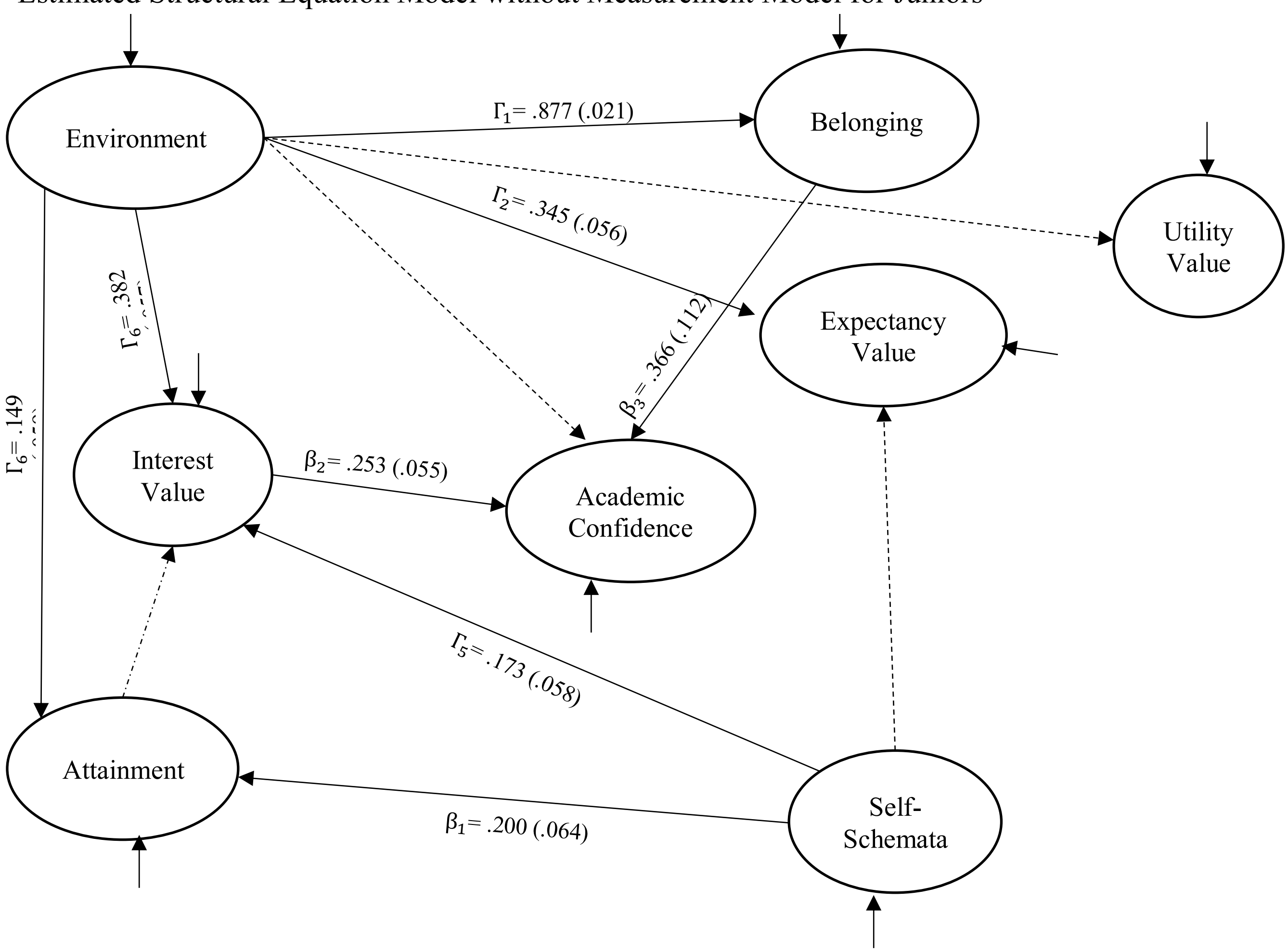


Note. Standard errors for coefficients presented in parentheses (). Dotted lines represent non-significant paths.

indirect results indicated a small significant indirect effect of Attainment Value to Academic Confidence, $\beta = .051$, $p = .001$. Additionally, the effect of Self-Schemata to Interest Value via Attainment Value was also significant, $\beta = .267$, $p = .041$. Because the direct path of Self-Schemata to Interest was not significant, the presence of an indirect path through Attainment Value suggests Attainment Value is a full mediator for this relationship for Sophomores.

Figure 4

Estimated Structural Equation Model without Measurement Model for Juniors



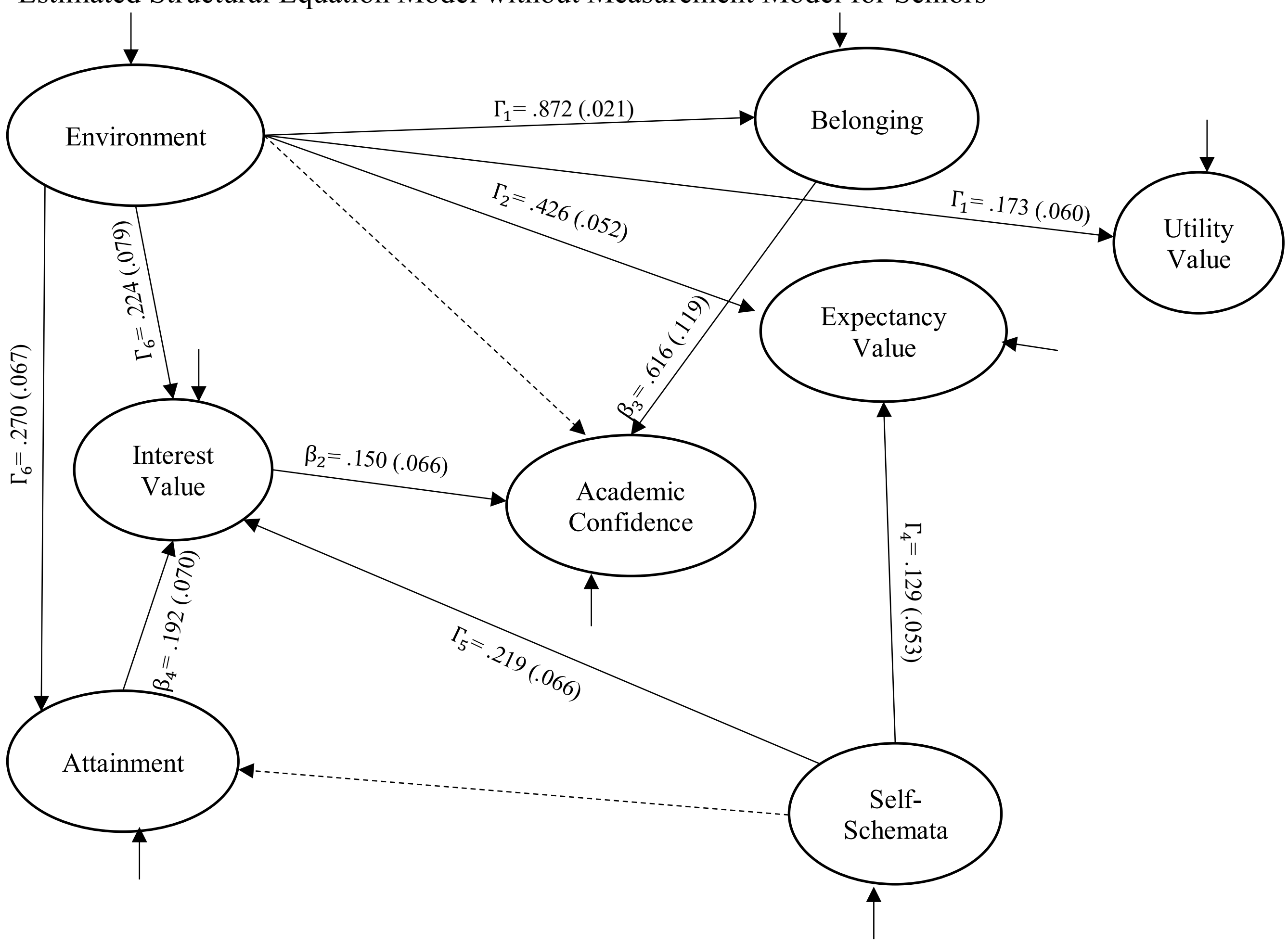
Note. Standard errors for coefficients presented in parentheses (). Dotted lines represent non-significant paths.

Juniors

Figure 4 presents overall results for Juniors. Like Sophomores, Juniors experienced a non-significant path between Environment and Utility Value and a lack of significant paths for Self-Schemata. However, the hypothesized path of Self-Schemata regressed on Attainment Value was significant for Juniors. This suggests that on average for Juniors their thoughts and abilities on overall goal setting influences their attainment

Figure 5

Estimated Structural Equation Model without Measurement Model for Seniors



Note. Standard errors for coefficients presented in parentheses (). Dotted lines represent non-significant paths.

of said goals. Interestingly for this group, the direct influence of perceptions of environment on Academic Confidence was not significant. However, there was a significant indirect influence of Environment to Academic Confidence through Sense of Belonging, β = .321, p = .001. This suggests that Sense of Belonging fully mediates the relationship between Environment and Academic Confidence.

Seniors

Results from the SEM for the senior group were like Juniors and full results can be found in Figure 5. However, there are some notable differences. Secondly, the path from Environment to Utility Value was significant for Seniors, $\Gamma = .173, p = .004$, suggesting a change of influence in the senior year. Secondly, the indirect effect of Environment on Academic Confidence through Sense of Belonging strengthened for Seniors, β = .537, $p < .001$. Finally, the significant path from Self-Schemata to Attainment Value found for Juniors was not significant for Seniors. This suggests something is occurring in the junior year that is influencing this relationship.

DISCUSSION

The purpose of this study was to examine the influence perceptions of the classroom environment had on motivation, sense of belonging, and academic confidence in undergraduate engineering students. Research stemmed from a central question: To what extent does the relationship between student perceptions of classroom environment and their motivation, sense of belonging, and academic confidence differ between academic classifications? To adequately answer this question, we conducted analyses in two main phases. First, we examined correlations of motivational, sense of belonging, and academic confidence constructs for Sophomores, Juniors, and Seniors. Then we used statistical modeling to examine the complex multivariate relationship of the constructs for Sophomores, Juniors, and Seniors.

Overall, the results paint an interesting picture of how motivation, sense of belonging, and academic confidence are influenced by student perceptions of the classroom environment. Through measurement invariance testing we were able to establish configural invariance indicating the factor structure was the same across groups. Metric invariance was not achieved, indicating that the factor loadings were different across academic classifications. Statistically speaking, this limited our ability to compare latent factor means using statistical difference testing to indicate whether factor means were statistically different between each academic classification. However, developmentally speaking, that makes theoretical sense that students would have different factor loadings as Sophomores, Juniors, or Seniors. We would expect the latent factor to influence their responses on items differently as they progress academically. Therefore, we examined model parameter estimates to understand where those differences might occur.

The correlational analysis indicated mostly significant correlations, but those had a small effect. However, consistent with the literature (Freeman et al., 2007; Hurtado et al., 2007; Walton & Cohen, 2011; Walton et al., 2012; Wilson et al., 2015; Zumbrunn et al., 2014), correlations between sense of belonging and academic confidence indicated a large effect size. The positive correlation indicated that as one construct increases the other increases as well. Similarly, the medium to large effect size and positive correlations between academic confidence and expectancy, and academic confidence and interest, suggests that these two aspects of motivation are the stronger aspects when it comes to students and their academic confidence (Conley, 2012; Dietrich et al., 2019; Gaspard et al., 2018; Musu-Gillette et al., 2015). One interesting result was a non-significant correlation between utility and self-schemata. Situated Expectancy-Value Theory (SVET) has consistently indicated a connection between self-schemata and subjective task-values, of which utility is on aspect (Eccles, 2005; Eccles-Parsons et al., 1983; Eccles & Wigfield, 2002; Wigfield & Eccles, 2000, 2020). However, there is some competing views on the factorial structure of subjective task-values which could help explain the lack of correlation between the constructs (Part et al., 2020; Song & Chung, 2020). Additionally, Eccles & Wigfield (2020) discuss the subtle differences between subjective task-values and suggest the distinction lies in the centrality of the goals to the individual. In the context of this study, this statement makes sense because the self-schemata construct focuses on long-term goal setting and utility value focuses on immediate goals and values.

Combining our conceptual model with results from the correlational analysis, we were able to justify our hypothesized paths when constructing the SEM. The results of our models indicated, similarly across academic classifications, significant path models except for the utility construct. Perceptions of the environment's significant paths with sense of belonging, academic confidence, and expectancy mirrors relevant literature (Ahn & Davis, 2019; Freeman et al., 2007; Good et al., 2012; Strayhorn, 2012; Walton & Cohen, 2011; Walton et al., 2012; Wilson et al., 2015; Zumbrunn et al., 2014). We observed changes across academic classifications for these relationships. However, perceptions of the environment's influence on sense of belonging remained the largest. This suggests that regardless of the academic class, sense of belonging is influenced more by perceptions of the environment considering the other two constructs. Results found across our models provide some evidence against research that states motivation relationship with academic achievement increases as students age but might be weaker for college students (Finney & Schraw, 2003; Hendy et al., 2014; Wigfield et al., 2009). The result is much more complicated. For example, Self-Schemata shared significant correlations with other constructs yet there were no significant direct or indirect paths found in our hypothesized model. Moreover, we observed some mediated effects that could account for prior research stating the relationship becoming weaker. However, a more robust mediation analysis is warranted to substantiate this claim.

The lack of significant paths from environment to utility value for Sophomores and Juniors, but significant for Seniors provides evidence on the weight students give to aspects of subjective value over time, something Eccles and Wigfield (2020) state as a need. For Sophomores, the associated p-value for this path was above .367; however, it had fallen to .261 for Juniors before becoming statistically significant for Seniors (p = .004). This suggests that as students move from Sophomore to Senior, the perception of their environment starts to influence the utility value of their coursework. Again, more research is needed to better understand the phenomenon. Nevertheless, our results point us in that direction.

Individuals throughout their lives are reciprocally interacting with their environments. Meaning, while proximal and distal ecological forces are acting on individuals, the individual is, in turn, exerting forces on that most proximal environment. These influences are most impactful during formative year and shape how individuals come to understand the world around them. Proximal processes extend throughout individuals' lives across time and context (see Kegan, 1994). One cannot deny that college is a formative experience and over an educational experience, students experience growth and development (see Baxter Magolda, 1992, 2001 for review). The PPCT model provides a way to understand these processes. Through the lens of the PPCT model, we assume development varies as a function of the person, the environment, the processes under review, and changes in the environment over time (see Fig. 1).

In the context of this study, the answer to our central research question is that the relationship between perception of the environment, motivation, sense of belonging, and academic confidence differ a great deal across academic classifications, at least in terms of the individual constructs themselves. What does not change much over time is the significant relationship between those constructs and perception of the environment. Certainly, the strength of those relationships might fluctuate from Sophomore to Senior year. The constant is perceptions of the environment.

Implications for Practice & Future Work

The results of this study highlight the nuanced nature of students interacting with their classroom environments, and, more importantly, the results provide direction for practice. For example, the changes in the relationship between sense of belonging and perceptions of the environment from Sophomore to Senior year demonstrate for departments that a one-size-fits-all approach to students' sense of belonging would not be beneficial. From a programmatic standpoint, the results help departments focus their approach to effectively impacting their students through the environments they create. For example, a classroom environment that helps students reflect on past successes while providing opportunities for success positively impacts the students' perception of that environment. This positive impact, in turn, positively impacts sense of belonging and academic confidence. Positive increases in those areas leads to higher persistence and matriculation into the engineering field. The level and scale of the intervention in the classroom environment would depend on the targeted academic classification. However, the outcomes would reciprocally ripple throughout engineering programs.

The focus of this study was the relationships among perceptions of the environment, motivation, sense of belonging, and academic confidence at the academic classification level. This was intentional because of the special relationship between developmental contexts and time. Future work would benefit from focusing on how these relationships might trend over periods of time in response to the changing environment. Moreover, future work should focus on the indirect effects of environment on other variables. Finally, future research should investigate the path between environment and utility value. The emergence of a significant path for the senior group only posits questions about the structural and ideological aspects of engineering classrooms for Seniors. Could the increased competitive nature of the classroom play a significant role in the relationship? An examination of specific aspects of the environment could answer that question.

Limitations

One central limitation of this research was the use of data as a secondary source. This limits the types of items analyzed and situates the current work in the context of the previous work. Moreover, the lack of matched data pairs limited the types of statistical modeling we could use. The lack of full or partial measurement invariance limited the ability of statistically testing differences in model parameters that would have provided a stronger conclusion. This study focused on a single engineering department, therefore limited to that specific major. Other generalizability might not hold across all engineering domains. Finally, the single snapshot of each academic classification does not provide results on what might be the impetus for some of the differences observed. Without an in-depth look at changes within academic classifications over time, we have no way of ascertaining that information.

Conclusion

Humans are, in part, shaped by the experiences they have and the perceptions they hold, and research demonstrates these concepts to be similarly applied to college students. This study extends that research by examining a conceptual model (see Fig. 1) in the context of a specific academic department and through the lens of ecological systems theory. We found that students' perceptions of the classroom environment had a significant relationship with sense of belonging, motivation, and academic confidence. Moreover, we found that for Juniors and Seniors, the impact of perceptions of the environment was completely mediated by their sense of belonging. These results illustrate the complex nature of engineering students as they academically progress. Finally, this work provides avenues for future work to build on. For example, examining what cultural, ideological, and structural aspects of the classroom shape student perceptions.

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APPENDICES

Appendix A

Regression Coefficients and Standard Errors of Model

Table 8

Regression Coefficients and Standard Errors of Model

Construct/Item	Sophomore		Junior		Senior	
	λ [a] Estimate	*S.E.*	λ Estimate	*S.E.*	λ Estimate	*S.E.*
Belonging						
Item 1	.596	.027	.567	.034	.543	.032
Item 2	.401	.031	.363	.036	.354	.037
Item 3	.602	.031	.581	.032	.655	.035
Item 4	.632	.027	.569	.033	.644	.033
Item 5	.634	.027	.572	.032	.623	.033
Item 6	.702	.025	.654	.031	.690	.027
Item 7	.454	.036	.431	.038	.468	.044
Item 8	.738	.025	.728	.025	.778	.026
Item 9	.794	.026	.838	.021	.904	.013
Item 10	.860	.016	.831	.025	.846	.027
Item 11	.882	.014	.862	.023	.909	.013
Item 12	.814	.020	.837	.018	.814	.035
Item 13	.835	.016	.796	.020	.823	.020
Item 14	.793	.029	.738	.024	.775	.026
Item 15	.847	.017	.801	.021	.805	.026
Utility Value						

Item 1	.863	.018	.896	.014	.840	.022
Item 2	.656	.025	.736	.026	.620	.027
Item 3	.950	.011	.973	.008	.972	.012
Item 4	.936	.011	.923	.015	.957	.010
Expectancy						
Item 1	.866	.017	.852	.025	.914	.016
Item 2	.950	.012	.873	.029	.953	.014
Item 3	.838	.021	.791	.027	.845	.031
Self-Schemata						
Item 1	.682	.033	.603	.036	.661	.034
Item 2	.635	.028	.568	.029	.590	.040
Item 3	.716	.028	.636	.031	.715	.034
Item 4	.621	.037	.542	.039	.554	.042
Item 5	.768	.024	.749	.025	.734	.039
Item 6	.796	.022	.762	.025	.820	.022
Attainment						
Item 1	.486	.034	.473	.036	.490	.039
Item 2	.593	.035	.621	.034	.571	.039
Item 3	.551	.036	.586	.035	.544	.041
Item 4	.604	.032	.665	.031	.608	.039
Item 5	.678	.032	.731	.037	.707	.039
Item 6	.784	.028	.821	.029	.806	.032
Interest						

Item 1	.821	.026	.780	.029	.803	.027
Item 2	.871	.017	.863	.019	.851	.028
Item 3	.899	.017	.879	.017	.864	.027
Item 4	.682	.028	.629	.029	.656	.037
Item 5	.764	.024	.741	.027	.706	.037
Item 6	.573	.039	.584	.041	.602	.045
Item 7	.602	.041	.587	.046	.636	.042
Item 8	.571	.039	.580	.045	.631	.044
Item 9	.507	.043	.527	.048	.517	.047
Acad. Conf. [b]						
Item 1	.337	.048	.462	.047	.526	.034
Item 2	.646	.037	.667	.034	.642	.044
Item 3	.685	.038	.671	.044	.577	.061
Item 4	.718	.038	.774	.034	.627	.056
Item 5	.721	.033	.715	.040	.635	.057
Item 6	.723	.038	.676	.038	.767	.037
Item 7	.522	.036	.519	.036	.554	.039
Item 8	.715	.041	.694	.040	.743	.038
Item 9	.506	.042	.482	.039	.501	.044
Environment						
Item 1	.937	.010	.922	.013	.927	.016
Item 2	.910	.012	.890	.014	.899	.019
Item 3	.920	.010	.881	.020	.874	.024

Item 4	.896	.013	.905	.015	.894	.020
Item 5	.465	.035	.428	.028	.452	.042

Note. All estimates are significant at the .0001 level ($p < .0001$).

[a] Lambda Coefficient: standardized regression coefficient for SEM.

[b] Abv for Academic Confidence.

CHAPTER THREE

PURSUING PAVEMENTS: TRENDS OF STUDENTS IN CIVIL ENGINEERING

The United States has prioritized increasing the number of graduates trained in STEM disciplines to remain competitive globally (National Academy of Sciences, 2011; National Science Board, 2022; National Science Foundation [NSF], 2019; The White House, 2009). Simply searching 'engineering education research' on any search engine confirms the uptick in scholarly research in response to this priority. One aim in engineering education research is to better understand constructs such as sense of belonging, motivation, and academic confidence in undergraduate students (Hernandez et al., 2017; Morelock, 2017; Robinson et al., 2019; Sarac, 2018; Strayhorn, 2012; Wilson et al., 2005). While results from research examines initiatives that seek to increase access for all students, one thought remains. Engineering education might be more accessible, but is it equitable for students (Bottia et al., 2015; Dewsbury, 2017a; Eastman et al., 2019; Evenhouse et al., 2018)? For students who choose potential careers in STEM fields, and particularly engineering fields, individual perceptions and prior experiences play a key role in the ultimate success of these students (Duckworth et al., 2007; Freeman et al., 2007; Good et al., 2012; Lizzio et al., 2002; London et al., 2021; Scheidt et al., 2020; Walton & Cohen, 2011). Understanding the impact sense of belonging, motivation, and academic confidence have on the student experience is explored in engineering education literature. However, when examining the influences these constructs exert on the student experience, research often fails to consider the role of the environment (Bandura, 1977, 1978; Bronfenbrenner, 1977, 1992, 2001). Strayhorn (2015), for example, takes into consideration environmental influences in his research on sense of belonging by looking at the university environment overall. Much of the research considering environmental influences typically focus on a student's home environment or overall school environment. This level of broad focus can often mask the role of other environments, particularly the classroom environment, of undergraduates advancing through a degree program. What seems to be lacking from current engineering education research is an explicit focus on the reciprocal and dynamic relationships among students and their classroom environments. Understanding how classroom environments impact students' motivation, sense of belonging, and academic confidence could aid engineering programs in decision-making practices that result in more equitable environments for students to thrive.

Results from this type of research support initiatives implemented by engineering education, especially when those initiatives seek to increase access and equity for all students. For example, research funded through the National Science Foundation's (NSF) Revolutionizing Engineering Departments (RED) program provides opportunities for engineering departments to enhance the education they provide through structural and/or cultural changes (NSF, n.d.). It should come as no surprise that research supports the notion that diverse backgrounds and experiences brought to the classroom enhance positive academic outcomes for all students (Barrington, 2004; Gay, 2018; Marchesani & Adams, 1992). These results are often situated at the microlevel however, when attempting to eliminate barriers to student success results need to ripple across ecological levels and involve institutions, policy makers, and industry (Long & Mejia, 2016).

Purpose of Study

The aim of this study is to examine how sense of belonging, motivation, academic confidence, and students' perceptions of the classroom environment trend over time. Specifically, this project examines an engineering department's attempt to develop a culture of inclusion and innovation through curricular, cultural, and community transformations.

Research Questions

Using data supported by NSF's Improving Undergraduate STEM Education (IUSE)/Professional Formation of Engineers (PFE): Revolutionizing Engineering Departments (RED) grant, this paper analyzes sense of belonging, motivation, academic confidence, and classroom environment trends between Sophomores, Juniors, and Seniors across a four-year period. Particularly, this paper seeks to answer the following research question: What are the trends among sense of belonging, motivation, academic confidence, and perceptions of the environment for Sophomores, Juniors, and Seniors in an academic department implementing curricular, cultural, and community transformations? We answer central question through two sub-questions:

1. How are the trends characterized by academic year?
2. How might differences in trends across academic classifications might be explained by changes in the department?

Next, we examine relevant literature, theoretical frameworks, and prior research that informs the research questions.

RELEVANT LITERATURE

This study draws from the theoretical lens of relational developmental systems (RDS) theories as well as acculturation science. Specifically, inference is drawn from bioecological systems theory (Bronfenbrenner, 1977, 1992, 2001; Bronfenbrenner & Morris, 2006) and the specificity principle (Bornstein, 2010, 2017; Lerner & Bornstein, 2021). Both theoretical lenses aid in shaping the understanding of sense of belonging, motivation, academic confidence, and students' perceptions of the environment trends over time. Moreover, both theories help to demonstrate the dynamic and reciprocal relationship among the constructs.

Bioecological Systems Theory and The Specificity Principle

Perspectives on human development indicate "that *all* the levels of organization involved in human life are linked integratively in the constitution of the course of individual ontogeny" (Lerner, 2005, p. xiv). The person interacting with contexts helps inform the proximal processes that their drive development. Individual's response to stimuli is partially based on prior experiences and perceptions (Bandura, 1978). Those reactions to decisions shape future reactions to environmental stimuli, then reciprocally that behavior simultaneously shapes the environment and future responses to individual's actions. Two RDS frameworks offer a unique lens in which we can make sense of findings—Bioecological Systems Theory and The Specificity Principle.

Bioecological systems theory explains human development through various, nested, ecological levels (Bronfenbrenner, 2001; Bronfenbrenner & Morris, 2006). Similarly, the Specificity Principle posits that specific characteristics in specific individuals are affected by specific experiences in specific ways at specific times

(Bornstein, 2017). Moreover, both theories model ways in which aspects of the theory interact with one another. For example, bioecological systems theory has a process-person-context-time (PPCT) model that serves as a conceptual model to simultaneously examine the impact of the developmental systems to better understand development. What is gleaned from this conceptual model is an understanding of how developmental differences are a result of the biproduct of the developing person, situated in a context where the processes are occurring, with changes happening over time connected to the lived experiences of individuals.

The specificity principle, while like bioecological systems theory, introduces the concept of acculturation. Acculturation is important in the context of this study because as students go through an engineering program, they are also acculturated into the engineering profession (Godwin & Lee, 2017; Godwin et al., 2016; Hadgraft & Kolmos, 2020)). For purposes of this study, culture is defined using Bornstein's (2017) definition which defines culture as "shared meanings, understandings, or referents, and it permeates a wide array of biological, psychological, and social processes" (p. 4). Within the principle, acculturation occurs through specific processes. For example, students in engineering programs are socialized and instructed in specific ways to meet specific standards (Godwin & Lee, 2017; Huet, 2018). Using both theories together can potentially aid practitioners in decision-making that is better aligned with attributes of students in their programs. The specificity principle allows us to examine the nuances of acculturation that allows a focus to be placed on key factors of influence (Bornstein, 2017). Moreover, bioecological systems theory aids in our understanding of the dynamic nature of individual and context relations (Bronfenbrenner, 2001; Bronfenbrenner & Morris, 2006; Lerner & Bornstein, 2021).

As students navigate changes in their classroom environments, research designs should consider the experiences students are having in these changing environments. Traditionally engineering classroom offer a focus on individual achievement, competition, task orientation, and limited opportunities for involvement with peers and professors (Seron et al., 2018). Furthermore, because the context in which a student is experiencing their environments is central to understanding differences in sense of belonging, motivation, and academic confidence, it is reasonable, then, to assume that changes in the context of the environment would result in changes in students' sense of belonging, motivation, and academic confidence, at least on average. That is, as classroom environments context evolve, we could expect to see some trends over time.

Prior Research

A central component in the evolution of human development is context. To make sense of activated processes, researchers often situate those processes in a specific context. For example, understanding how students learn is often situated in the context of the classroom. Additionally, people are influenced by what is happening within the context itself (Bandura, 1977, 1978; Bronfenbrenner, 2001). Turning back to the example, the classroom context, or classroom environment can enrich or restrain growth and development of students. Positive classroom environments can enhance student motivation and confidence, for instance, while negative environments can do the opposite (Copeland & Levesque-Bristol, 2011; Cromley et al., 2016; Wilson et al., 2015). Yet, research has suggested the impact might not be the same for all students (Belsky & Pluess, 2009; Freeman et al., 2007; Good et al., 2012; Lizzio et al., 2002; Walton & Cohen, 2011).

While researching the benefits of a positive classroom environment is needed for a robust educational research portfolio, it is crucial for educational researchers to also understand what about the negative environments adversely impact students. Therefore, this study turns to understanding how the classroom environment is constructed. One potential area in post-secondary education where there is a need to better understand the environments impact on a student is in science, technology, engineering, and mathematics programs (STEM majors). STEM majors encompass a wide variety of classroom environments with variations in how environmental factors impact students across STEM fields (Baber, 2015; Cromley et al., 2016; Wilson et al., 2015; see also Bottia et al., 2015; Mau, 2016; O'Hara, 2022).

Because context is central to understanding student growth and development, attempting to examine all areas of STEM at once constrains researchers' ability to explore the nuances of classroom environments. Partitioning STEM into functional areas allows researchers to better examine the impact of the environment. The engineering classroom environment is a useful place to start because even though there are several types of engineering majors and research has suggested there is a singular collective identity as an engineer (Godwin & Lee, 2017; Hernandez et al., 2017; Kirn et al., 2016; Murphy et al., 2015; Nadelson & Fannigan, 2014; Patrick & Borrego, 2016; Perez et al., 2014; Rodriguez et al., 2018).

Engineering Classroom Environment

Engineering culture is the invisible driver of everyday actions, reactions, and interactions in undergraduate engineering education (Secules et al., 2018). Perhaps the difficulty in defining engineering culture lies in the idea that it is engrained in the lives of engineers therefore they cannot see it, and more importantly cannot truly be objective about it. The troubling feature of engineering culture is not the invisibleness in and of itself. Albeit certain aspects of the culture are toxic for both the field and those being acculturated into the field. Consequently, if engineering culture stays "subjective" to its members then it can never fully examine itself "objectively" (Kegan, 1994). That is, when things are so engrained into who we are we cannot separate ourselves from them to fully examine the influence it has on us. Individual students have limited agency to go outside the constructed process that is designed to create engineers (Secules et al., 2018). So, moving away from the individual student to the larger system, we can start to breakdown the mechanisms that inhibit the success of students and eventual engineers. Engineering curriculum is often organized by specific courses or units within a sub-specialization. To meet the demand of complexity they need to be designed in a systemic way (Hadgraft & Kolmos, 2020).

Prior research in engineering education has demonstrated the interconnectedness between the classroom environment and constructs such as sense of belonging, motivation, and academic confidence in undergraduate students (Freeman et al., 2007, Hernandez et al., 2017; Morelock, 2017; Robinson et al., 2019; Sarac, 2018; Strayhorn, 2012; Wilson et al., 2005). However, larger systemic issues within engineering classrooms can potentially have an adverse effect on students, particularly those from underrepresented backgrounds (Byars-Winston et al., 2016; Cano et al., 2018; Freeman et al., 2007, Hernandez et al., 2017; Morelock, 2017; Park et al., 2018; Perez et al., 2014; Robinson et al., 2019; Sarac, 2018; Strayhorn, 2012; Wilson et al., 2005). For example, a professor assuming the intelligence of a student based on skin color is a form of systemic racism presented as a cultural stereotype that students of color might experience in the classroom (Grossman & Porche, 2014; Sheth, 2019). Racist stereotypes like this could lead professors to interact with students of color differently than white students, causing a negative impact on those students' motivation, sense of belonging, or academic confidence. Other examples of the classroom environment associated with systemic racism include the curriculum and assessments used (Ladson-Billings, 2009) and the classroom design and pedagogies (Huet, 2018; Kranzfelder et al., 2019). These issues impact students' motivation, engagement, sense of belonging, academic confidence, and self-efficacy (for a review, see Carpi et al., 2017; Cromley et al, 2016; Grossman & Porche, 2014; Nadelson et al., 2017; and Wilson et al., 2015).

Sense of Belonging

A very basic level of human need is the need to feel belongingness to something (Maslow, 1954). In the realm of educational research, sense of belonging is often contextualized by a person and their environment. This could be framed as interpersonal connections (Goodenow, 1993), perceptions of acceptance or fit (Locks et al., 2008; Museus & Maramba, 2010), and even correlating with goals, achievement, and engagement (Freeman et al., 2007; Walton et al., 2012). In the context of this study, sense of belonging is understood as a feeling or perception of a sense of connection to specific areas of a student's educational experience (Ahn & Davis, 2019; Strayhorn, 2012; Wilson et al., 2015). Canning and colleagues (2020) looked at competition in STEM classrooms and its impact on academic outcomes for first generation students. The study emphasized the negative impact classroom competition had on, among other psychological constructs, sense of belonging. Results indicated that competition in the classroom had negative impacts on all students but were more pronounced for first-generation students. The authors stated that while all students at one point or another experience some sense of not belonging, the culture of competition and individualism versus a communal approach underpinned the results found.

Additional research using an inclusive curriculum lens found that sense of belonging mediated relations between perceived climate and engineering identity (Raisa et al., 2021). That study supports prior findings of classroom environments having the largest impact on sense of belonging in the engineering community (O'Hara et al., 2020). In terms of the structure of the course itself, Eddy & Hogan (2014) found that changes in the course structure made students feel like they belonged and led to increases in engagement and academic performance. This study examined student attitudes and course-related behavior using a traditional taught course and one with increased structure. Both courses included the same content and were taught by the same instructor. Students stated that the increased structure of the course made the culture of the classroom more open to risk taking and better engagement. These results overall highlight how the culture of the classroom can impact a student's sense of belonging. However, this impact doesn't occur in a vacuum; therefore, we turn to research on motivation.

Motivation

Motivational research has spanned student populations from kindergarten to college and beyond (Abeysekera & Dawson, 2015; Ames, 1992; Belland, et al., 2013; Imms & Byers, 2014; Mellat & Lavasani, 2011; Pintrich, 2004; Tinberg & Weisberger, 1998; Young, 2005). Additionally, further research has discussed the impact environments have on motivation (Brooks, 2011; Chiu & Cheng, 2017; Linden, 2018), as well as ways to improve motivation through pedagogical methods (Cano et al., 2018; Chyr et al., 2017; Evenhouse et al., 2018; Gordon & Ball, 2017). In the context of this study, motivation is viewed through situated expectancy-value theory (SEVT) where the importance of the situation or context is placed at the forefront (Eccles & Wigfield, 2020).

Using a mixed-methods design, Zumbrunn et al. (2014), looked at support, sense of belonging, motivation, and engagement within the context of the college classroom. The researchers wanted to show support for the influential role the classroom contexts have on student outcomes and how sense of belonging interacted with motivation. What the authors found was that when instructors showed support to students this contributed to feelings of belonging. Those increased feelings of belonging led to positive effects on motivation and achievement overall driving home the importance of the context in which researchers are examining motivation. Similarly, Ford and colleagues (2020) in a study examining student engagement, self-efficacy, and motivation in an intermediate mechanical engineering course found that different aspects of motivation correlated with overall course motivation.

Interestingly, those results suggested that as students make progress through a program, they may leverage motivation in differing ways depending on their career goals or aspirations (Ford et al., 2020). Connecting motivational constructs and engineering students' academic performance, Anwar et al. (2020) used achievement goals, self-efficacy, and task value individually to predict exam scores in first-year engineering courses while accounting for prior success. Results indicated that while prior results accounted for the most variance overall when accounting for students' motivational goals and self-efficacy predicted exam grades. However, the results were limited to first-year engineering students in a single class.

Academic Confidence

Engineering classroom culture can often create unrealistic expectations for engineering students and could potentially serve as one of the main reasons students leave engineering (Eastman et al., 2019). This coupled with competitive messages and individualistic goals could contribute to isolation and alienation in engineering classroom environments (Canning et al., 2020; Long & Mejia, 2016) and a general decrease in the academic confidence of students. Academic confidence is rooted in beliefs students hold about their ability to succeed, given the demands of their major (Sander & Sanders, 2006, 2009). Theoretically, it draws from expectancy-value theory (Wigfield & Eccles, 2000), self-efficacy theory (Bandura, 1977), and social comparison theory (Skaalvik & Skaalvik, 2002) to help researchers understand the complexity in which students view themselves academically. Within this study, we understand academic confidence as the perception students have in their abilities to succeed in academic coursework and with their field of study (Patrick & Borrego, 2016; Rodriguez et al., 2018).

Engineering Culture

One problem with acculturating students into the engineering profession is the process can place certain groups at a disadvantage (Bottia et al., 2015; Cromley et al., 2016). This disadvantage might stem from engineering classrooms perpetuating cultures that disenfranchise populations of students (Baber, 2015; Grossman & Porche, 2014; Ladson-Billings, 2009, 2012; Ladson-Billings & Tate, 1995). Moreover, engineering education research has helped researchers come to understand that when students have a strong sense of belonging and are motivated, they are more likely to enter the engineering profession (Benson et al., 2017; Godwin et al., 2016; Kirn et al., 2016; Lee et al., 2020; O'Hara et al., 2020; O'Hara et al., 2021; Verdin et al., 2018; Wilson et al, 2015). However, there are specific behaviors, attitudes, and norms that are deeply embedded in engineering education culture (Eastman et al., 2019). Often described as a zero-sum environment, the engineering classroom is where students receive messages about competition, steep grade curving, and individualistic goal setting (Canning et al., 2020). For example, conventional pedagogies typically focus solely on content delivered from the professor in a high-stakes competitive manner that is often devoid of social thought and evolutions in societal structure (Dewsbury, 2017a). Research has demonstrated the pivotal role faculty play in setting the context for learning in classroom environments (O'Leary et al., 2020; O'Hara et al., 2020). Research over the past decade has increased its focus on engineering culture, specifically in the classroom and how it impacts students pursuing careers in engineering.

METHOD

Using Bronfenbrenner's (2001) bioecological systems theory and Bornstein's (2017) specificity principle this project realizes that socialization and meaning making over time are crucial aspects to understanding how students build confidence. Working in tandem, both theories aid in making sense of the complicated and complex processes that occur in humans. Furthermore, they situate our understanding of how the constructs operate in practice. This framing coupled with an understanding of the cultural environment of the engineering classroom informs the design of this project.

Research Design

The question guiding this study was: What are the trends among sense of belonging, motivation, academic confidence, and student perceptions of the classroom environment for Sophomores, Juniors, and Seniors over a four-year period? That question gave way to two sub-questions: (a) how are the trends characterized by academic year and (b) how might differences in trends across academic classifications be explained by changes in the department?

Within engineering education, programs are challenged to develop newer ways to educate and acculturate students to enter an engineering workforce. One funding opportunity to address this challenge comes from the *Improving Undergraduate STEM Education (IUSE)/Professional Formation of Engineers (PFE): Revolutionizing Engineering Departments* (RED) program (National Science Foundation [NSF], 2019).

Data for the current study came from an NSF RED funded project. That project aimed at creating a culture of inclusion within an engineering department. This culture was created through innovated curricular, cultural and community transformations. The current study focused on the cultural and curricular transformations which are presented in the results section of the current study.

Data Collection and Population

The NSF RED funded project took place at a Research 1 institution in the southeastern United States. Data were collected, each semester, from Fall 2017 to Spring 2021 using a Qualtrics® designed instrument and administrated during required labs in the Sophomore, Junior, and Senior Year in a single engineering department. Total undergraduate enrollment at the institution in the 2017-2018 academic year was 19,172 students and rose to 20,796 students in the 2020-2021 academic year. The institution is classified as a predominately white institution (PWI) with about 81% of students identifying as white and is roughly evenly split between male and females.

The engineering department was in the College of Engineering, Computing, and Applied Sciences. During the study timeframe enrollment in the college went from 5,610 in 2017-2018 academic year to 5,617 in the 2020-2021 academic year. Gender breakdown for the college is predominately male (~77%) and predominately white (~79%). The total sample size for the current study was 1,383, and sample demographics are similar to that of the College of Engineering, Computing, and Applied Sciences. Table 1 includes a breakdown by year of project and academic classification.

Table 1

Sample Breakdown by Academic Classification

Academic Classification	2017-2018 *n*	2018-2019 *n*	2019-2020 *n*	2020-2021 *n*	Total *n*
Sophomore	123	234	141	90	588
Junior	120	193	108	58	479
Senior	66	100	41	109	316
Total Sample	309	527	290	257	1383

Data Preparation

Because the focus of the current study looks at trends across a four-year period, the variable indicating when the survey was administrated (Fall vs Spring semester) was collapsed into a new variable called "year." For example, 'Fall 2017' and 'Spring 2018' variables were collapsed to create '2018 cohort.' Additionally, surveys were taken in a required course during a student's sophomore, junior, or senior year and was taken in either the fall semester or spring semester depending on a student's course sequence. Therefore, a student would only take the survey in the fall or spring of the academic year and collapsing the variable indicating when the survey was administrated would not create duplicate entries. Moreover, this allowed the course variable to become synonymous with academic classification. Shaping the data this way allowed it to be aggerated by academic classification across the four-year period.

Instrument

The instrument used in the original study was a previously validated instrument (Benson et al., 2013; Kirn & Benson, 2018) that had been tested on multiple engineering populations (Kirn, et al., 2016; O'Hara et al, 2020; O'Hara et al., 2021). A sub-set of items were adapted and used in the current study. Fifty-seven items were used representing motivation, sense of belonging, academic confidence, and student perceptions of the classroom environment. Items were rated on a 7-point Likert Scale. Due to the items being adapted from the original instrument, a Cronbach's Alpha estimate was used to measure internal consistency of the grouped items (Table 2). A previous study using the same adaptations explored latent factor structures for the grouped items and found adequate fit statistics indicating the current items groups represented an acceptable model (O'Hara et al., 2023).

The sense of belonging scale, 15 items, focused on the sense of connection students felt at their institution and within the engineering community. The academic confidence scale, nine items, asked to rate their level of confidence to complete their work within their engineering major. Student's perceptions of the classroom environment, five items, asked students if they perceived to be supported, accepted, and comfortable in their engineering classrooms. The motivation scale, 28 items, were broken into five areas: interest value, attainment value, utility value, expectations for success, and self-schemata (goal setting) aligning with expectancy-value theory (Wigfield & Eccles, 2000, 2020). A full list of items grouped by constructs can be found in the supplemental materials (Table 3).

Table 2

Constructs and Cronbach's Alpha

Construct	# Of Items	Cronbach's α
Sense of Belonging	15	.94
Utility Value	4	.91
Expectancy Value	3	.91
Self-Schemata	6	.83
Attainment Value	6	.80
Interest	9	.90
Academic Confidence	9	.90
Environment	5	.89

Statistical Analysis

Results from a previous study (see O'Hara et al., 2023) informed our understanding of the relationship between sense of belonging, motivation, and academic confidence for sophomores, juniors, and seniors, on average. Statistical analysis for this study focused on how those groups might have changed over a four-year period. A trend analysis using estimated factor scores calculated with the regression method (DiStefano et al., 2009; Skrondal & Laake, 2001) using SPSS (Version 27) for each group across the four-year period. In SPSS factor scores estimated using the regression method have a mean set at 0 and the variance is equal to the squared multiple correlation between estimated factor scores and true factor values. In terms of interpreting the trend figures in the results, estimates above 0 (positive) are interpreted as above the sample average.

Alternatively, estimates below 0 (negative) are interpreted as being below the sample average. Table 4 in the supplemental materials includes group size, mean, and standard deviations for all constructs across time.

Trend analysis for each of the constructs were done using Microsoft® Excel (Version 16.69.1). Factor scores were imported into excel and used to construct line plots. Each line plot had “Year” as the y-axis and construct “Factor Score” as the x-axis. Additionally, each of the three lines represented sophomores, juniors, or seniors. Following the creation of each line plot, a trendline was added to the plot. Trendlines in excel represent the general pattern of the data and the relationship between the dependent and independent variables using mathematical equations calculated from the data. Fit of the trendline was measured by the R^2 estimated for each trendline for each academic classification. The results yielded two types of trendlines: linear and polynomial. Liner trends are characterized as the data having a constant rate of change. That is, the increases or decreases are the same, or very similar, over the data. Polynomial trends represent how the data fluctuates and are characterized by their order. In these types of trends, the order is determined by the number of “peaks” and “valleys” of the data line. Two types of polynomial trends were observed, second- and third-order polynomial trends. Second-order polynomial trends have one peak or valley, while third-order polynomial trends have one or two peaks and valleys.

RESULTS

This study aimed to better understand sense of belonging, motivation, academic confidence, and student perceptions of the classroom environment trends over a four-year period. To help achieve this aim, we explored two sub-questions:

1. How are the trends characterized by academic year?
2. How might differences in trends across academic classifications be explained by changes in the department?

The hypothesis driving this analysis was that we expected positive changes in responses to items over time. That is, we expected to see positive, linear trends in the constructs. The hypothesis was drawn from literature and changes implemented by the department. These results are situated in the context of engineering education culture, specifically the classroom culture, and what one department implanted to transform its culture. Therefore, the results begin with a review of curriculum and cultural changes that have occurred in the department over the four-year period.

Cultural & Curriculum Changes in Department

In the summer of 2017, the Glenn Department of Civil Engineering was awarded an NSF Revolutionizing Engineering Department (RED) grant to create a culture of inclusion and redesign the curriculum of the department. Over the next four years, the department implemented a new sequence of design course experiences dubbed the ARCH Initiatives. These initiatives served as the starting point for redesigning the curriculum of the department. Coinciding with the ARCH Initiatives, the department created and implemented a peer mentoring program, restructured faculty and staff alignment in the department, and increased diversity, equity, and inclusion (DEI) initiatives throughout all levels of the department. By using funding report documents, department recruiting materials, and discussions with members of the research team, we were able to identify key cultural and curricula changes that can offer insight into the trends observed from student responses.

ARCH Initiatives

Inspired by its namesake, the ARCH Initiatives is designed to reimagine interactions between students, faculty, and industry partners. In Fall of 2019, sophomore students began taking Springer I and Springer II courses. These courses laid the foundation for the formation as a civil engineer while also stressing the importance of teamwork, ethics, design processes, and professional communication. The Springer courses bridged the gap between engineering curriculum and real-world application (Sarasua et al., 2020). Building upon concepts learned in the Springer courses, juniors are engaged in three-hour design studio block courses. In these studio courses, students pair their design projects with stakeholder involvement to focus more on teamwork and valued collaboration. These courses push students beyond the technical skills and grapple with complex socio-cultural issues that can impact the work of civil engineers. During their senior year, students participate in the senior capstone course called the "Keystone Design Experience." Like the keystone of an arch, this course ties all the courses work and experiences together. Utilizing a project-based format, teams of students are assigned a subdiscipline within civil engineering and are tasked with designing a theoretical project. Teams must then present their designs to a panel of industry experts, using technical and oral communication skills learned throughout their coursework. Overall, the ARCH Initiatives design focuses on enhancing five specific skills for all civil engineering graduates, (a) Technical skills, (b) Professional communication skills, (c) Resolving conflict, (d) Project and time management, and (e) Self-awareness.

Cultural Transformations - Diversity, Equity, and Inclusion

While the ARCH Initiatives focused on curriculum changes within the department, there have been other transformations for the department. One early cultural change involved shifting faculty from being organized by subdisciplines to working together on "soft-wired" teams. Organizing faculty this way allowed them to be arranged around specific problems that were facing the department. For example, faculty may be organized in a specific way to handle the additional curriculum demands of the department. This flexible structure has introduced adaptability into the department and helped some faculty become leaders. Additionally, a group of faculty, educational theorists, and industry partners formed a "Groundbreakers" group to monitor national trends, identify new competencies for civil engineering graduates, and spearhead faculty development initiatives. Both changes have helped to increase faculty interaction within the department and resulted in the department adopting a set of departmental core values during the 2018-2019 academic year.

On the student side of cultural transformation, the department has focused on diversity, equity, and inclusion issues. The department identified the transition from general engineering to a specific major as an area where students from historically underrepresented populations often fall through the cracks. To help with retaining those students in engineering majors, the department developed the CE-MENT program (Ogle et al., 2020). CE-MENT is a peer mentor program where upper-class students participate in outreach and development of interpersonal relationships with students who might be interested in becoming civil engineering majors. Students were expected to participate in professional development workshops and on average serve as a mentor to three new civil engineering majors. However, as the program grew—from seven mentors in year one to ~25 currently—the department realized the need for a more sustainable way of providing these types of experiences to its students. This resulted in the creation of the CEMENT course which offers both professional development and academic success skills to all students. Finally, to develop a stronger culture of inclusive excellence within the department, the department implemented a hard-hat ceremony. The hard-hat ceremony serves as the students' official introduction into the department and civil engineering profession. Students are given their own university branded hard-hat with their last name printed across the back, and it symbolizes that they belong to the department and profession.

Trend Analysis

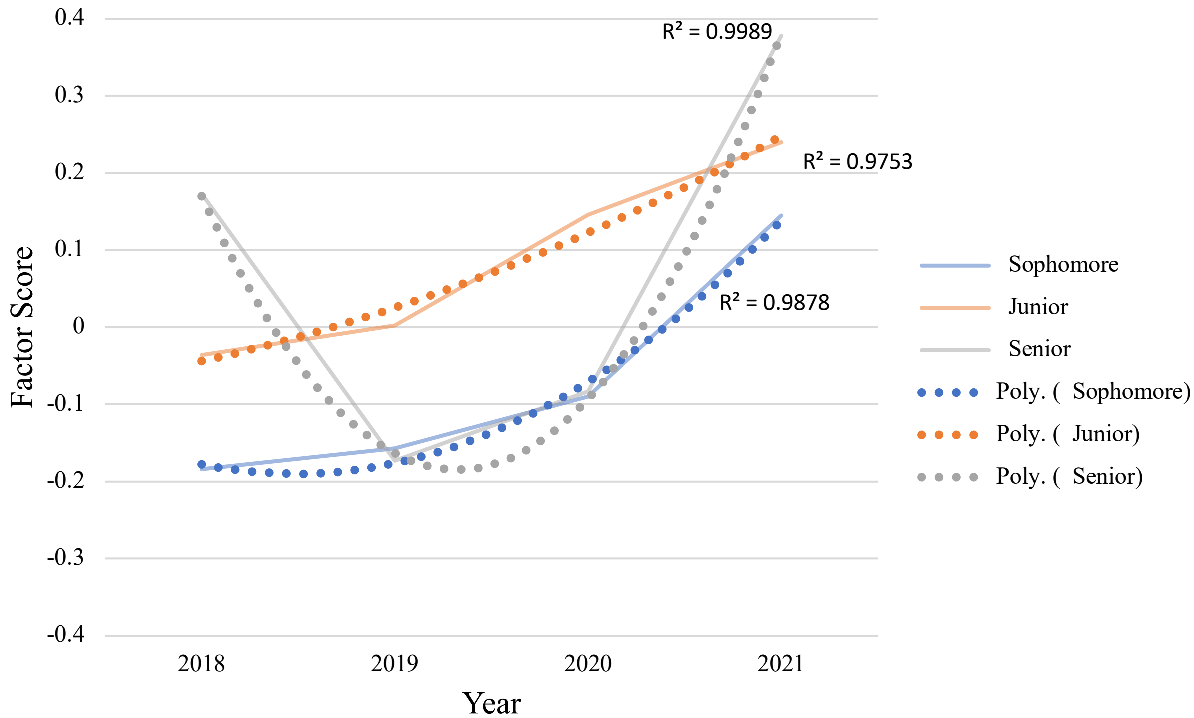
Recall from above that a trend analysis is a visual representation of the general pattern of the data based on the relationships between the dependent and independent variables. For this paper, a trend analysis was constructed for each of the constructs of interest using a factor score estimate. Factor scores can invoke multiple meanings and can be calculated using several different techniques. For this paper, factor scores estimates were produced using an ordinary linear regression and standardized. That is, for each construct the mean was set to 0 and the variance was equal to the squared multiple correlation between the estimated factor score and the true factor value. The following trend lines are interpreted as above the sample average if the estimate is above 0 and below the sample average if the estimate is below 0 (DiStefano et al., 2009; Skrondal & Laake, 2001). Additionally, trend lines are characterized as linear or polynomial. Academic classifications (e.g., sophomores) are referred to as cohorts in an effort to keep the comparisons across the classifications and not between the classifications.

Sense of Belonging Trend

Trend analysis results indicated, on average, seniors during the first year of the project (2017-2018) indicated sense of belonging levels above the sample average. While sophomores and juniors, in the same academic year, indicated levels below the sample average. By year 2021, all three cohorts had sense of belonging scores above average. However, all those paths were non-linear for the groups. Figure 1 below shows the trend curve for each group as a dotted line. Sophomore, junior, and senior cohorts experienced second order polynomial trends. That is each group experienced a drop in levels then a rise suggesting that the rate of change over time is not constant.

Figure 1

Trend Analysis for Sense of Belonging Latent Construct



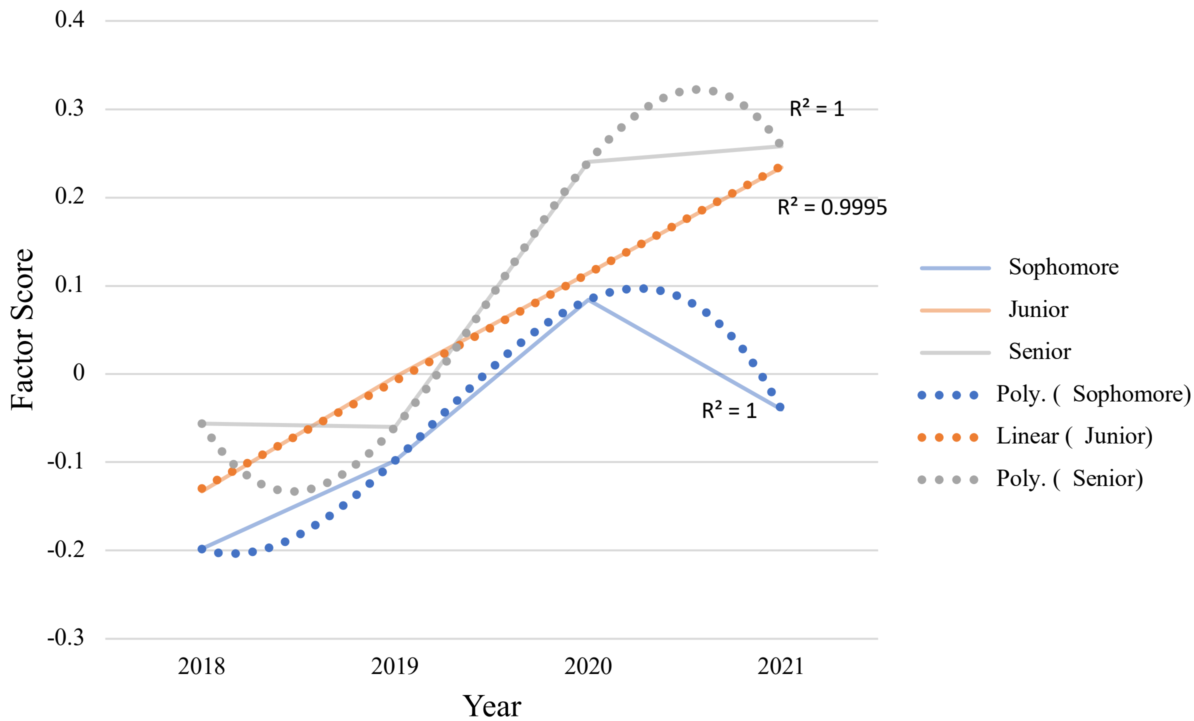
Note. R^2 beside each trend line indicates overall fit of the trend line

Academic Confidence Trend

Results from analysis of student perceptions of academic confidence trend over time indicated that all three cohorts responded, on average, with below average levels of academic confidence. By year 2021 of the project, junior and senior cohorts indicated above average levels of academic confidence. Conversely, the 2020 sophomore cohort saw a spike in academic confidence levels during that year, but the 2021 cohort of sophomores were back to below average levels. As shown in Figure 2, the senior cohorts experienced a slight plateau between year 2018 and 2019 but saw a rise in year 2020 that looks to be starting to level off by year 2021. Results for this trend analysis might not be so surprising given that sophomores, on average, might feel less confident in their abilities while seniors, on average, might feel more confident in their abilities. Junior cohorts had a linear trend, suggesting a constant rate of change over the four-period for each cohort. Sophomores and seniors both experienced polynomial trends.

Figure 2

Trend Analysis for Academic Confidence Latent Construct



Note. R^2 beside each trend line indicates overall fit of the trend line

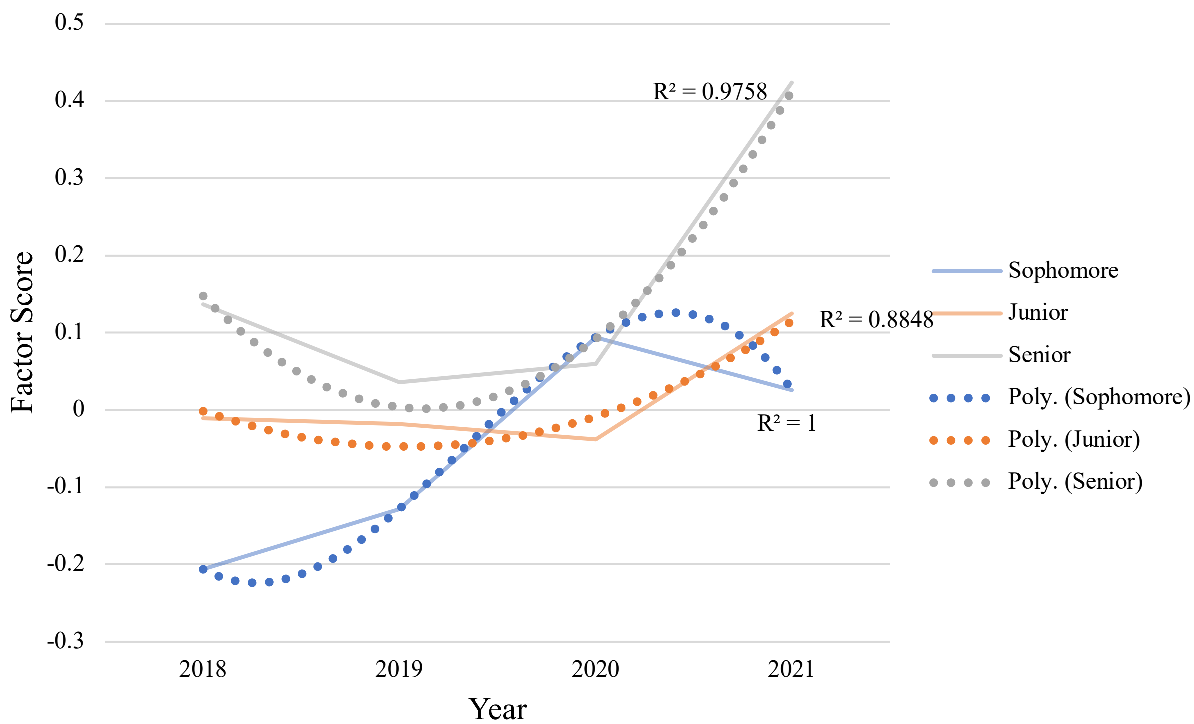
Perceptions of Environment Trend

Figure 3 presents the results for the trend analysis regarding students' perceptions of their environment. Interestingly, senior cohorts, on average, reported perceptions of their environment above average across all four years (2018-2021). However, the rate of change was not constant as there was a drop in year 2019 seniors, a slight rise for year

2020 seniors and finally a large spike for year 2021 seniors. Junior cohorts followed similarly, but their levels started below average, held steady, dipped for year 2020 juniors, and rose to above average for year 2021 juniors. Sophomore cohorts started with the lowest levels of perceptions of environment (year 2018), experienced a rise over 2019 and 2020 sophomore cohorts reaching the above average point by 2021. However, a slight decrease was observed for the year 2021 sophomore cohort.

Figure 3

Trend Analysis for Perceptions of Environment Latent Construct



Note. R^2 beside each trend line indicates overall fit of the trend line

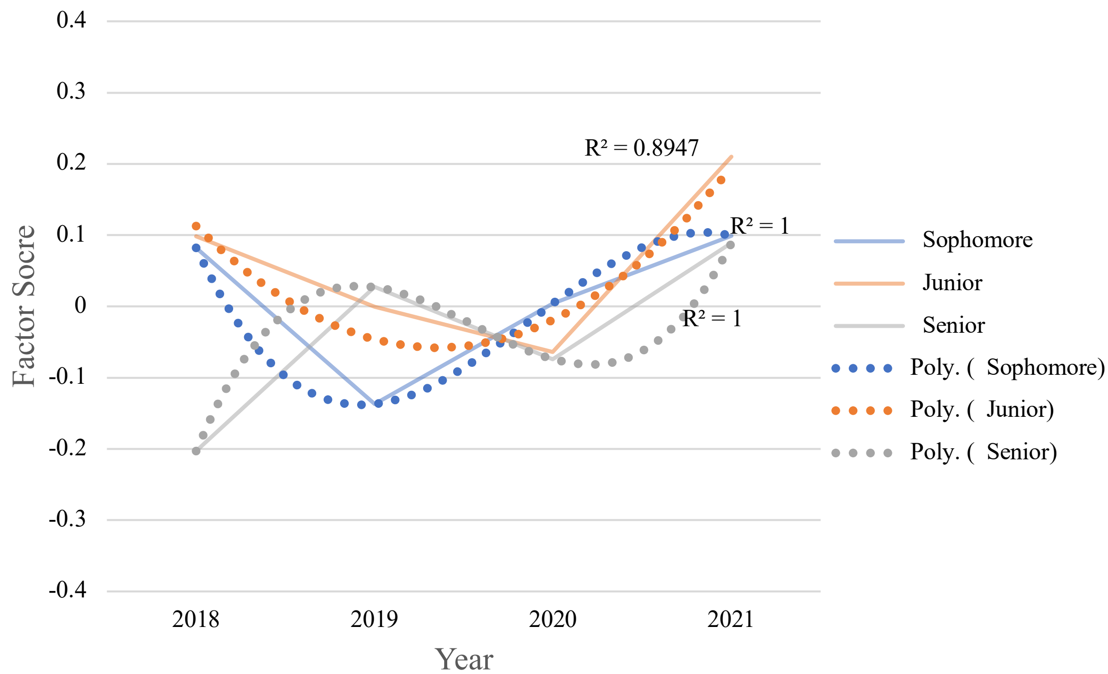
Motivation Trends

In this section, we present the results for motivation trends broken down by each of the five aspects of motivation.

Utility Value Trend. How students, on average, rated the usefulness of their course in relation to their academic program is shown in Figure 4 below. Like the results for perceptions of the classroom environment, utility value experienced polynomial trends for sophomore, junior, and senior cohorts. Sophomore in 2018, on average, had a factor score above the sample average in 2018 but the next cohort experienced a sharp decline in 2019. This decline was followed by a slow rise for sophomores in 2020 and 2021 ending at a score like sophomores in 2018. Juniors, like sophomores, had factor scores above the sample average in 2018 followed by a steady decline for juniors in 2019 and 2020. However, the trend from 2020 juniors to 2021 juniors took a sharp incline to levels above 2018 juniors. The trend line for seniors tells an interesting story. On average, the 2018 senior cohort started out below the sample average, but the 2019 senior cohort experienced a sharp incline from the previous cohort. However, cohorts trended downward from 2019 to 2020 but rose to rates similar to the junior cohort by 2021.

Figure 4

Trend Analysis for Utility Value Latent Construct

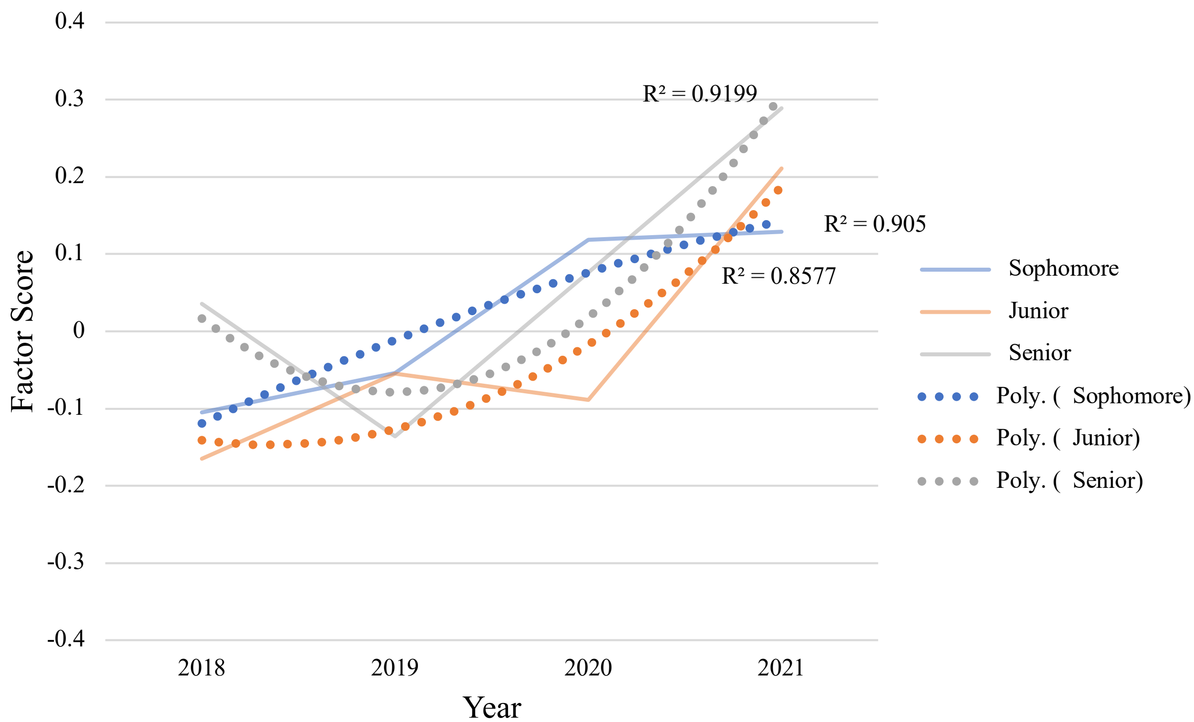


Note. R^2 beside each trend line indicates overall fit of the trend line

Expectations for Success Value Trend. When it came to what students expected out of their classes and the level of satisfaction for those classes, sophomore, junior, and senior cohorts were all trending upward by 2021. Moreover, all three cohorts in 2021 were above the sample average, as shown in Figure 5. However, it did not begin that way. The 2018 seniors were the only cohort who began with a factor score higher than the group average. Yet, there was a decline in 2019 seniors from 2018 seniors. The 2018 sophomore cohort and the 2018 junior cohort on the other had started below the sample average, however their trends were not the same. Overall, from 2018 to 2021, sophomore cohorts experienced a liner upward trend. They spent 2018 and 2019 below the sample average and 2020 and 2021 above the sample average. Junior cohorts experienced a polynomial trend with peaks in 2019 and 2020. Although the 2019 senior cohort experienced a decline from 2018 seniors, the rise from 2019 to 2021 was the sharpest incline and resulted in 2021 seniors having the highest ratings over expectancies for success on average.

Figure 5

Trend Analysis for Expectancy Values Latent Construct

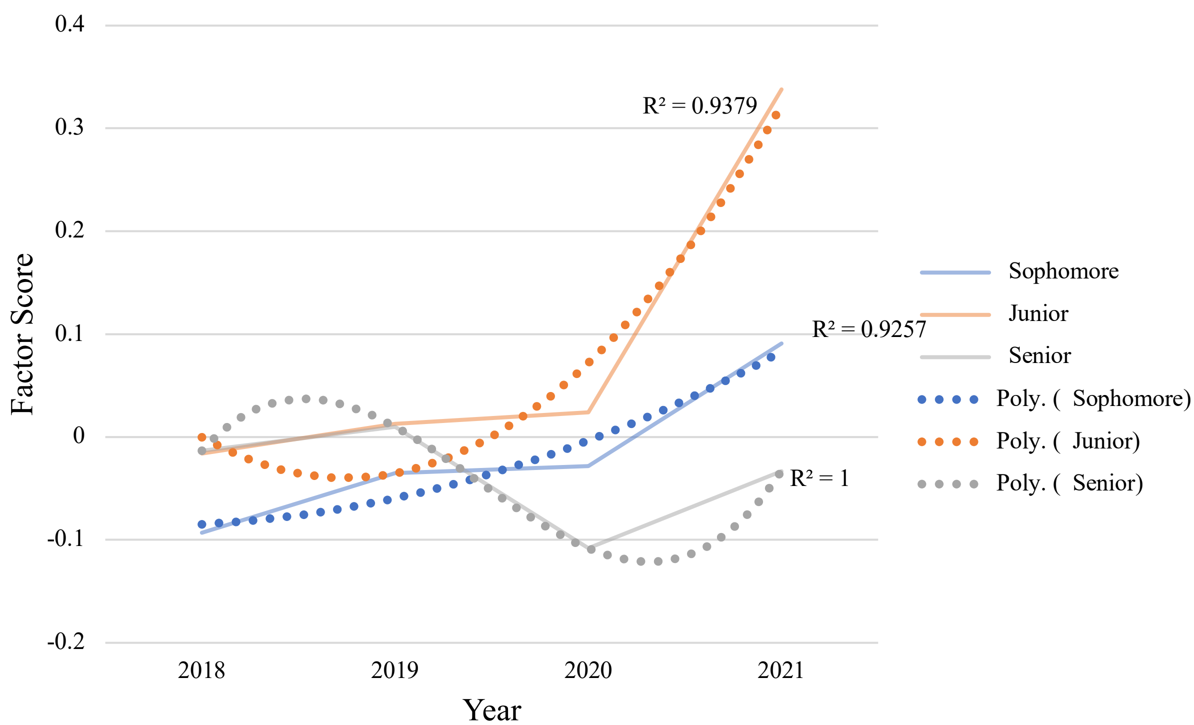


Note. R^2 beside each trend line indicates overall fit of the trend line

Attainment Value Trend. Figure 6 show the results for how each group trended when it came to the value placed on attaining a goal or completing tasks, either set by themselves or related to their coursework. In this figure, sophomore cohorts saw a linear trend from 2018 to 2021. This trend is also characterized as a positive trend because attainment value ratings went from below the sample average to above the sample average from year one to year four. Junior and senior cohorts experienced polynomial trends. Juniors were below the sample average and remained mostly constant from 2018 to 2020. However, from 2020 to 2021 there was a dramatic increase in attainment value ratings. Seniors remained mostly constant from 2018 to 2019 but took a sharp decrease from 2019 to 2020 with the 2021 senior cohort experiencing a slight recovery by 2021.

Figure 6

Trend Analysis for Attainment Value Latent Construct

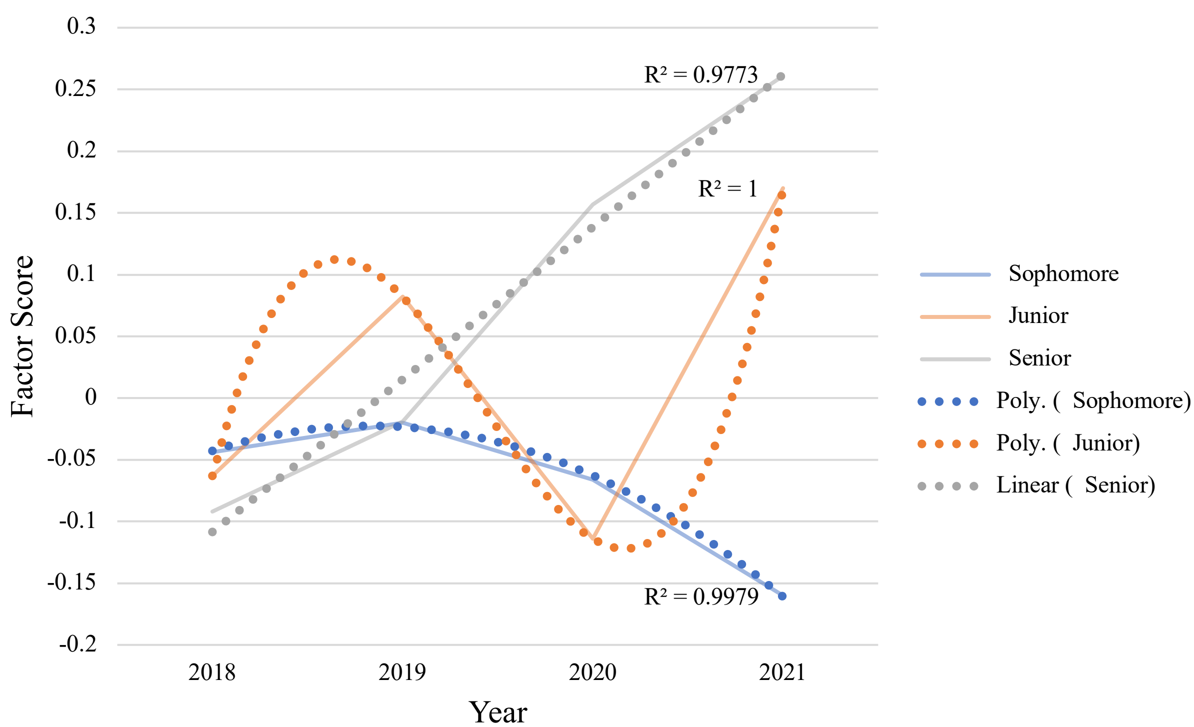


Note. R^2 beside each trend line indicates overall fit of the trend line

Interest Value Trend. The results for the interest value trend for each group is found in Figure 7 below. Here we see the how students' interest in science and engineering trended over the four-year period. Interestingly, the 2018 sophomore cohort was below the sample average in, and the 2019 cohort remained mostly steady. After 2019, sophomores' interest value started trending downward through 2021. The 2019 junior cohort's interest value ratings increased from the 2018 junior cohort's ratings. Then those ratings took a steep downward trend for 2020 juniors but have since taken a sharp trend upward for 2021 juniors. Senior cohorts, however, experienced a positive linear trend from 2018 to 2021.

Figure 7

Trend Analysis for Interest Value Latent Construct

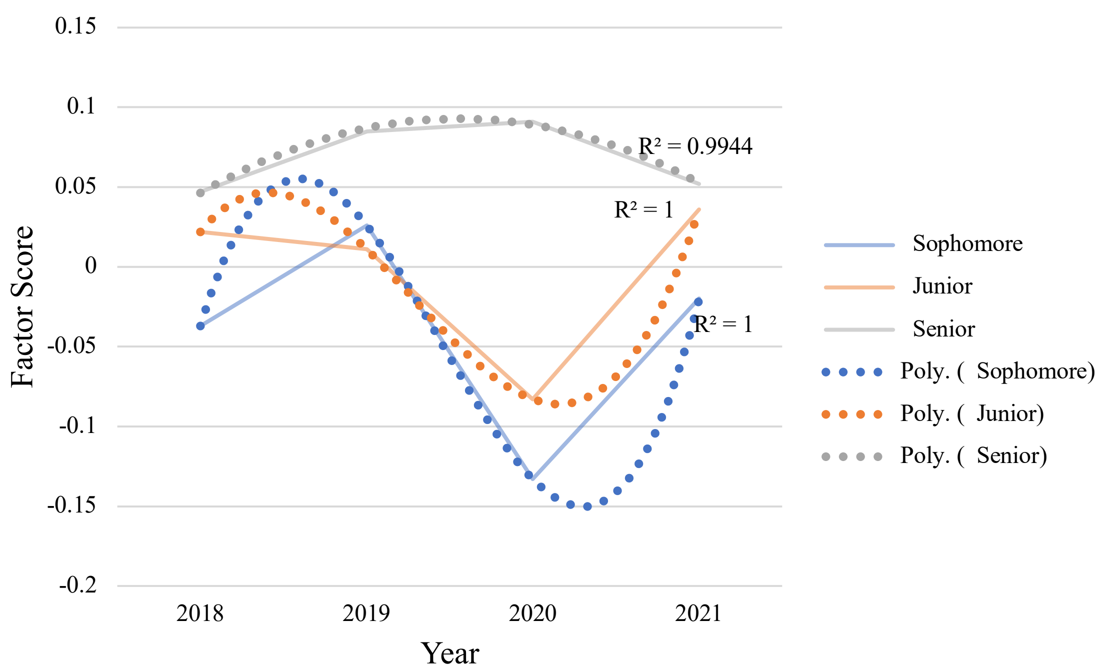


Note. R^2 beside each trend line indicates overall fit of the trend line

Self-Schemata Trend. How the groups, on average, felt about goal settings and planning for the future are shown in Figure 8 below. These trends produced interesting results. The 2019 sophomore cohort trended upward from 2018 sophomores, while the 2019 junior cohort took a small downward trend during the same time. Both 2020 sophomore and junior cohorts trended downward from the 2019 cohorts, however, the downward trend for 2020 sophomores was larger. From 2020 to 2021, both groups trended upward with 2021 juniors having a higher rating, on average, than 2021 sophomores. The 2019 senior cohort, conversely, trended upward slightly from 2018 seniors and 2020 seniors trended slightly upward from 2019 seniors. However, 2021 seniors trended downward slightly from 2020 seniors. Even so, seniors still had the highest ratings, on average, between all three groups.

Figure 8

Trend Analysis for Self-Schemata Latent Construct



Note. R^2 beside each trend line indicates overall fit of the trend line

DISCUSSION

The purpose of this study was to examine the how sense of belonging, academic confidence, perceptions of the classroom environment, and motivation trend over a four-year period. Specifically, we examined one department's attempt to be more inclusive and innovative through curricular and cultural transformations. The trend analysis results give an indication of what is potentially happening among sophomore, junior, and senior cohorts over a four-year period. The results suggest shifts from year to year for the groups. However, those changes were not all linear. The polynomial nature of the trends is indicative of unequal changes over time.

On face value, the differences between one cohort in one year and that same cohort in another year is a result of group differences by chance. Still, if that were the fully the case, we would expect to see consistent similar-typed trends for each construct and cohort over the four-year period; yet that is not the case. Thinking about the results through the lens of bioecological systems theory and the specificity principle we can begin to see how the changes described above might be explained. That is, by contextualizing the results as students being acculturated into a profession coupled with their own developmental changes interacting with changes to the classroom environment overtime might partially explain the trends observed.

Characterizing Trends

The first research sub-question of this study sought to characterize the trends of sophomores, juniors, and seniors as they relate to motivation, sense of belonging, academic confidence, and perceptions of the engineering classroom environment. In some regard, there is an expectation that as we go from year 2018 to year 2021, we would see higher scores for each cohort from one year to the next. This line of thinking extends from the understanding that cultural changes would create opportunities for students to rate the constructs higher, on average. This would indicate somewhat of a linear trend over the four-year period. However, the results in this study saw polynomial trends for many of the constructs and each group. These polynomial trends suggest that the rate of change over the four-year period is not the same.

Prior research has pointed toward the classroom environment and the type of impact it can have for students' belonging and persistence toward a degree (Bancroft, 2018; Bottia et al., 2015; Cromley et al., 2016; O'Hara et al., 2020; Rodriguez & Blaney, 2021; Wilson et al., 2015). Moreover, when thinking through the lens of acculturation we can start to understand the characterization of trends as this process of disorganization and reorganization (Bornstein, 2017). Students come into the classroom with prior knowledge, skills, and assumptions. In turn, these interact, individually and collectively, with the classroom environment and mutually influence one another (Bronfenbrenner, 2001). While this view does not fully explain why there are non-linear trends, it does echo prior work. Secules and colleagues (2018) examined cultural construction and ability and discussed the need for research to "zoom out" from the individual. However, if we do zoom out, as the authors suggest, we must include the impact mutually influencing ecological systems have on students. To examine that, we turn to the second research question.

Departmental Changes Influencing Trends

The second sub-research question of this study examines how differences in trends across academic classifications might be explained by changes in the department. The engineering classroom environment sustains a culture that embraces meritocracy, competition, a narrow ontological perspective, and one that prepares students to become members of a group (Canning et al., 2020; Freeman et al., 2014; Ladson-Billings, 2009; Malcom & Felder, 2016; O'Leary et al., 2020; Wilson et al., 2015; Zumbrunn et al., 2014). However, this environment and culture has been shown to negatively impact, among other things, academic confidence, motivation, and learning (Canning et al., 2020). Moreover, institutional barriers at the micro- and macro-system often drive students from engineering disciplines (Long & Mejia, 2016). For example, lower academic expectations and repeated microaggressions towards students from historically underrepresented contribute to isolation and alienation in their educational environments.

Data collected during the first year of the project (2018) serves as baseline data for each of the academic classifications. Much of the first year of the project dealt with putting everything into place and allow for stakeholders to provide input on proposed initiatives as part of the proposal. Moreover, this baseline data provided the department with a snapshot of how sophomore, junior, and senior cohorts were experiencing the department, on average. Starting in year 2019, year two of the project, saw the implementation of some of the first departmental changes. Some of the initial trends in the constructs from year 2018 to year 2019 possible result from student concerns over new things being implemented into the curriculum and department. For example, in terms of sense of belonging, academic confidence, and perceptions of the environment, 2019 sophomores and 2019 juniors, on average, trended upward from year 2018 to year 2019. However, on average, 2019 seniors trended down for sense of belonging and perceptions of the environment while remaining constant on academic confidence. These trends align with research around acculturation, students further along in the acculturation process might be less susceptible to broad changes (Bornstein, 2017; 2019).

At the same time the department implemented the “soft-wired” team structure which aligned with research calling for more inclusive teaching practices. Civil engineering restructuring around needs is a step towards reconfiguring academic structures. By critically looking at how effective the department was at meeting the needs of students, they were able to start a paradigm shift in how their faculty approached inclusive excellence (Dewsbury, 2017a; 2017b). Additionally, the aim at creating equity in engineering classrooms coupled with “soft-wired” teams allows faculty to take some ownership in achieving equity in the classroom. Often, this type of work is typically left up to staff and specific campus centers (O’Leary et al., 2020). As the “soft-wired” teams were establishing their footing, a new set of design courses were being implemented into the department through the ARCH Initiatives.

Several strands of engineering education research have examined potential pedagogical deficiencies (Eastman et al., 2019) in engineering classrooms. Regularly, results suggest that critical thinking, project-/problem-based learning, and other pedagogical designs that place an emphasis on the students building knowledge together enhances engagement and promote academic gains (Eddy & Hogan, 2014; Freeman et al., 2014; Prince & Felder, 2006). For example, Long & Mejia (2016) recommend that engineering educators help students learn how engineering relates to social, cultural, and historical contexts. By implementing the junior studio design courses, the department offers students the ability to apply technical skills and learn about societal issues that do not often have an answer. The Springer courses were designed to bridge the gap between engineering curriculum and real-world practice during the sophomore year and introduced teamwork into the pedagogy which allowed for a strengthening of academic confidence and a better perception of the classroom environment. Moreover, this bringing in and connecting course content with real-world impacts helps students increase the value they place on the course (Eddy & Hogan, 2014).

Implications for Practice & Future Work

The results characterized trends among sophomores, juniors, and seniors while providing insights into what might be the force behind those trends. More importantly, the results provide some direction for practice. For example, the presence of polynomial trends reinforces research stating that the environment may not always influence students in the same way. Furthermore, it demonstrates the need for a multi-prong approach to curricular and cultural changes in an engineering department. Integrating broader social-historical contexts and technical skills into project-based coursework tended to have positive effects in the long-run as most of the trends by year four were trending upward.

Lastly, these results provide insight for departments regarding the structuring of course work. For example, changes in the trends for juniors and seniors might be different from sophomores due to early course work in the program focusing more on identity and persistence. Those differences might be decreased if programs integrate ways for their students to be more confident and resilient. Not only could it increase belongingness, but it is also linked to academic success (Long & Mejia, 2016; Strayhorn, 2012).

This study sought to examine sense of belonging, motivation, academic confidence, and students' perceptions of the classroom environment trended over time. Specifically, this study used one engineering department's attempt to revolutionize itself through cultural and curricular transformations. Future work would benefit from expanding beyond a single department and track trends across multiple engineering departments. Moreover, additional qualitative follow-up could better explain why one group trended upward and another trended downward. Finally, future research should extend beyond just departmental change and incorporate how changes in individual students interact with how sophomores, juniors, and seniors change over time.

Limitations

This work was limited to the context of the secondary data source and is potentially only generalizable to other civil engineering departments undergoing curriculum and cultural transformations. Secondly, data were aggregated and examined at the group level therefore, within differences that could potentially leverage the trends were not examined. Primary data collection could potentially solve this limitation.

COVID-19 & Shifting to Online Environment

Previous research examined students and their experiences in online and/or hybrid learning environments (see Abeysekera et al., 2015; Chyr et al., 2017; Linden, 2018). However, in March of 2020, steps taken by many institutions in response to the COVID-19 world-wide pandemic forced students into online environments for all coursework (Lenderman, 2020). In the context of this study, the pandemic impacted students in the second half of year three (Spring 2020) and the first half of year four (Fall 2020). While the overall impact of COVID-19 measures is still being assessed by institutions, it is worth mentioning that the trends between year two and year four of the project are impacted by decisions made at the macro-, exo-, and meso-systems. Most easily seen is the impact switching to an online environment had on students' motivation. Motivational trends saw some of the largest downward trends from year two to year three and some of the largest upward trends from year three to year four when students began attending classes in person again.

Conclusion

Research has shown how the classroom environment can impact students in positive and negative ways. This study contributes and extends that research by (a) contextualizing specific changes to an engineering department, and (b) incorporating curriculum changes to examine specific trends over time. We found that trends over time for sophomores, juniors, and seniors were not all linear trends. Several were found to be non-linear suggesting an uneven impact for students, on average. Moreover, we offered suggestions as to what might be influencing trends over a four-year period of curriculum and cultural transformations in an engineering department. These results suggest some fluidity in how students, on average, perceive their classroom environment, sense of belonging, motivation, and academic confidence. However, further research is needed to fully articulate the long-term impact.

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APPENDICES

Appendix A

Survey Items

Table 3

Survey Items

Sense of Belonging Items	
I enjoy going to school here	
I wish I had gone to another school instead of this one [a]	
People at this school are friendly to me	
I feel there is a sense of community at this school	
I feel there is a strong feeling of togetherness on campus	
Engineering students make me feel wanted and accepted	
I am disliked by students in engineering [a]	
There is a sense of community in engineering	
Engineering faculty and staff in engineering make me feel wanted and accepted	
I feel comfortable in engineering	
I am supported in engineering	
I am accepted in engineering	
I feel I belong in engineering	
There is a strong feeling of togetherness in engineering	
I enjoy being in engineering	
Motivation Items	
Utility Value	
Doing better than the other students in this class on exams	
Proving to my peers that I am a good student	
Doing better than the other students in the class on assignments	
Getting a better grade than other students in this class	
Expectancy Value	
Knowing more than I did previously about these course topics	
Really understanding this course's material	
Feeling satisfied that I got what I wanted from this course	
Self-Schemata	

I don't think much about the future [a]

It's really no use worrying about the future [a]

I don't like to plan for the future [a]

It's not really important to have future goals for where one wants to be in five or ten years [a]

One shouldn't think too much about the future [a]

Planning for the future is a waste of time [a]

Attainment Value

Given the choice, it is better to get something you want in the future than something you want today

It is better to be considered a success at the end of one's life than to be considered a success today

The most important thing in life is how one feels in the long run

It is more important to save for the future than to buy what one wants today

Long range goals are more important than short range goals

What happens in the long run is more important than how one feels right now

Interest Value

Learning science will improve my career prospects

Science is helpful in my everyday life

Science has helped me see opportunities for positive change

Science has taught me how to take care of my health

Learning science has made me more critical in general

Engineering can improve our society

Engineering will give me the tools and resources I need to make an impact

Engineering can improve our quality of life

I see engineering all around me

Academic Confidence

I will use the information I learn in this engineering course in the future

I am confident I can do an excellent job on the exams in this engineering course

What I learn in my engineering course will be important for my future occupational success

I do not connect my future career to what I am learning in this course [a]

I am considering switching majors [a]

I am confident about my choice of major

Engineering is the most rewarding future career I can imagine for myself

My interest in an engineering major outweighs any disadvantages I can think of	
I want to be an engineer	
Environment	
I feel accepted in my engineering class	
I feel comfortable in my engineering class	
I feel supported in my engineering class	
I feel that I am a part of my engineering class	
I feel invisible in engineering classes [a]	

Note. [a] Reverse-coded item.

Appendix B

Trend Analysis Group Means Construct by Year

Table 4

Trend Analysis Group Means Construct by Year

Variable	2018			2019			2020			2021		
	n	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*
Belonging												
Sophomore	122	-0.184	0.910	232	-0.157	1.110	140	-0.090	0.999	90	0.145	1.010
Junior	108	-0.036	0.923	189	0.002	0.900	108	0.146	0.979	58	0.240	0.730
Senior	65	0.173	0.826	100	-0.173	1.000	41	-0.083	1.137	109	0.378	0.851
Utility												
Sophomore	116	0.082	1.010	231	-0.137	0.910	141	0.004	1.200	88	0.099	0.930
Junior	119	0.098	0.995	186	-0.001	1.077	104	-0.064	0.896	58	0.210	0.945
Senior	66	-0.203	1.095	97	0.027	0.910	41	-0.074	1.191	109	0.089	0.928
Expectancy												
Sophomore	116	-0.105	1.093	231	-0.054	1.190	141	0.119	1.090	88	0.129	0.665
Junior	119	-0.165	0.992	188	-0.055	0.890	104	-0.089	0.855	58	0.211	0.773
Senior	65	0.036	1.093	100	-0.136	1.187	41	0.076	1.094	108	0.289	0.665
Attainment												
Sophomore	115	-0.093	0.864	231	-0.035	0.965	141	-0.028	0.861	88	0.091	0.910
Junior	119	-0.016	0.828	190	0.013	0.953	105	0.024	0.940	58	0.338	0.793
Senior	66	-0.013	0.864	97	0.010	0.965	40	-0.108	0.861	108	-0.033	0.906
Interest												
Sophomore	104	-0.044	0.916	228	-0.020	0.943	141	-0.066	0.975	87	-0.160	0.816
Junior	112	-0.063	0.930	184	0.082	0.836	104	-0.114	1.094	57	0.170	0.840
Senior	62	-0.092	0.916	94	-0.019	0.943	37	0.157	0.975	108	0.261	0.816

Academic Confidence												
Sophomore	115	-0.198	1.150	231	-0.098	1.020	141	0.084	0.870	88	-0.040	0.840
Junior	119	-0.133	0.919	190	-0.003	0.919	105	0.114	0.823	58	0.234	0.765
Senior	66	-0.056	1.148	96	-0.060	1.020	40	0.240	0.870	408	0.258	0.840
Self-Schemata												
Sophomore	114	-0.037	1.002	231	0.026	0.822	141	-0.133	0.919	88	-0.020	0.945
Junior	119	0.022	0.734	190	0.011	0.824	105	-0.083	0.996	58	0.036	0.875
Senior	65	0.047	1.002	97	0.085	0.822	40	0.091	0.919	108	0.052	0.945

CHAPTER FOUR

UNLOCKING SUCCESS: MOTIVATION, SENSE OF BELONGING, & ACADEMIC CONFIDENCE IN ENGINEERING CLASSROOMS

Contextual factors of an educational system that continue to disenfranchise certain populations of students seem to be an underlying thread of modern education in the United States. Moreover, layers of complexity are added when researchers try to understand the characteristics used to explain educational systems. For example, the doctrine of separate but equal dominated education for over a half a century (*Plessy v. Ferguson*, 1896) segregating schools on the basis of race. This was subsequently ruled unconstitutional and overturned in 1954 (*Brown v. Board of Education*, 1954). However, educational systems found other ways to structure segregation in schools through funding, curriculum, and district rezoning (Delgado & Stefancic, 2017; Ladson-Billings, 2009, 2012; Ladson-Billings & Tate, 1995). These examples support a large systemic issue that plagues early and secondary schools in the United States and often have ramifications for post-secondary education that can often inhibit a student's success.

When attempting to understand the influence current classroom environments have on undergraduate students, research should start with individual's perceptions and attitudes of their own environment. That is important because whatever deficiencies or inequalities students experienced in their upbringing do not disappear when they come to college; instead they provide insights into how student perceive and make sense of their environments (Spencer, 1999; Spencer et al., 1997; Velez & Spencer, 2018). This distinction is important, not to make excuses for students, but rather to underscore the fact that not all students have had the same educational experiences. For example, a colloquial idiom often heard in education is 'shoot for the moon, even if you miss, you'll land among the stars.' On the surface, this seems like a harmless statement intended to motivate students. However, what if students do not know what catapults are or how to build them? The statement assumes that all students have the necessary knowledge to understand and use the statement to their advantage. However, research has demonstrated that prior experiences might not have the same impact for all students, even if they have the same or similar experiences (Belsky & Pluess, 2009; Bornstein, 2017, 2019; Freeman et al., 2007; Good et al., 2012; Lizzio et al., 2002; Walton & Cohen, 2011). Moreover, when it comes to trying to understand student perceptions of the classroom environment, these differences matter (Canning et al., 2020; Gummadam et al., 2016; Lee et al., 2020).

Previous research has demonstrated the importance of experiences students bring with them to the college classroom, particularly those who come from minoritized backgrounds (London et al., 2021). Educators should strive to create environments that scaffold opportunities for students to achieve the standards set; to just demand high standards in the classroom is not enough for students to be successful. One area in post-secondary education where there is a high demand for success, but it is often lacking in the scaffolding to ensure that success is engineering education (citation). Engineering classrooms often feature competitive environments that are associated with negative course outcomes for all students and could force students to focus on being the best in the course instead of working with their peers to achieve a common goal (Canning et al., 2020).

One factor inhibiting a student's success in engineering comes from aspects of the classroom environment and a general lack of understanding of the types of lived experiences students bring with them to the engineering classroom. However, recent trends have taken engineering education from the traditional lecture halls of the past to a more student-driven, student-centered approach to learning with signs pointing toward a more individualized curriculum model that provides students the opportunity to develop a portfolio of skills needed for the complex industries they seek to enter (Hadgraft & Kolmos, 2020). Yet, there is still a need for complexity, cross-disciplinarity, and a system thinking approach to curriculum where individuals have a shared mutual understanding of learning and development (Hadgraft & Kolmos, 2020; Zhou et al., 2012). This shared mutual understanding has the potential to lead to positive experiences for students inside and outside the classroom. In turn, these positive experiences lead to higher levels of engagement and persistence for students in higher education (Hankey et al., 2019; Pascarella & Terenzini, 2005).

Purpose of Study

Previous research (O'Hara et al., 2023; O'Hara, 2023) examined students' motivation, sense of belonging, and academic confidence in relation to their perceptions of the classroom environment between sophomores, juniors, and seniors. This study aimed to expand understanding of the classroom environment's impact on undergraduate engineering students by examining differences between engineering majors, academic classifications, and potential interactions between major and academic classification. Moreover, it included information about daily life experiences students might have in college as an indicator of the types of phenomena potentially impacting how students assign meaning and significance to those experiences (Spencer et al., 1997). The primary goal of this research was to underscore the importance of the person within a context when it came to engineering students' sense of belonging, motivation, and academic confidence.

Research Questions

To achieve the goal of this study, we focus on a central research question: To what extent are force and resource characteristics attributed to the individual student and their life experiences versus their major and academic classification? Force and resource characteristics are two of three person characteristics (Bronfenbrenner & Morris, 2006) that people bring with them into situations and are discussed in greater detail below. We further breakdown this question into two parts:

1. To what extent is there variation between students?
2. To what extent is there variation between academic classifications and majors?

The following section examines relevant literature, theoretical framing, and prior research that led to the central research question.

RELEVANT LITERATURE

Relational developmental systems theories (RDST) emphasize the reciprocal multidirectional relationship between developmental systems where an individual and their environment influence one another. These types of developmental theories view humans as complex and interconnected organisms whose development is a product of "mutually influential relations between developing individuals and the multiple levels of their complex and changing contexts" (Geldhof et al., 2014, p. 67). One model relating to RDST is Bronfenbrenner's bioecological systems theory (Bronfenbrenner, 1977, 1992, 2001; Bronfenbrenner & Morris, 2006). However, some have questioned the application of bioecological systems theory and called for revised frameworks that are more inclusive (Garcia Coll et al., 1996; Lee, 2008; Spencer, 1999; Spencer et al., 1997; Williams & Deutsch, 2016; Velez & Spencer, 2018; Vélez-Agosto et al., 2017). One such framework is the phenomenological variant of ecological systems theory or PVEST (Spencer et al., 1997; Velez & Spencer, 2018). This study draws from both bioecological systems theory and PVEST to better explain the phenomena in question.

Bioecological Systems Theory & PVEST

When people have experiences, they often are not solely passive to those experiences. These experiences can influence all aspects of a person's life and result in different outcomes from person to person—even for the same experience (Garcia Coll et al., 1996; Spencer et al., 1997). The differences in experiences can be best explained through a bioecological systems theory framework. How people respond to and make meaning of their experiences depends on a complex and interconnected relationship between the individuals and the systems they interact with. For example, differences in response to stressful situations can occur partly due to pure biological differences in people (e.g., fight or flight response) and partly from the family and cultural environment's influence on the individual. Bronfenbrenner (1977, 1992, 2001) and colleagues (Bronfenbrenner & Morris, 2006) explained human development through a series of nested ecological systems in which the individual is placed at the center.

The individual's development is shaped by proximal and distal forces stemming from the nested ecological systems. For example, the classrooms in which the individual interacts with daily are called microsystems. These microsystems are the most proximal to the individual and exert the most influence on them because individuals are directly involved. As ecological systems move distally from the individual, the individual become less directly involved but are still influenced by those ecological systems. For example, individual students are not directly involved in administrative decision-making for their institution. Those decisions would occur at the exosystem, however those decisions made by administrators would still influence the student; albeit somewhat indirectly through…. As individuals navigate the lifespan, they experience increasingly complex interactions with the various ecological systems that shape developmental outcomes.

PVEST merges a phenomenological approach with bioecological systems theory to explain how individuals perceive or make sense of their experiences within ecological environments (Spencer, 1999; Spencer et al., 1997; Velez & Spencer, 2018). The PVEST framework allows for researchers to understand variation in developmental pathways. Phenomenological experiences of social constructs (e.g., race and gender), along with context of those experiences, influence how individuals self-organize. Spencer et al. (1997), explain that it is not only experiences that influence the meaning and significance individuals give themselves but also the perception of those experiences. Within the PVEST framework, children of color are placed at risk and navigate environments linked with sociocultural contexts that are the source of the risk. Navigating these environments force children of color to constantly go through a self-other appraisal process which ultimately influence developmental outcomes for children of color (Spencer, 1999; Spencer et al., 1997; Velez & Spencer, 2018). PVEST allows researchers a tool to better understand the dynamic influence of specific environmental contexts and its influence.

Bioecological systems theory and PVEST together provides a more enriched understanding of context, culture, and person interacting with one another, and allow researchers to understand development through a process, person, context, and time (PPCT) model that considers the unique developmental experiences of individuals. What is gleaned from this model is an understanding that developmental differences are a result of the developing person, situated in a context where the processes are occurring, with changes happening over time connected to the lived experiences of individuals. Within the PPCT, the person is operationalized with three types of characteristics: force, resource, and demand characteristics (Bronfenbrenner & Morris, 2006). Force characteristics are specific behavioral dispositions (e.g., temperament) that can set developmental processes in motion, sustain them, or somehow interfere with those processes.

Resource characteristics are those biopsychological aspects of a person, such as ability, knowledge, skills, and experiences that become increasingly complex overtime and interact with developmental processes in both positive and negative ways. The final person characteristics are demand characteristics which refer to demographic characteristics that can elicit reactions from environments. The current study focuses on the force and resource characteristics of the person within the PPCT. Put differently, this study focuses on individual students' sense of belonging, motivation, and academic confidence along with the types of daily life experiences students have in engineering classroom environments.

Prior Research

Prior research has examined motivation, sense of belonging, and academic confidence's relationship with perceptions of the classroom environment (O'Hara et al., 2023) and the impact on students in engineering. Moreover, another study (O'Hara, 2023) focused on the context in which proximal processes were occurring over a 4-year period. In this study, focus was placed on personal characteristics of the student in the context of engineering classroom environments. Specifically, we focused on force and resource characteristics examining what, if any, differences are present across academic majors and academic classifications.

Environments that emphasize effective educational practices see greater gains from undergraduate students in and outside of the classroom (Copeland & Levesque-Bristol, 2011; Umbach & Wawrzynski, 2005). Furthermore, positive classroom environments have been shown to increase confidence, motivation, and even sense of belonging in students (Copeland & Levesque-Bristol, 2011; Cromley et al., 2016; Wilson et al., 2015). For example, a student's motivation is potentially increased when students can work on projects within the context of their major/discipline. This type of project-based pedagogy helps students think of the experience as more authentic with deliverables that go beyond just a grade in a course while building critical knowledge and skills needed for successful careers (Eastman et al., 2019; Eddy & Hogan, 2014; Freeman et al., 2014; Hadgraft & Kolmos; Prince & Felder, 2006; Zhou et al., 2012).

However, effective educational practices in the classroom are not the entire solution to problems facing higher education (Chavez & Longerbeam, 2016). Moreover, research has stressed the importance of educators understanding that the impact of these positive or negative experiences in the classroom may not be the same for all students ((Belsky & Pluess, 2009; Freeman et al., 2007; Good et al., 2012; Lizzio et al., 2002; Walton & Cohen, 2011). Within STEM and specifically engineering education, students are often the ones who bear the responsibility of remedying these issues (Long & Mejia, 2016; Martin et al, 2018). Eastman and colleagues (2019) suggest that a lack of examining engineering education's culture is to blame. While others have suggested it is the lack of student agency outside the structure of the classroom (Secules et al., 2018). Yet, engineering departments cannot afford to wait for a full-scale engineering or institutional cultural change. They need to examine how their policies, structures, and habits hinder or promote access to engineering programs (Lee et al., 2020).

Force & Resource Characteristics

These changes need to be strategic and intentional because students' perceptions of the environment are shaped and reshaped by force and resource characteristics (Lee et al., 2020; Martin-Hansen, 2018; Rainey et al., 2019; Robnett et al., 2018; Rodríguez et al., 2018). In this study, force and resource characteristics refer to engineering students' motivation, sense of belonging, and academic confidence in the context of the engineering classroom. While there is evidence to suggest that specific aspects of motivation, sense of belonging, and academic confidence are more important than others (Ahn & Davis, 2019; Good et al., 2012; Freeman et al., 2007; Strayhorn, 2012; Walton & Cohen, 2011; Walton et al., 2012; Wilson et al., 2015; Zumbrunn et al., 2014), when interacting with the classroom environment, these force and resource characteristics are heavily influenced by issues in the classroom (Carpi et al., 2017; Cromley et al, 2016; Grossman & Porche, 2014; Nadelson et al., 2017; and Wilson et al., 2015). For example, sense of belonging and academic confidence shares a strong positive relationship (Freeman et al., 2007; Hurtado et al., 2007; Walton & Cohen, 2011; Walton et al., 2012; Wilson et al., 2015; Zumbrunn et al., 2014) and when interacting in a classroom environment that is highly competitive can have highly negative results overall for students (Canning et al., 2020). While prior research has posited that little is known about the classroom environments impact on motivation, sense of belonging, and academic confidence collectively (Freeman et al., 2007; Zumbrunn et al., 2014), there is ample research exploring these characteristics individually.

Motivation

Motivation is often viewed as multifaceted and is approached from various theoretical backgrounds. For example, motivation can be explained through the lens of self-determination theory (Deci & Ryan, 1985; Ryan & Deci, 2000) and focus on social-cognitive factors. Therefore, motivation can be thought of as a concept that is contextualized by the situation currently experienced by students (Kaplan et al., 2019; Nolen 2020). In this study, motivation is understood through situated expectancy-value theory (SEVT) where context is highlighted when understanding motivation (Eccles & Wigfield, 2020). Research has discussed the environment's impact on motivation (Brooks, 2011; Chiu & Cheng, 2017; Linden, 2018), how to improve motivation through pedagogy (Cano et al., 2018; Evenhouse et al., 2018), and across disciplines (Anwar et al., 2020; Ford et al., 2020; Zumbrunn et al., 2014). Using the context of a mechanical engineering course, Ford et al. (2020) found that over the course of the semester students leveraged motivation in different ways. Similarly, Anwar and colleagues (2020) found that when accounting for prior academic success, student's motivation was able to predict exam grades. Both studies highlight the importance of considering context when researching motivation.

Sense of Belonging

Sense of belonging has been characterized in various ways (Bollen & Hoyle, 1990; Freeman et al., 2007; Good et al., 2012; Goodenow, 1993; Locks et al., 2008; Museus & Maramba, 2010; O'Brien et al., 2011; Walton & Cohen, 2011; Walton et al., 2012). This study defines sense of belonging as the student feeling a sense of connection to their educational experiences (Ahn & Davis, 2019; Freeman et al., 2007; Strayhorn, 2012; Wilson et al., 2015). Studies have looked at the environment of engineering classrooms and its impact on sense of belonging (Canning et al., 2020; Eddy & Hogan, 2014; Raisa et al., 2021). For example, Eddy & Hogan (2014) found that when engineering courses were more structured students stated that the culture of the classroom made them feel like they belonged. Taken together, prior research has demonstrated that the classroom environment can have varying impacts on students' sense of belonging.

Academic Confidence

Academic confidence draws from several theoretical frameworks to underscore the complexity in how students view themselves academically and beliefs that students have regarding the ability to succeed in their major (Sander & Sanders, 2006, 2009). Within this study, academic confidence is captured as the student's confidence in being academically successful in both courses and field of study (Patrick & Borrego, 2016; Rodriguez et al., 2018). One reason for students leaving engineering programs might have to do with the expectations set by faculty in engineering programs (Eastman et al., 2019). These unrealistic goals coupled with research examining engineering classroom environments and decrease in academic confidence in students might be a major contributor student alienation (Long & Mejia, 2016). Moreover, research has shown the role faculty have in shaping classroom environments that impact academic confidence (O'Leary et al., 2020; O'Hara et al., 2020).

METHOD

The guiding research question of this study was: To what extent are resource and force characteristics attributed to the individual student and their life experiences versus their major and academic classification? That question was further supported by two sub-questions for the study: (a) to what extent is there variation between the students and (b) to what extent is there variation between academic classifications and majors? The design of this study followed a fixed cross-sectional design that built upon results from previous studies (O'Hara et al., 2020; O'Hara et al., 2021).

Data Collection and Population

Students were recruited from across an academic college consisting of engineering, computer, and applied science programs consisting of 13 majors (14 if General Engineering is included). The current enrollment for this college is 5,454 students (74.7% White, 22.9% Non-white). The current gender percentages are 24.4% of students identified as female and 75.6% identified as male. This study aimed to collect data from 300 undergraduate engineering students across six engineering majors during the Spring 2023 semester. The six highest enrolled programs in the college of engineering, computing, and applied sciences are: Bioengineering, Biosystems Engineering, Civil Engineering, Environmental Engineering, Industrial Engineering, and Mechanical Engineering. Enrollment in these six majors account for 41% of the enrollment for the entire college.

Table 1

Race/Ethnicity breakdown for population

Category	*n*	Percent of enrollment
Traditional Race/Ethnicity Categories		
Non-Resident Alien	49	0.9
American Indian or Native Alaskan	7	0.1
Asian	297	5.4
Black or African American	293	5.4
Native Hawaiian or Pacific Islander	7	0.1
Hispanic or Latino	428	7.8
White	4073	74.7
Two or more races	215	3.9
Unknown	85	1.6
IPEDS [a]		
URM [b]	838	15.4
Non-URM	4616	84.6

Note. Percentage values may not equal 100 due to rounding.

[a] Integrated Postsecondary Education Data System.

[b] Under-Represented Minority, Students IPEDS Race/Ethnicity is Hispanic, African American, American Indian, Pacific Islander, or Two or more races.

Student emails from across the six programs, totaling 2,232 emails, were compiled into an excel spreadsheet and assigned a random number then sorted by the random number from smallest to largest. The first 300 random numbers were chosen as the sample for this study. Those emails were used to generate a unique link on Qualtrics® to distribute the survey to selected participants. Researchers also recorded how many participants were enrolled in each of the six majors. The breakdown of students in each major for the sample was proportional to major's enrollment for the population. Participants had two weeks to complete the survey after which the survey link would expire. After initial links expired, the number of participants who had not completed the survey were noted, and additional participants were drawn from the population. Researchers took note of the major for each student who did not complete the survey, and that number was used to draw additional participants at random from each of the six majors. This was done to ensure that the number of participants in each major stayed proportional to the population enrollment for that major. This process was repeated in four waves resulting in a sample size of 258 participants across the six majors. Table 2 includes a breakdown of the number of participants in each major and academic classification for the sample.

Table 2

Sample Breakdown: Academic Classification by Major

Academic Classification	Bioengineering *n*	Biosystem [a] *n*	CE [b] *n*	EE [c] *n*	IE [d] *n*	ME [e] *n*
Sophomore	5	3	19	0	13	35
Junior	15	1	19	4	15	32
Senior	18	3	19	5	25	27
Total Sample	38	7	57	9	53	94

[a] Biosystems Engineering

[b] Civil Engineering

[c] Environmental Engineering

[d] Industrial Engineering

[e] Mechanical Engineering

Instrument

Items were adapted from the Motivation & Attitudes in Engineering (MAE) survey, a previously validated instrument (Benson et al., 2013; Kirn & Benson, 2018) that has been tested on multiple engineering populations (Kirn, et al., 2016; O'Hara et al, 2020; O'Hara et al., 2021).

Additionally, the Daily Life Experiences Frequency scale (DLE-F; Harrell, 1997; Lee et al., 2021) was added to the instrument resulting in one survey for students. Items adapted from the MAE survey are on a 7-point Likert Scale and ask for student perceptions or experiences. Prior research using the same adaptations found adequate model fit statistics for each of the latent factor structures (O'Hara, 2023; O'Hara et al., 2023).

The DLE-F is a 5-point frequency scale ranging from never to once a week or more. The DLE-F measures the frequency of race-related microaggressions that server as indicators of negative life experiences and is calculated as an aggregate of the 18 items. Items deal with overt discrimination (three items), nonracial microaggressions (five items), and general racial discrimination (10 items). Earlier research on the psychometric properties of the DLE-F demonstrated the items to be reliable (α = .89) and valid (Harrell, 1997; Lee et al., 2021). Recently, Lee et al. (2021), demonstrated that the DLE-F was a unidimensional scale that yields valid and reliable scores and should be treated as such.

Sense of belonging (15 items) focused on connections students felt with their institution and/or the engineering community. The academic confidence scale (8 items) rated students' level of confidence in being academically successful in their major. Student perceptions of classroom environment was measured across 18 items and asked students their perceptions of support, acceptance, and comfortability in their engineering classrooms. Motivations was conceptualized through the lens of expectancy-value theory (Wigfield & Eccles, 2000, 2020) and consisted of 27 items. The DLE-F scale consisted of 18 items asking students to rate the frequency of negative life experiences during their studies. Internal consistency of all constructs was assessed using Cronbach's Alpha in this study (Table 3). A full list of all the items is included in the supplemental material (Table 4).

Table 3

Constructs and Cronbach's Alpha

Construct	# Of Items	Cronbach's α
Sense of Belonging	15	.92
Motivation	27	.84
Academic Confidence	8	.82
Environment	18	.91
Daily Life Experiences	18	.90

Data Analysis

The first step in data analysis was screening and cleaning the data. This included determining missingness, and partial responses were estimated using a maximum likelihood estimator. Descriptive statistics techniques were used to test for normality, skewness, and kurtosis (Azen & Walker, 2011; Pituch & Stevens, 2016). Cutoff values for skewness were -3 to +3 and cutoff values for kurtosis were -10 to +10 (Brown, 2006). All the scales showed skewness and kurtosis levels within the acceptable range expect for the DLE. Several items on the DLE were heavily skewed right with long tails. However, given the nature of the items on the scale this was to be expected. The data being skewed to the right is indictive of participants having few negative life experiences. Nonetheless, raw item scores were not of interest, but rather an aggregate score from the 18 items. We examined skewness and kurtosis for the distribution of DLE aggregate scores and those values were within the acceptable range indicated above.

Major and academic classification was used as grouping variables for statistical modeling. When examining groups sizes (see Table 2) for analysis, we noticed both

Environmental Engineering and Biosystems Engineering had the smallest group sizes, nine and seven respectively. This distribution is not surprising given Environmental Engineering and Biosystems Engineering had the smallest enrollment of the six majors in the study. Additionally, the other four majors in the study were both academic departments and academic majors. For example, Civil Engineering is the sole undergraduate major in the Department of Civil Engineering. However, Environmental Engineering and Biosystems Engineering are housed in the same academic department—the department of Environmental Engineering and Earth Sciences. Therefore, to increase the group size for analysis both majors were grouped together.

Factor Scores were estimated using SPSS (version 29). Factor scores are estimated as the linear combinations of shared item variance and errors associated with the items. This results in factor scores that are highly correlated with latent factors and produces unbiased estimates of actual factor scores (DiStefano et al., 2009). For this study, factor scores were estimated using the Bartlett method (Bartlett, 1937) which is like the traditional regression method (see Thomas, 1934 and Thurstone 1935). This method minimizes the error across the factors and estimated scores are correlated to its corresponding factor. Factor scores estimated using this method are unbiased estimates of the true factor scores (Estabrook & Neale, 2013; DiStefano et al., 2009; Skrondal & Laake, 2001). This distinction is important because factor scores used in subsequent analysis are used as both independent and dependent variables so unbiased estimates are needed to produce unbiased results (Skrondal & Laake, 2001). Factor scores produced are standardized scores with a mean of 0 and a variance that is equal to the squared multiple correlation between the items and factor.

An unconditional multilevel model (MLM) was performed using estimated factor scores in *RStudio* (version 2023.03.1+446) using the *lmer* function within the *lmer4* package (Bates et al., 2015). The two-level model was designed with student responses at level one and academic classification nested in academic major at level two. This resulted in 257 observations at level one, three academic classifications nested in five academic majors at level two. Estimation was conducted using a restricted maximum likelihood estimator and is best represented by the following equation:

$$Environment = Belonging + Motivation + Academic\ Confidence + DLE + (1 \mid Major/Class)$$

Where the "1" indicates varying intercepts at both the individual and group level and the "|Major/Class" indicates academic class is nested within academic major. Based on MLM results (see below), subsequent regular and multigroup path analyses were conducted using Mplus (version 8.1) and prior estimated factor scores.

RESULTS

This study sought to expand understanding on the engineering classroom's impact on its undergraduate students. This was done by examining differences in force and resources characteristics attributed to undergraduate students coupled with differences among engineering majors and academic classifications. Moreover, items related to daily life experiences were added as indicators of potential phenomena impacting how students perceive their classroom environments. To meet this aim, this study focused on a central research question: To what extent are force and resource characteristics attributed to the individual students and their life experiences versus their major and academic classification? Furthermore, we divided the question into two areas:

1. To what extent is there variation between the students?
2. To what extent is there variation between academic classifications and majors?

Below, we report the results of the study followed by a discussion, implications for practice and future work, and limitations.

Multilevel Model

Results of the multilevel model indicated all the variables, except daily life experiences, were significant predictors of students' perceptions of the environment. However, the intraclass correlation coefficient (ICC) was 0.06 indicating the grouping does not matter (Table 4). The ICC is the proportion of variance in the dependent variable attributed to the grouping. Put differently, it is the amount of variance known in the outcome just by knowing the group membership. In this instance, only 6% of the overall variance is known by group membership. Moreover, the estimated variance between group membership (τ_{00}) at level two is small indicating the groups are not explaining much of the estimated differences. Based on the results of the multilevel model, we decided to explore any changes in slope estimates when it came to a particular major and academic classification.

Table 4

Multilevel Model Results

	Environment		
Predictors	Estimates	CI	*p*
(Intercept)	0.06	-0.12 – 0.23	.518
Belonging	0.50	0.39 – 0.62	<.001
Motivation	0.11	0.01 – 0.21	.034
Academic Confidence	0.18	0.08 – 0.28	<.001
Daily Life Experiences	-0.07	-0.16 – 0.03	.161
Random Effects			

σ^2 [a]	0.52
τ_{00} Class: Major [b]	0.01
τ_{00} Major	0.02
ICC	0.06
N_{Class}	3
N_{Major}	5

Note. Number of observations = 255, Marginal R^2 = 0.49. CI = confidence interval.

[a] Overall variance.

[b] Between group variance.

Path Analysis with Factor Scores

Based on prior results (O'Hara et al., 2020; O'Hara et al., 2023) demonstrating differences when it came to the classroom environments impact on force and resource characteristics, a standard path analysis (Figure 1) was estimated then compared to a multigroup path analysis. A path analysis was chosen over a traditional structural equation model due to issues with cell counts and variance. That is because some of the individual groups had low *n*s the issue of variance on individual items hindered model estimation. Because factor scores were already estimated for the MLM, we decided to treat the latent factor scores as observed variables in the path analysis.

A simple model was estimated using the hypothesized paths in Figure 1 using a standard maximum likelihood estimator. Model fit indices indicated acceptable model fit. The model χ^2 test of fit was not significant ($\chi^2(3) = 6.506$, $p = .09$) indicating the model was one possible representation of the data. Additional localized fit indices were also examined for appropriate model fit. The Root Mean Square Error of Approximation (RMSEA), a scaled badness-of-fit index, for the model was 0.068 indicating acceptable fit. RMSEA values of less than .08 are considered acceptable fit (Hu & Bentler, 1999). Both the Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI) were evaluated. For the CFI and TLI values above .95 (Hu & Bentler, 1999) are indicative of acceptable model fit. The estimated model had a CFI of .99 and TLI of .967 indicating acceptable model fit. Finally, the standardized root mean square residual (SRMR), which measures the differences between predicated and observed residuals, was evaluated. Values of less than or equal to .08 indicate acceptable fit; the estimated model had a SRMR value of .021 indicating acceptable fit.

All hypothesized paths were significant in the final model and those path coefficients can be found in Table 5. Additionally, indirect paths for Daily Life Experiences (DLE) influence on motivation and academic confidence were estimated. Table 5 contains the total indirect effect for both motivation and academic confidence. Four significant indirect paths between DLE and academic confidence were found with the largest (-0.105, $p < .001$) indirect influence from DLE through the environment. This suggests that students' daily life experiences influence on students' academic confidence is partially mediated by their perceptions of the environment. Additional, smaller indirect effects were found moving through all the paths in the model. The negative sign of the indirect effect estimate suggests that higher instances of negative daily life experiences ultimately can decrease students' academic confidence. Put differently, a one unit increase in daily life experiences results in a 0.172 ($p < .001$ total decrease in academic confidence.

Figure 2
Hypothesized Path Model

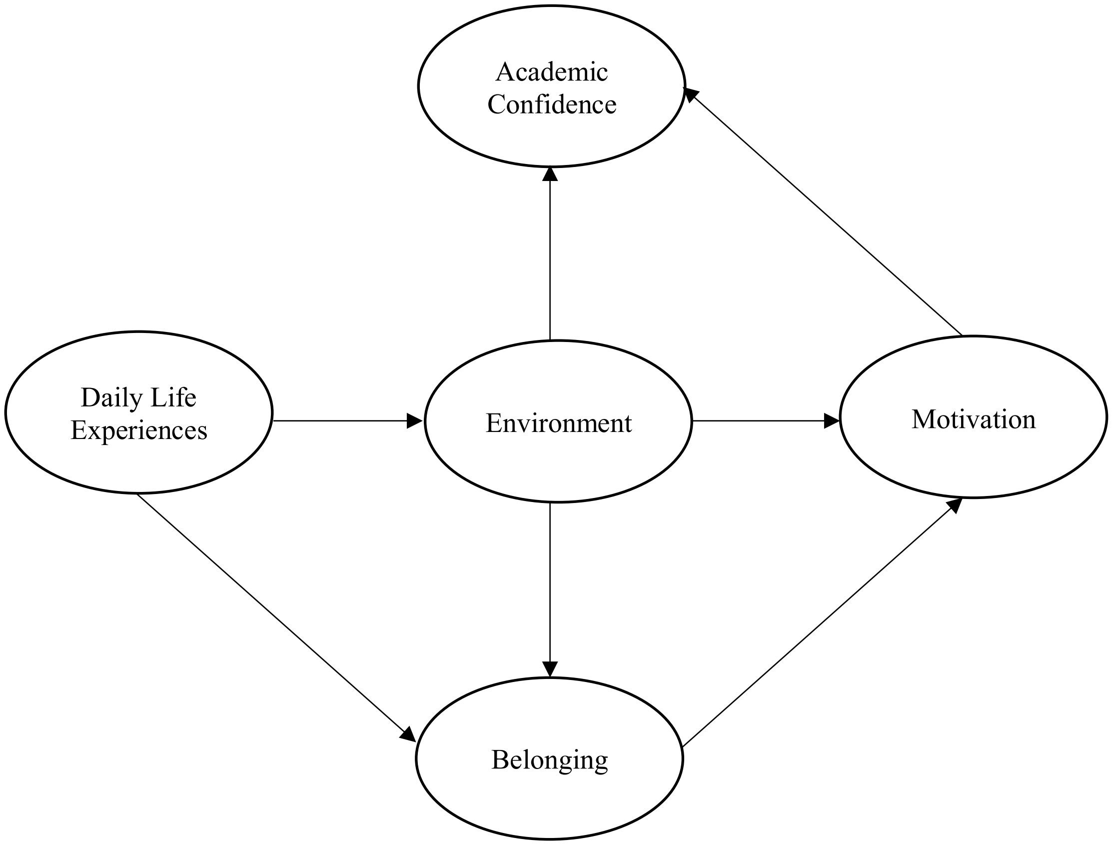

Table 5

Results of Full Path Analysis

Path	*β*	*SE*	*z-score*	*p*
DLE → Environment	-0.308	0.058	-5.267	<.001
DLE → Belonging	-0.193	0.047	-4.097	<.001
Environment → Belonging	0.597	0.048	12.466	<.001
Environment → Academic Confidence	0.341	0.061	5.609	<.001
Environment → Motivation	0.260	0.074	3.496	<.001
Motivation → Academic Confidence	0.343	0.059	5.832	<.001
Belonging → Motivation	0.310	0.075	4.153	<.001

Model Indirect Effects

DLE → Academic Confidence	-0.172	0.035	-4.980	<.001
DLE → Motivation	-0.197	0.037	-5.389	<.001

Note. DLE = Daily Life Experiences.

DLE also has an indirect effect on students' motivation through various paths and has a slightly larger overall indirect effect than academic confidence. However, the indirect effect of DLE on motivation seems to be slightly more evenly distributed through the paths. The largest share of the overall indirect effect of DLE on motivation comes through student perceptions of the classroom environment (-0.080, p = .004). However, DLE had an indirect effect on motivation through sense of belonging (-0.060, p = .004) and an indirect effect through both environment and sense of belonging is -0.057 (p = .002). Here we see that a student's sense of belonging and perceptions of environment, both together and separately, mediate the influence daily life experiences have on students' overall motivation. Like the indirect effect on academic confidence, the negative sign associated with the indirect effect suggests that a one unit increase in daily life experiences results in a 0.197 (p < .001) total decrease in students' motivation.

Next, two multigroup path analyses were conducted; the first using academic classification as a grouping variable and the second using major as a grouping variable. Both models were then each compared to first model using a likelihood ratio test (LRT). The LRT test compares the likelihood of the null model (i.e., first model) to the likelihood obtained for an alternate model. Here the alternate models are the multigroup model for academic classification and the multigroup model for major. First, we will discuss the academic classification model.

Academic Classification Path Model

The -2 Log-Likelihood difference between the first model and the academic classification path model was, $-2\Delta LL = 70.742$. This difference resulted in a significant (p < .0001) likelihood ratio test indicating that we should reject the null hypothesis and assume that the multigroup model (i.e., more complex model) is a better fit for the data. Examining the multi-group model fit statistics, we found a significant global test of fit (χ^2(9) = 18.744, *p* = .028). However, seeing as this test is susceptible to sample size, we examined local fit indices. For the multigroup academic classification model we found that the RMSEA = .113, CFI = .975, TLI = .916, and SRMR = .042. Due to the conflicting local fit indices, we examined standardized residuals and residual correlations for all three groups to locate potential misfit. Standardized residual covariances indicate standardized differences in observed and model implied covariance matrix. While residual correlations indicate how each pair of variables is reproduced by the model (Kline, 2011).

Typically, residual correlations of less than |.10| and standardized residuals of less than |1.96| indicate acceptable fit (Kline, 2011). For all three groups we found no standardized residuals greater than or equal to |1.96|. However, for the sophomore group a residual correlation of .128 between motivation and DLE and -.176 between academic confidence and DLE were found. For juniors a residual correlation of .173 between academic confidence and DLE was found. The senior group had a residual correlation between motivation and DLE of -.117. These indicate that the model is underestimating the relationship between these variables. Based on these results, we decided that the model was not an adequate representation of the data even though the likelihood ratio test suggested it was a better fit than the less complex model. We do not discuss the results of that model here; however, they can be found in the supplemental material (Table 6).

Major Path Model

The same process was repeated for the multigroup path model using major as the grouping variable. The likelihood ratio test was significant, $-2\Delta LL = 70.742, p = .028$. Suggesting that we reject the null hypothesis and assume the more complex model fits the data better. Again, we found a significant global test of fit (χ^2(15) = 30.049, p = .012). Local fit indices were also conflicting: RMSEA = .14, CFI = .96, TLI = .866, SRMR = .054. As a result, residual output was examined for each major group. Three of the five groups had standardized residuals below |1.96|. Mechanical Engineering (ME) had a standardized residual of 2.324 between belonging and academic confidence indicating a significant difference between covariances at the .05 level. Industrial Engineering (IE) also produced a standardized residual of 1.963 between academic confidence and DLE indicating a very slightly significant difference between covariances. All groups had residual correlations that were greater than or equal to |.10|. Bioengineering produced residual correlations of -.140 between belonging and academic confidence and .138 between academic confidence and DLE. Residual correlations of .110 between motivation and DLE and -.113 between academic confidence and DLE for Civil Engineering (CE). Environmental Engineering and Earth Sciences (EEES) saw residual correlations of .192 between belonging and academic confidence and -.284 between academic confidence and DLE. Both ME and IE saw residual correlations of -.108 and .248, respectively, between academic confidence and DLE. Like the academic classification model, we do not feel that the model is an adequate representation of the data and do not discuss those model results here. However, they are listed as Table 7 in the supplemental material.

DISCUSSION

Humans are placed at risk, and this frames how people make sense of their experiences (Spencer, 1999; Spencer et al., 1997; Velez & Spencer, 2018). Moreover, when students enter the classroom, they do so with varied developmental pathways. The phenomenological experiences occurring in bidirectional nested ecological systems shape how students self-organize, give meaning and significance to themselves, and has implications for how they perceive those experiences. This understanding is central to the construction of this study because if students perceive they are at risk in their learning environment, whether from direct lived experiences or perceived threats to their well-being, then that has implications for how they view themselves in that environment.

The study aimed to investigate the impact of the engineering classroom on undergraduate students by examining differences in force and resource characteristics, considering variations among engineering majors and academic classifications. Additionally, this study explored the influence of daily life experiences on students' perceptions of their classroom environments. The results presented an interesting glimpse into the minds of undergraduate students in one of five engineering majors. However, those results were not without some unexpected developments when it came to modeling the data collected. Drawing from both a bioecological systems theory (Bronfenbrenner, 2001; Bronfenbrenner & Morris, 2006) and PVEST (Spencer et al., 1997; Velez & Spencer, 2018) emphasis on the reciprocal relationship between the individuals and their environment, we start this section by making sense of the results as they relate to the larger field of research. We then follow up with some implications for practice and future work and discuss our limitations.

Aligning with prior research on motivation, sense of belonging, and academic confidence in the context of the classroom environment, we centered this study around variance and wanting to understand how much variance in student perceptions of the classroom is accounted for within students and between academic classifications and majors. For example, Lee et al., (2020) suggested studies disaggregate STEM disciplines into specific majors to understand the nature and scope more fully of what is impacting students and to provide more targeted interventions. This highlights the importance of considering both proximal and distal forces within ecological systems in shaping individuals' development (Bronfenbrenner & Morris, 2006; Spencer et al., 1997).

The multilevel model attempted to implement this suggestion. However, the results indicated the groups did not matter much when it came to understanding what impacted students' perceptions of the environment. Specifically, the ICC of .06 indicated that only 6% of the overall variance was known just by identifying group membership. Perhaps your academic classification and major truly do not matter; however, there may be an explanation for the results found. Engineering offers a unique opportunity for researchers in that while there are several different engineering majors, there is a collective identity as an engineer (Godwin & Lee, 2007; Hernandez et al., 2017; Kirn et al., 2016; Murphy et al., 2015; Nadelson & Fannigan, 2014; Patrick & Borrego, 2016; Perez er al., 2014; Rodriguez et al., 2018). This could be one explanation for these results of this study, but one that needs additional research to confirm.

With part of the research question answered by the lack of importance in groups from the multilevel model, we turned to looking at variation between students. Prior research demonstrated the type of impact the engineering classroom environment can have on force and resource characteristics of the individual student (Bancroft, 2018; Bottia et al., 2015; Cromley et al., 2016; O'Hara et al., 2020; Rodriguez & Blaney, 2021; Wilson et al., 2015). It emphasizes the importance of positive classroom environments that foster academic confidence, motivation, and sense of belonging in students (Dewsbury, 2017; Eastman et al., 2019; Freeman et al., 2014; Lee et al., 2020). However, it also highlights the need for educators to recognize that the impact of these experiences may vary among students and calls for strategic and intentional changes to address students' force and resource characteristics. We know the person develops as a function of these characteristics within the PPCT (Bronfenbrenner, 2001) and the mechanisms they use to make sense of that development (Spencer et al., 1997). Therefore, we sought to situate the lived experiences as the focal point of subsequent analyses as seen by the path analyses presented in the results.

The hypothesized paths in the path model were all significant, suggesting the importance of the relationships among perceptions of the classroom environment, sense of belonging, motivation, academic confidence, and daily life experiences. These findings support the notion that the classroom environment plays a significant role in shaping students' motivation, sense of belonging, and academic confidence (Eastman et al., 2019; Eccles & Wigfield, 2020; Eddy & Hogan, 2014; Freeman et al., 2007; Ford et al., 2020; Long & Mejia, 2016; O'Leary et al., 2020; Walton & Cohen, 2011). The path analysis also revealed significant indirect effects of daily life experiences on academic confidence and motivation. The results indicated that students' perceptions of the environment partially mediated the influence of daily life experiences on academic confidence, with the environment being the strongest mediating factor. Higher instances of negative daily life experiences were associated with decreased academic confidence. Similarly, daily life experiences had an indirect effect on motivation, with the environment and sense of belonging mediating this relationship with higher instances of negative daily life experiences decreasing motivation.

This information is valuable because 82.4% of the sample indicated having at least one negative daily interaction in a given week, including all but one of the participants that identified with a historically minoritized population. Moreover, only 45 of the 255 participants in the sample (17.6%) indicated no negative daily life experiences. However, the overwhelmingly majority of those participants identified as white (86.7%). PVEST can assist in making some sense of these results. Recall that while PVEST was conceptualized to account for deficiencies in Bioecological Systems Theory, it did so by focusing on risk in the development of children of color (Spencer, 1999; Spencer et al., 1997). Perhaps some participants thought about the DLE items as risks to their success in engineering or the effect of the five nonracial microaggressions items on the DLE-F scale outweighed the other responses. While we have no definitive explanation for these results, we are reminded of the understanding that human development is influenced by complex interactions between individuals and their environments (Bronfenbrenner, 2001; Geldhof et al., 2014; Spencer, 1999).

The present study's findings contribute to this body of research by highlighting the role of the engineering classroom environment in shaping students' academic confidence. It is important for faculty and institutions to consider the impact of their practices, policies, and structures on students' academic confidence to promote a supportive and empowering environment for engineering students. To that end, we now turn to implications for practice and future work in this area.

Implications for Practice & Future Work

In this study, the classroom environment served as a crucial context for exploring force and resource characteristics of engineering students, namely their motivation, sense of belonging, and academic confidence. These findings have implications for engineering education and highlight the need for intentional efforts to create inclusive and supportive classroom environments. By understanding the influence of the classroom environment on motivation, sense of belonging, and academic confidence, educators and institutions can design educational practices that enhance students' experiences, promote their well-being, and contribute to their academic success. It is crucial for engineering departments to examine their policies, structures, and habits to identify areas where changes can be made to create an environment that fosters positive developmental outcomes for all students, regardless of their backgrounds and identities.

For example, departments can provide professional development opportunities for educators to enhance their ability to create supportive learning environments and foster inclusive teaching practices. Moreover, these professional developments can also promote inclusivity and diversity. Initiatives that increase diversity among students, faculty, and staff promotes cultural competence while enhancing resources and support for minoritized groups. At the very least, engineering educators need to focus on inclusive and supportive classroom environments that have the potential to foster sense of belonging, motivation, and academic confidence among undergraduate engineering students. Incorporating strategies such as peer support, respectful communication, and opportunities for active learning are ways departments can begin to create these types of environments. Implementing these implications can aid departments and institutions in creating positive and supportive classroom environments that enhance students' motivation, sense of belonging, and academic confidence that ultimately can lead to improved learning outcomes and higher retention rates.

Future research can build upon these findings by exploring additional contextual factors that influence students' motivation, sense of belonging, and academic confidence within the engineering classroom. Longitudinal studies can provide insights into the long-term effects of the classroom environment on students' development and academic trajectories. Furthermore, investigating the experiences of underrepresented groups in engineering education can help identify strategies to address the unique challenges they face and promote greater equity and inclusivity within the field. Future work can be aided by exploring technology's role in force and resource characteristics within the engineering classroom. Finally, future work could implement comparative studies across different STEM disciplines to examine similarities and differences in the factors influencing force and resource characteristics. The benefit to comparative studies is its ability to bring discipline-specific challenges to the surface. These are a few examples of what future work can do to deepen the understanding of the factors that impact force and resource characteristics in engineering education.

Limitations

While this study provides valuable insights into the relationships between force and resource characteristics there are some limitations that need to be acknowledged. One major limitation of the study is the sole use of self-reported measures. Data used in this study relied on participants responding to an online survey and may not accurately reflect true experiences and perceptions. In addition to self-reported measures, this study used a single data collection method. Considering the complexity of human development and experiences future work should consider supplementing survey data with classroom observations, participant interviews, or another type of artifact collection. Moreover, the cross-sectional design of this study limits the ability to establish causal relationships or true directionality of relationships. Using longitudinal designs would greatly enhance the findings of this study. While the study had a sample size of 255 participants, when broken down into the various groupings some of the groups had small *n*s. This potentially was the reason why we saw the low intraclass correlation coefficient in the multilevel model and might explain the local misfit in the multigroup path analysis. Even though the likelihood ratio test indicated those more complex models fit data better.

Lastly, data from this study focused on a single institution that is a predominately white institution. While some of the results may be able to be generalized to institutions with similar demographic profiles, they be done so with caution. Incorporating different institutional profiles or student population may yield different results and more fully capture the array of experiences present in engineering education writ large. While the implications and recommendations for practice would not inherently do harm for institutions, acknowledging the limitations of this study allows researchers and practitioners to contextualize the findings presented here. Moreover, it provides necessary transparency for potential improvements to this study.

Conclusion

In conclusion, this study provides information on the impact negative daily life experiences and perceptions of the classroom environment have on force and resource characteristics in undergraduate engineering students. Results contribute to the growing body of research demonstrating the importance the classroom environment has in impacting force and resource characteristics in undergraduate engineering students. While our findings are consistent with prior research, the results regarding the direct and indirect influence of negative daily life experiences on the undergraduate student standout. This study emphasized the importance of the person interacting with a specific context. By understanding the reciprocal relationship between individuals and their environment, engineering programs have the potential to create classrooms that support and empower students' developmental outcomes. Moreover, these results can aid engineering programs in creating more inclusive and equitable engineering educational environments.

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APPENDICES

Appendix A

Supplemental Material

Table 6

Results of Path Analysis – Academic Classification

Path	Sophomores				Juniors				Seniors			
	β	*SE*	*z*	*p*	*β*	*SE*	*z*	*p*	*β*	*SE*	*z*	*p*
DLE → Environment	-.205	.091	-2.268	**.023**	-.494	.089	-5.545	**<.001**	-.234	.115	-2.037	**.042**
DLE → Belonging	-.147	.076	-1.917	.055	-.151	.096	-1.583	.113	-.330	.072	-4.565	**<.001**
Environment → Belonging	.556	.095	5.865	**<.001**	.579	.100	5.792	**<.001**	.623	.063	9.892	**<.001**
Environment → Academic Confidence	.619	.124	5.008	**<.001**	.243	.101	2.397	**.017**	.247	.098	2.528	**.011**
Environment → Motivation	.486	.127	3.842	**<.001**	.028	.139	.200	.842	.286	.110	2.605	**.009**
Motivation → Academic Confidence	.163	.125	1.304	.192	.372	.085	4.382	**<.001**	.428	.106	4.024	**<.001**
Belonging → Motivation	-.037	.126	-.299	.765	.620	.134	4.629	**<.001**	.296	.115	2.565	**.010**
Model Indirect Effects												
DLE → Academic Confidence	-.142	.067	-2.118	**.034**	-.226	.064	-3.503	<.001	-.147	.059	-2.477	**.013**
DLE → Motivation	-.090	.050	-1.797	.072	-.285	.082	-3.454	.001	-.207	.071	-2.934	**.003**

Note. DLE = Daily Life Experiences. Bolded cells = significant paths at the .05 level.

Table 7

Results of Path Analysis – Major Groups

Path	BioE		CE		EEES		IE		ME	
	B	P	B	P	B	P	B	P	B	P
DLE → Environment	-.008	.961	-.266	**.020**	-.261	.522	-.277	**.015**	-.396	**<.001**
DLE → Belonging	-.320	**.013**	-.116	.132	-.777	**.027**	-.340	**.001**	-.109	.153
Environment → Belonging	.502	**<.001**	.591	**<.001**	.527	**.017**	.669	**<.001**	.637	**<.001**
Environment → Academic Confidence	.153	.417	.342	**<.001**	.254	.390	.561	**<.001**	.327	**.001**
Environment → Motivation	.375	**.031**	.257	.126	.354	.073	.227	.227	.180	.150
Motivation → Academic Confidence	.559	**.003**	.456	**<.001**	.335	.379	.181	.165	.324	**.001**
Belonging → Motivation	.130	.463	.361	.057	.096	.579	.216	.167	.471	**<.001**
Model Indirect Effects										
DLE → Academic Confidence	-.027	.720	-.167	**.018**	-.127	.482	-.187	**.022**	-.208	**.001**
DLE → Motivation	-.045	.629	-.167	**.018**	-.180	.407	-.176	**.023**	-.241	**<.001**

Note. BioE = Bioengineering, CE = Civil Engineering, EEES = Environmental Engineering & Earth Sciences, IE = Industrial Engineering, ME = Mechanical Engineering. Bolded cells = significant paths at the .05 level.

Indirect Paths for Academic Classification Model

DLE to Academic Confidence

Sophomores
DLE→Environment→Academic Confidence: -0.127, *p*=.039
DLE→Belonging→Motivation→Academic Confidence: -0.001, *p*=.774
DLE→Environment→Motivation→Academic Confidence: -0.016, *p*=.278
DLE→Environment→Belonging→Motivation→Academic Confidence: -.001, *p*=.773

Juniors
DLE→Environment→Academic Confidence: -.120, p=.028
DLE→Belonging→Motivation→Academic Confidence: -.035, p=.156
DLE→Environment→Motivation→Academic Confidence: -.005, p=.842
DLE→Environment→Belonging→Motivation→Academic Confidence: -.066, p=.013

Seniors
DLE→Environment→Academic Confidence: -.058, p=.113
DLE→Belonging→Motivation→Academic Confidence: -.042, p=.051
DLE→Environment→Motivation→Academic Confidence: -.029; p=.136
DLE→Environment→Belonging→Motivation→Academic Confidence: -.018, p=.142

DLE to Motivation

Sophomores
DLE→Belonging→Motivation: -0.005, *p*=.768
DLE→Environment→Motivation: -0.100, *p*=.051
DLE→Environment→Belonging→Motivation: -0.004, *p*=.768

Juniors
DLE→Belonging→Motivation: -.094, p=.134
DLE→Environment→Motivation: -.014, p=.842
DLE→Environment→Belonging→Motivation: -.177, p=.002

Seniors
DLE→Belonging→Motivation: -.098, p=.025
DLE→Environment→Motivation: -.067, p=.109
DLE→Environment→Belonging→Motivation: -.043, p=.115

Indirect Paths for Major Model

DLE to Academic Confidence
Bioengineering
DLE→Environment→Academic Confidence: -.001, *p* = .961
DLE→Belonging→Motivation→Academic Confidence: -.023, *p* = .493
DLE→Environment→Motivation→Academic Confidence: -.002, *p* = .961
DLE→Environment→Belonging→Motivation→Academic Confidence: .000, *p* =.961

Civil Engineering
DLE→Environment→Academic Confidence: -.091, *p* = .051
DLE→Belonging→Motivation→Academic Confidence: -.019, *p* =.251
DLE→Environment→Motivation→Academic Confidence: -.031, *p* = .216
DLE→Environment→Belonging→Motivation→Academic Confidence: -.026, *p* = .167

Environmental Engineering & Earth Sciences
DLE→Environment→Academic Confidence: -.066, *p* =.607
DLE→Belonging→Motivation→Academic Confidence: -.025, *p* = .646
DLE→Environment→Motivation→Academic Confidence: -.031, *p* = .619
DLE→Environment→Belonging→Motivation→Academic Confidence: -.004, *p* = .709

Industrial Engineering
DLE→Environment→Academic Confidence: -.155, *p* = .039
DLE→Belonging→Motivation→Academic Confidence: -.013, *p* = .348
DLE→Environment→Motivation→Academic Confidence: -.011, *p* = .393
DLE→Environment→Belonging→Motivation→Academic Confidence: -.007, *p* = .370

Mechanical Engineering
DLE→Environment→Academic Confidence: -.130, *p* = .011
DLE→Belonging→Motivation→Academic Confidence: -.017, *p* = .217
DLE→Environment→Motivation→Academic Confidence: -.023, *p* = .209
DLE→Environment→Belonging→Motivation→Academic Confidence: -.038, *p* = .042

DLE to Motivation
Bioengineering
DLE→Belonging→Motivation: -.042, *p* = .481
DLE→Environment→Motivation: -.003, *p* = .961
DLE→Environment→Belonging→Motivation: -.001, *p* = .961

Civil Engineering
DLE→Belonging→Motivation: -.042, *p* = .238
DLE→Environment→Motivation: -.068, *p* = .201
DLE→Environment→Belonging→Motivation: -.057, *p* =.150

Environmental Engineering & Earth Sciences
DLE→Belonging→Motivation: -.075, *p* = .591
DLE→Environment→Motivation: -.093, *p* = .546
DLE→Environment→Belonging→Motivation: -.013, *p* = .680

Industrial Engineering
DLE→Belonging→Motivation: -.075, *p* = .203
DLE→Environment→Motivation: -.063, *p* = .279
DLE→Environment→Belonging→Motivation: -.040, *p* = .240

Mechanical Engineering
DLE→Belonging→Motivation: -.051, *p* = .185
DLE→Environment→Motivation: -.071, *p* = .176
DLE→Environment→Belonging→Motivation: -.119, *p* = .011

Appendix B
Survey Items

Table 4

Survey Items

Sense of Belonging Items
I enjoy going to school here
I wish I had gone to another school instead of this one [a]
People at this school are friendly to me
I feel there is a sense of community at this school
I feel there is a strong feeling of togetherness on campus
Engineering students make me feel wanted and accepted
I am disliked by students in engineering [a]
Engineering faculty and staff in engineering make me feel wanted and accepted
I feel comfortable in engineering
I am supported in engineering
I am accepted in engineering
I feel I belong in engineering
There is a strong feeling of togetherness in engineering
I enjoy being in engineering
There is a sense of community in engineering
Motivation Items
Doing better than the other students in this class on exams
Proving to my peers that I am a good student
Doing better than the other students in the class on assignments
Getting a better grade than other students in this class
Knowing more than I did previously about these course topics
Really understanding this course's material
Feeling satisfied that I got what I wanted from this course
I don't think much about the future [a]

It's really no use worrying about the future [a]

I don't like to plan for the future [a]

It's not really important to have future goals for where one wants to be in five or ten years [a]

One shouldn't think too much about the future [a]

Given the choice, it is better to get something you want in the future than something you want today

It is better to be considered a success at the end of one's life than to be considered a success today

The most important thing in life is how one feels in the long run

It is more important to save for the future than to buy what one wants today

Long range goals are more important than short range goals

What happens in the long run is more important than how one feels right now

Learning science will improve my career prospects

Science is helpful in my everyday life

Science has helped me see opportunities for positive change

Science has taught me how to take care of my health

Learning science has made me more critical in general

Engineering can improve our society

Engineering will give me the tools and resources I need to make an impact

Engineering can improve our quality of life

I see engineering all around me

Academic Confidence

I will use the information I learn in this engineering course in the future

I am confident I can do an excellent job on the exams in this engineering course

What I learn in my engineering course will be important for my future occupational success

I do not connect my future career to what I am learning in this course [a]

I am considering switching majors [a]

I am confident about my choice of major

Engineering is the most rewarding future career I can imagine for myself

My interest in an engineering major outweighs any disadvantages I can think of

I want to be an engineer

Environment

The resources I need to do my work effectively are readily available

My growth and development have been supported through opportunities within my major

I receive recognition and praise for my good work similar to my peers

There is someone in my major who encourages my professional development

I feel like I belong in my major

I feel respected and valued by faculty in my major

I feel respected and valued by staff in my major

I feel respected and valued by students in my major

When I speak up in my daily interactions within my major's community, my opinion is valued

I feel that my work or studies contribute to the excellence of my major

I trust the administration in my major to be fair to all employees and students

In CECAS, I have opportunities to work or learn successfully in settings with diverse individuals

The culture of my major is accepting of people with different ideas

The culture of CECAS is accepting of people from all backgrounds

I believe diversity is imperative to the success of CECAS

I see people who look like me in positions I aspire to hold within CECAS

I feel respected and valued by my primary supervisor in my major

There is someone in my major who encourages my academic success

Daily Life Experiences – Frequency

Being treated rudely or disrespectfully

Being ignored, overlooked or not given service (in a restaurant, store, etc.)

Being accused of something or treated suspiciously

Others reacting to you as if they were afraid or intimidated

Being observed or followed while in public places

Being treated as if you were "stupid", being "talked down to"

Your ideas or opinions being minimized, ignored, or devalued

Overhearing or being told an offensive joke or comment
Being insulted, called a name, or harassed
Others expecting your work to be inferior
Not being taken seriously
Being left out of conservations or activities
Being treated in an "overly" friendly or superficial way
Other people avoiding you
Being mistaken for someone who serves others
Being stared at by strangers
Being laughed at, made fun of, or taunted
Being mistaken for someone else

Note.

[a] Reverse-coded item.

CHAPTER FIVE

CONCLUSION

The research discussed in this dissertation highlighted the kinds of impact the classroom environment has on undergraduate engineering students. Results support prior research indicating students' perceptions of the environment are linked to students' sense of belonging, motivation, and academic confidence (Copeland & Levesque-Bristol, 2011; Good et al, 2012; Freeman et al., 2007; Park et al., 2018; Strayhorn, 2015; Vaccaro & Newman, 2016; Walton & Cohen, 2011; Walton et al., 2012; Wilson et al., 2015; Won et al., 2018; Zumbrunn et al., 2014). Moreover, the complex nature of these relationships become apparent as students move through their college experience. Findings also suggested that these relationships and complexities hold across other engineering majors, as demonstrated in chapter four. This study theoretically and conceptually linked together three manuscripts through research design and theoretical framing. The process-person-context-time (PPCT) model within bioecological systems theory (Bronfenbrenner, 2001; Bronfenbrenner & Morris, 2006) made it possible for each manuscript to focus on aspects of students' experiences in the classroom while providing a lens for interpretation of the results (Navarro et al., 2022).

Manuscripts one and two (i.e., Chapters 2 & 3 respectively) utilized a secondary data analysis highlighting one engineering major. Chapter two: *Perceptions of the Classroom Environment: The Unseen Impact*, emphasized the importance of how students perceive their classroom environments. Results indicated these perceptions predicted sense of belonging, motivation, and academic confidence. Sense of belonging was found to be a mediator, specifically for juniors and seniors. These results underpinned the need for engineering classrooms to foster a positive classroom environment with an emphasis on cultivating a sense of belonging in its students. The mediating role of sense of belonging for both juniors and seniors suggests that it is critical for supporting students throughout their academic journey.

Chapter three: *Pursuing Pavements: Trends in CE Students*, expanded on the prior study and examined trends among sophomores, juniors, and seniors in the same department over a four-year timeframe. Moreover, these trends were coupled with curriculum and cultural changes implemented in an engineering department. Sense of belonging, motivation, and academic confidence trends were expected to be linear over time, while expecting changes in the students' perceptions of the environment trend due to changes in department that affected the classroom. However, results indicted non-linear trends for all the constructs, either in sophomores, juniors, or seniors. One of the most notable changes implemented was restructuring curriculum around a design-course sequence that scaffolded aspects of the engineering profession leading up to the senior capstone course (Sarasua et al., 2020). This change aligned with researchers call for increasing engagement and emphasizing students building knowledge together (Eddy & Hogan, 2014; Freeman et al., 2014; Prince & Felder, 2006); something that is the anthesis of traditional engineering classrooms. While these changes generally saw positive trends from students, they were impacted by the COVID-19 global pandemic. Nonetheless, results speak to the existence of fluctuations in students, collectively, within their environments overtime and that the impact can vary throughout a four-year curriculum

(Ogle et al., 2020; Secules et al., 2018; Wilson et al., 2015). However, more long-term research is needed to better understand the effects of these fluctuations.

Chapter four: *Unlocking Success: Motivation, Sense of Belonging, & Academic Confidence in Engineering Classrooms*, used primary data collected from sophomores, juniors, and seniors across five engineering majors. This study focused continued its focus on the relationships among perceptions of the classroom environment, sense of belonging, motivation, and academic confidence in undergraduate engineering students. However, students were asked about the types of negative daily life experiences they have in their environments. Specifically, items asked about racial and nonracial microaggressions they might experience (Lee et al., 2021). That information was included in the analysis. Results highlighted the direct and indirect effect these experiences have on student characteristics, in particular the influence these experiences have on students' perceptions of the environment. Additionally, results showed when considering differences in these relationships across academic year and major those groupings only accounted for 6% of the overall variance. This has the potential to support other research suggesting an underlying engineering identity thread regardless of the specific major (Godwin & Lee, 2007; Hernandez et al., 2017; Kirn et al., 2016; Murphy et al., 2015; Nadelson & Fannigan, 2014; Patrick & Borrego, 2016; Perez er al., 2014; Rodriguez et al., 2018). Moreover, results raised the importance of human development affected by complex interactions between individuals and their environments (Bronfenbrenner, 2001; Geldhof et al., 2014; Spencer, 1999). This came about because

~82% of the sample indicated having at least one negative daily interaction in a given week; yet only ~13% of the sample identified as being from a minoritized group.

Communicating Impact of Results

Engineering departments, program faculty, and administrators may find themselves wondering the usefulness of this type of research so before discussing implications for practice, I offer some suggestions regarding the importance of communicating these results to relevant stakeholders. First, it would be useful to highlight how these results directly relate to everyone's role in shaping the educational experiences of engineering students. Therefore, start with that context. Everyone in engineering education from administrative staff to deans do valuable work educating and mentoring students. For faculty, this means emphasizing that their influence goes beyond the subjects they teach. For example, the expectations they set in their classrooms and how they interact with students plays a critical role in the overall success of the student. Those interactions can also shape how students engage and stay in faculty members' courses.

Connecting to overall student outcomes can stress the importance of these results to stakeholders. When engineering programs foster a supportive and inclusive environment not only leads to improved learning outcomes but can lead to well-rounded, confident, and successful engineering professionals (Ford et al., 2020; Hadgraft & Kolmos, 2020). This is the type of positive effect inclusive and equitable learning environments have on student potential (Booker et al., 2016; Cromley et al., 2016; Evenhouse et al., 2018; Ford et al., 2020). Moreover, as seen in the departmental changes implemented in Chapter three, encouraging collaboration and professional development amongst faculty can have positive impacts on engineering students' educational experiences. Not only does this increase supportive environments, but it also aligns with best practice suggestions already offered in existing research (e.g., Eastman et al., 2019; Freeman et al., 2014; Lee et al., 2020; Long & Mejia, 2016; Scheidt et al., 2021). Results from these studies provide empirical evidence demonstrating the complex nature of engineering students' experiences and provide justification for engineering programs to address issues in classroom environments. Results from this dissertation study also have several implications for practice, which are discussed next.

Implications for Practice

Using the results from this dissertation study, several implications for practice can be suggested. Possibly the biggest implication for practice is the continued need for fostering positive engineering classroom environments (Barrington, 2004; Byars-Winston et al., 2016; Canning et al., 2020; Cano et al., 2018; Gay, 2018; Han et al., 2017; Ladson-Billings & Tate, 1995; Mau, 2016; Park et al., 2018; Perez et al., 2014; Strayhorn, 2015). Collectively, results demonstrate the impact aspects of the engineering classroom have on students' sense of belonging, motivation, and academic confidence. The competitive, zero-sum nature of the engineering classroom creates an environment where students feel unmotivated, like they do not belong, and ultimately like they are not able to be successful. On the other hand, positive classroom environments encourage active engagement and promote collaboration among students (e.g., Freeman et al., 2014).

The mediating role sense of belonging in the reciprocal relationship between the classroom environment and student characteristics underpins the need for engineering programs to cultivate a sense of belonging. Many researchers have stressed the importance of sense of belonging (Ahn & Davis, 2019; Freeman et al., 2007; Good et al., 2012 Strayhorn, 2012; Wilson et al., 2015). However, this dissertation study was able to show the complicated nature of sense of belonging in engineering classrooms. Chapter three showed one department implanting a peer-mentoring program that fosters newer students' sense of belonging to the department had positive impacts on students' perceptions. Other examples engineering departments could implement include peer-support networks and general inclusivity and equity within the departments culture.

These results can aid engineering education in creating more inclusive and equitable environments. By examining the ideological, cultural, and structural aspects of the engineering classroom, these studies shed light on the importance of ensuring that students feel valued, represented, and supported in their learning environments. Stakeholders should use these results to implement inclusive teaching practices, a curriculum that represents the diversity of engineering, and incorporate assessments that measure various types of learning and knowledge (Hankey et al., 2019; Pascarella & Terenzini, 2005). Variance observed in students' perceptions of the environment, sense of belonging, motivation, and academic confidence across the three studies presented here spoke to the complex reciprocal relationship students have with their environment (Bancroft, 2018; Bottia et al., 2015; Cromley et al., 2016; O'Hara et al., 2020; Rodriguez

& Blaney, 2021; Wilson et al., 2015). Moreover, engineering programs can take these findings to implement targeted support and interventions improve student experiences.

The use of the daily life experiences frequency scale (Harrell, 1997; Lee et al., 2021) allowed this research to recognize the influence negative daily life experiences have on students in engineering. Stemming from ideological and cultural aspects of the classroom when students are made to feel like they are not smart enough or that their ideas are minimized, ignored, or not valued the result is a negative impact on their overall experiences. While these issues are addressed when classrooms have positive environments, students interact and are influenced by other systems in higher education. Therefore, programs should provide resources and information to larger campus counseling services. However, this need not be at the expense of student empowerment. That is, programs should not use these resources as a scapegoat in lieu of addressing genuine student concerns. Encouraging students to actively participate in their learning and educational experiences. Engineering educators should provide opportunities for students to provide input in decision making processes and co-create parts of their classroom experience.

Additionally, developing support systems within the department that can help students with issues outside of the classroom. This allows faculty, staff, and administrators to become institutional change agents (Long & Mejia, 2016). Addressing student issues inside and outside the classroom within the department provides an opportunity for continued professional development. This also gives faculty the chance to reconfigure the contextual lens through which they see their students (Dewsbury, 2017).

They become less of object that needs educating and more of a person with a lived experience that matters. Addressing some of these implications for practice can aid engineering departments to enhance students' sense of belonging, motivation, and academic confidence while also enhancing their perceptions of the classroom environment. Nevertheless, there is still a need for ongoing assessment, evaluation, and long-term research that informs evidence-based practices, continues to identify trends in students, and addresses challenges is needed from the engineering education field.

Limitations & Future Work

No study can incorporate everything, and this dissertation study is no exception. What follows is a discussion of some overarching limitations of this dissertation and presents some opportunities for future work as a result. One of the main limitations in the study, overall, was the sole use of self-reported survey results. While these types of data are good for generalizability of results, they lack authentic participant voice. That is, the use of qualitative research methods can capture students' perspectives and experiences directly. While Chapter three's study utilized department artifacts produced, they were not able to capture students' thoughts or opinions. Those methods can provide deeper insights into the psyche of student participants. Future work should include methodologies such as individual interviews and focus groups to better grasp the perspectives of students when it comes to the impact of the classroom environment.

Related to the first limitation is the use of data collected only from students. Data were not collected from faculty or administrators. Future work in this area should incorporate faculty perspectives relating the classroom environment and faculty perceptions of student behavior. Moreover, incorporating information regarding prior faculty development opportunities and participation rates could provide insight about the program's openness to improving the experiences of students. Those results compared with similar type results from this study could potentially also provide opportunities to address potential disconnects between faculty and students when it comes to aspects of the classroom environment. Additionally, future researchers could evaluate institutional initiatives. One of the advantages of a bioecological systems theory framework is the ability to build up the bidirectional influence systems have on the individual. Factoring in programs and interventions institutions have implemented to improve student experiences, retention, and graduation rates provides a more holistic picture of what is influencing the individual.

While chapter four attempted to incorporate different engineering disciplines, it was limited by a single-institution sample and small group sizes when splitting into discipline groups. Additional work should expand beyond a single institution sample and increase discipline group sizes. This would provide stronger insights into the environment's impact on different engineering disciplines while also shedding light onto any unique challenges or opportunities in an array of engineering disciplines. Moreover, there is the potential to expand beyond engineering and into other STEM disciplines. Expanding to other institutions and disciplines opens the door for researchers to conduct comparative studies. Comparative studies can aid research in examining how institutional culture, policies, and classroom practices impact students' sense of belonging, motivation, and academic confidence. An additional related limitation is the context itself. This study focused on the classroom environment in an in-person context. Future work would benefit from examining online learning environments and how those spaces can replicate aspects of physical classroom environments. With the educational realm coming to terms with the COVID-19 global pandemic, there are ample resources for work to situate itself in the virtual world. These are just a few examples of how future work could expand on the work presented in this dissertation study.

Conclusion

Overall, this dissertation collectively emphasized the importance of the classroom environment and its role in shaping engineering students' sense of belonging, motivation, and academic confidence. Using these results helps engineering programs better understand and potentially address students' perceptions of the environment which in turn can foster a better sense of belonging and, increase both motivation and academic confidence in their students. Moreover, programs can create inclusive and empowering environments for their students which can lead to overall success. There is always a need for further research to capture and begin to better understand the long-term implications of the classroom environment and this dissertation adds to the greater understanding of the environments impact on students. When educators implement research like presented here, they contribute to the reputation and success of engineering education and contribute to the overall success of their students. Through a focus on ideological, cultural, and structural aspects of the classroom environment programs can contribute to the creation of a more equitable and inclusive engineering educational environments.

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